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Table of Contents

Keynotes

Advances in Modeling Methodology for Agricultural Research

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To meet the increasing demand of our contemporary society on agricultural productivity, soil conservation, maintaining quality water supply, protection of ecology and environment, and effective utilization of limited financial resources, the research, engineering, planning and management of today's agricultural watersheds have become involved, complex, challenging and cost/time demanding. The research methodologies based on traditional scaled physical model testing, field observation, analytical (mathematical) prediction assisted by computing technology have found to have been ineffective, inadequate, and extremely costly in terms of money and time. Evidently, better and more cost-effective methodologies are needed. With rapid improvement in computing technology together with significant advances in mathematical/numerical modeling, a wider range of scientific research, engineering designs, planning and management problems could be investigated.

The National Center for Computational Hydroscience and Engineering of the School of Engineering at The University of Mississippi was supported by the US congress in 1989 to foster the computational modeling research in collaboration with the USDA Agricultural Research Service, National Sedimentation Laboratory. Since then, a number of computational models have been developed to study various agricultural watershed problems. These include: soil erosion and conservation, water and sediment in upland runoff and routing, sill and gully erosion, channel bank erosion and protection, dam/levee breach and flooding, dam rehabilitation, removal and sediment transport control, among other morphodynamic processes of watersheds. In the meantime, models needed for investigating water quality, impact of sediment transport on ecology and environment, etc., have also been developed. Most of these models have been demonstrated their capability of simulating the natural phenomena, at least approximately and cost-effectively, especially in time. Therefore the development of numerical models has been accelerated. With more institutions competing in producing and marketing of a large number of simulation models without carefully maintaining their quality, both professionals in the field and, especially, the professional societies, national and international, have promoted the efforts in verification and validation of the accuracy and reliability of numerical models.

The American Society of Civil Engineers is one of the leading societies in the field to have established task committees to uphold the quality of these newly developed research methodologies. The ASCE Task Committee on 3D Free Surface Flow Model Verification and Validation report was published by the ASCE in 2001. A systematic hydrodynamic model verification and validation procedure was suggested to both model developers and users how to develop and select quality models.

All computational models developed by scientists of NCCHE have been verified by analytic solutions and validated by both physical model measurements and field data to insure that models are free of mathematical and coding errors and capable of simulating real-life natural phenomena. In addition, all models of NCCHE have been continuously upgraded with newly reported physical principles and laws, as well as newly developed numerical solution methods. Furthermore, the new and more effective computing and information technologies, such as GUI, GIS databases, GPU, etc., have all been implemented to improve the capability and speed up the computing speed. In this brief review, several representative examples are presented to demonstrate the capabilities and effectiveness of the NCCHE models.

More recently, additional models and integrated modeling systems have been also developed for applications to the study of watershed processes of higher level of complications, as well as for the planning and management decision support, especially those decisions requiring the multi-disciplinary concerns. For example, an agricultural watershed management decision on what products to plant, what soil conservation, water and environmental quality to adopt, so that its profit/cost ratio can be higher and top soil and quality water can be conserved and the environmental quality can be protected to the level acceptable by our society. To support the decision makers, models capable of assessing the effectiveness of conservation of top soils, quality water supply, impacts on environment and ecology as well as predicting the agricultural products and the total costs of several selected alternative practice plans. Based on all of the reliable information generated by the agricultural engineering and cost analysis models, the soil erosion/transport models, water quality and agricultural contaminant transport/transformation models, environment/ecology quality prediction models, etc, the planning and management officials have a better way to select the best (often compromised) decision. From this simple planning and management decision support modeling system, one can see the need of a computational modeling system, which can make all the important predictions of the outcomes for each of the several options of practices systemically within a reasonable time as automatically as possible by an integrated application software system. Even though we have seen this trend is being developed for simpler applications to site-specific problems, the integrated computational modeling methodology applicable to agricultural watershed problems with higher level of complexity and multidisciplinary considerations need by our society now and especially in the future is quite challenging. Some recent ideas and accomplishments are presented; but more importantly, it’s hoped that this presentation shall stimulate newer and more valuable contributions from the research professional in the field.

Building with Nature: Mainstreaming the Concept

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Keywords: Building with nature, Soft engineering, Green engineering

More than half of humanity lives in urban areas located near rivers, deltas or coastal areas. As the world's population grows and prosperity levels rise, so too will the demand for goods (food, energy, merchandise) and services (transportation, accessibility, safety).

Accommodating this growth will involve the development of hydraulic infrastructure, such as harbours, access channels, land reclamation and flood defences. Sea level rise and climate change are reinforcing the urgent need for adaptable designs. At the same time, people need space for recreation – beaches, parks and waterfronts – which generates its own special demands on spatial and infrastructure planning. These developments need to be realized in often fragile environments that are under constant pressure and in complex societal settings, with a variety of stakeholders involved in decision making.

Sustainable development is crucial if we are to maintain river, delta and coastal environ-ments around the world, and the ecosystem services they provide that are essential for humankind. They include provisioning services, related to the supplies of food and other products; regulatory services, related to natural processes such as water purification, carbon sequestration and flood control; and cultural services, related to recreational, spiritual and other non-material benefits that people derive from nature. Finally, they offer support services that are necessary for the delivery of all other ecosystem services, but may not benefit humans directly, such as nutrient cycling, water storage, regulation and recharging, as well as wildlife habitats, nesting sites and foraging grounds. Balancing the sustainable functioning of ecosystems on the one hand, with the demand for their development and use on the other, is one of the greatest challenges for the future of humankind.

It is crucial that we learn to design infrastructure that can serve more than just one purpose, that is aligned with natural processes rather than working against them, and that is adaptable to cope with changing conditions such as sea level rise and climate change. Traditional approaches focus on minimizing the negative impacts of envisaged infrastructure projects (building in nature) and compensating for any residual negative effects (building of nature). As a next step beyond these 'reactive' approaches, building with nature aims to be proactive, utilizing natural processes and providing opportunities for nature as part of the infrastructure development process.

The challenge to accommodate the needs of nature and other stakeholders into new project designs is an essential element of the building-with-nature approach, in order to arrive at sustainable and socially acceptable solutions. In the past, project developers focused almost exclusively on the primary function, such as protection against flooding. The new approach challenges designers to combine flood defences with nature development and/or creating opportunities for other functions, such as recreation or housing.

The use of adaptable solutions allows society to respond gradually to changing circumstances such as sea level rise and climate change. Typical building blocks of such adaptable solutions are salt marshes, sand nourishments, shallow foreshores and ecosystem engineers. A traditional response to sea level rise, for example, is to strengthen coastal defences and to build higher dikes. These kinds of projects have a given design lifetime and are constructed all at once, based on an agreed scenario of design conditions. The Building with Nature approach promotes the consideration of more gradually developing solutions. Especially when used in combination with traditional, proven technologies, this approach can lead to cheaper and more aesthetically appealing solutions that adjust or can be adjusted to changing circumstances.

References

Adapted from: H.J. de Vriend and M. van Koningsveld (2012). Building with Nature, thinking, acting and interacting differently. EcoShape, Building with Nature, Dordrecht.

Flood Protection in Hamburg

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The city of Hamburg is the second largest city in Germany. Around 1.8 million people live in this metropolitan area which is a center for trade, transport and services and an important location for industry. Furthermore, the port of Hamburg is the largest seaport in Germany.
Hamburg is located at the Elbe estuary, 110 km away from the North Sea and is seriously threatened by storm surges from there. In addition, high waters coming downriver must not be neglected, not only the Elbe River but a lot of bigger and smaller rivers in Hamburg (s. Fig. 1). In the river marshes both risks may occur at the same time. About 45% of the city is located in low lying areas that would be flooded by storm surges without dykes regularly. That is a surface area of 342 km² (Fig. 1) with 326.000 inhabitants living there.

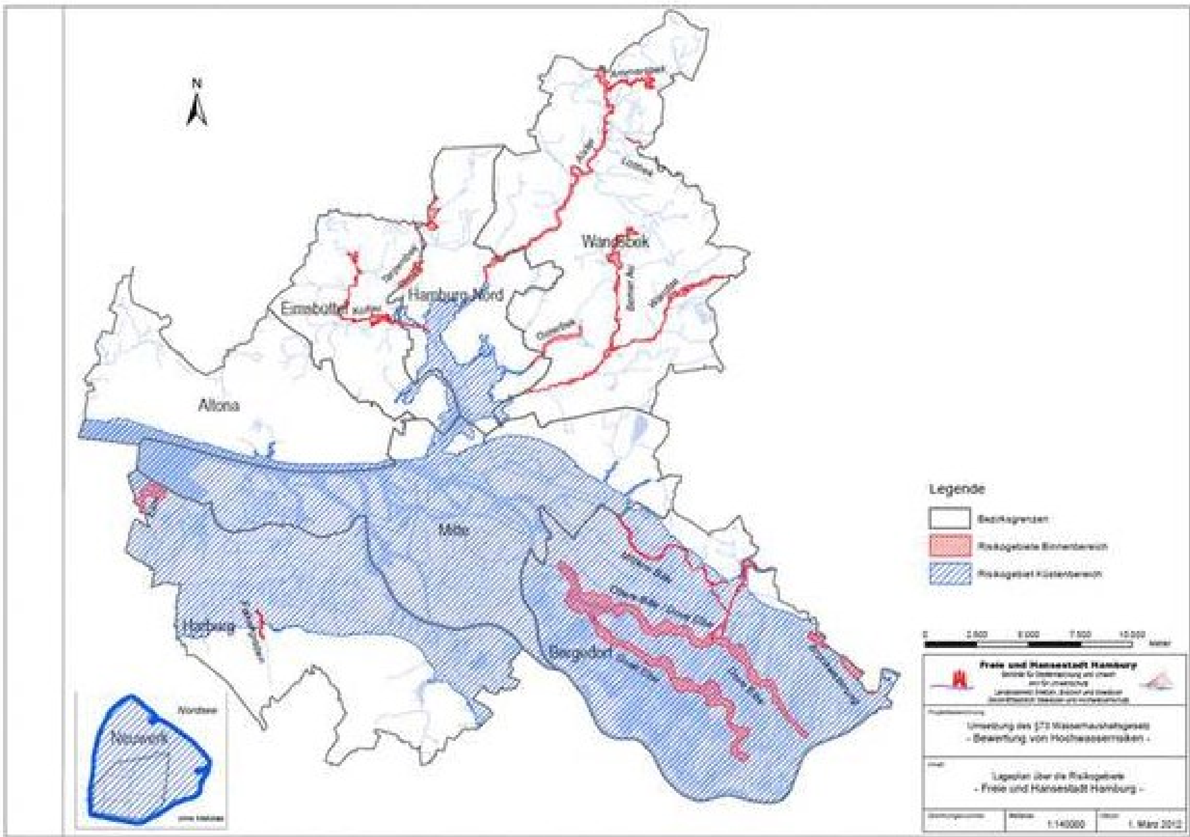

Figure 1. Risk Area in Hamburg (Free and Hanseatic City of Hamburg, BSU and LSBG).

The warning time of storm floods is extremely short; this is a clear difference to the high waters coming down our big rivers. Those high water levels can be predicted days before and allow adequate preparation.
There were two very high storm surges in Hamburg, the catastrophe in 1962 is still on everybody's mind in Hamburg and second in 1976 when nobody died but the Harbour area was flooded and lots of precious goods were destroyed. In the last decade there were four high water floods caused by heavy rainfalls in 2002, 2006, 2011 and 2013. It can be seen that Hamburg must be protected against both: storm surges and heavy rainfall.
The structure of Coastal Protection in Hamburg is based on three columns: Technical, preventive and operative Protection (Fig. 2), which is comparable with the structure of flood protection.

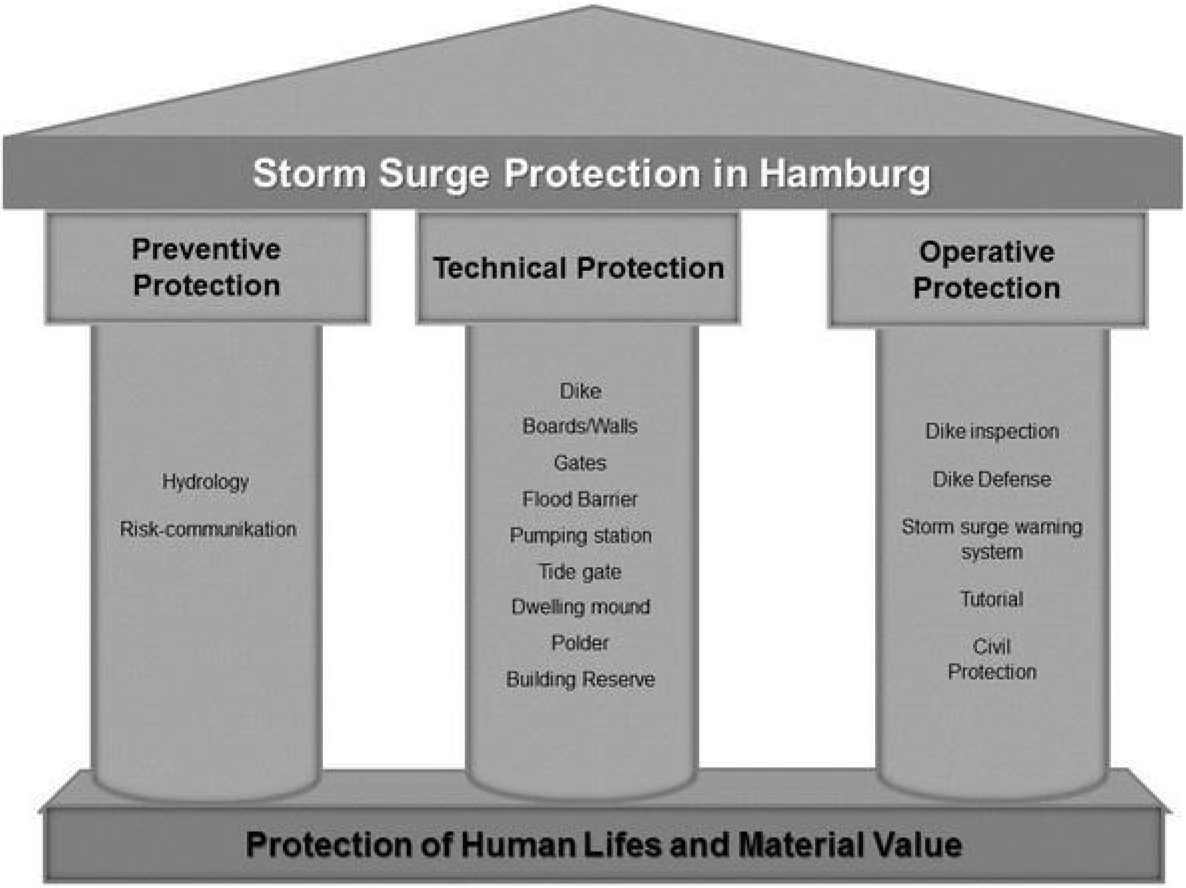

Figure 2. Structure of Coastal Protection in Hamburg (Free and Hanseatic City of Hamburg, LSBG).

The technical protection in Hamburg is divided into three parts, the public flood protection, consisting of flood protection walls and sea dikes, the private flood protection, mainly applied as individual object protection in the HafenCity, and the flood protection in the harbor area. The public flood protection contains more than 100 km of dikes and sea walls. Since the water level in the Elbe estuary is influenced by the tides in the North Sea the dikes along the Elbe in Hamburg are coastal protection.
The ‘storm surge protection facilities“ comprise coastal protection construction as well as property of objects, protected by special constructive measures sometimes in front of the public dike line — called main dike line. Buildings in front of the dike line are in the old harbour for example the so called “Speicherstadt“and the new HafenCity.
The guiding principle of coastal protection in Hamburg is to achieve a very high safety standard for the whole city. This will be ensured by the design level used for dimensioning storm surge protection facilities. The uncertainties of climate change scenarios and the growing risk due to the growing city necessitate a new flexible protection system. Such a concept has to involve a definition of the safety standard, the physics and hydrodynamic of storm surges and a good adaption strategy which helps to deal with future requirements. Heightening of the primary flood protection structures like sea dikes and barriers in city areas often causes problems due to a small availability of space. In order to face the challenges of rising sea levels, adaptation strategies are needed that fulfill both criteria of a very high safety standard on the one hand and a small demand of space on the other hand.

Flood Risk – a Global Problem

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Keywords: Flood disasters, Flood risk, Risk reduction, Risk management, Insurance

Water is responsible for most natural hazard losses in the world, and flood catastrophes are increasing in both number and intensity. This is creating challenges that must be tackled by governments, people, communities, companies and the financial sector.

Flooding comes from extreme precipitation, or may be a secondary hazard of windstorms and tropical cyclones (storm surges), high or low temperatures (snowmelt, ice jam), earthquake (tsunami) or technical failures (breaching of dams or embankments). The three main causes of flooding are river floods resulting from widespread, often basin-wide and long-lasting rainfall; flash floods and off-plain floods produced by intense precipitation; and storm surges caused by onshore winds blowing towards the coast. This variety of causes as well as the different extent, propagation and impact of floods must be reflected in risk reduction efforts, ranging from hazard identification and modelling to financial preparation and general awareness.

Extreme floods do not happen in a stationary environment. Initial conditions vary and flow paths are not strictly defined as water interacts with and changes channel and valley geometries, dykes fail and new, unforeseeable systems of pathways are created. Additionally, flood defence activities have a major influence. Nowadays, it is no longer enough to predict and forecast discharges, hydrographs, water levels, inundated areas and flow velocities (i.e. perform hydrologic and hydraulic modelling). Flooding eventually creates losses which need to be assessed in advance. This leads from hazard modelling to risk modelling.

The term "risk" encompasses hazard, values at risk and their vulnerability. The flood risk is changing continuously as each of its components is changing. Hazard is influenced by measures taken in the catchment area and by climate change, values at risk by development of flood plains, and vulnerability by the rising sensitivity of modern goods and building materials, but also by flood control measures.

The flood risk can be reduced by appropriate measures better than any other natural hazard. Flood prevention and flood control are highly cost-efficient. Each euro spent on flood control yields a much greater benefit in prevented loss. But awareness and preparedness on all levels are also crucial as the following examples show.

In 2011, a rare flood happened along the Mississippi. The United States was prepared for the event thanks to flood control efforts made over a period of several decades, and the flood waters were successfully managed to minimise losses. In the same year, a flood hit Thailand. This event not only overwhelmed practically all control devices but created huge losses because large industrial value concentrations had been developed in a careless and negligent way in areas prone to flooding.

Three coastal floods also revealed differences. Typhoon Haiyan's storm surge (Philippines, 2013) was surprising, huge and hit an area that was unprepared, and probably not even "preparable" at all. The scenarios of Hurricanes Katrina (US Gulf Coast, 2005) and Sandy (New York, 2012) were known, but the risk downplayed or ignored. Japan, in contrast, was quite well prepared for tsunamis, but not enough for an event like the one in 2011. However, the death toll of 16,000 would have been a great deal higher if there had been no programme of coastal protection and civil preparedness.

We will not be able to erase the flood risk. We have to live with it – and manage it. Managing the flood risk means we have to share it, refrain from exposing values to risk, erect and reinforce protection works, respond appropriately as a potential victim, and prepare for catastrophe financially, i.e. by taking out insurance cover. In doing so, flood losses cannot be completely prevented, but large catastrophes can be.

Integrated Environmental Modelling – What is the Vision? Is it Achievable?

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The importance of understanding the world and all the events and activities within it as a set of interconnected, interacting processes is now widely recognised. Early versions of the technology to achieve that understanding are now in place. What are lacking are the strategy, the institutional infrastructure and the resources to move that technology out of the research area into the domain of the early adopters. However, if those things could be put in place, then the opportunities that open up for finding sustainable solutions to present challenges and developing new products and services are almost beyond imagination.

In many spheres, simulation models have proved to be a highly effective method of exploring processes, encapsulating our knowledge of them and predicting their behaviour. This is true for all the physical sciences and applies to many social and economic sciences as well. To date most modelling development has taken place in relatively isolated discipline specific “islands of excellence”. There has been little communication across disciplines. Consequently, by comparison with the investment in model development, very little work has been undertaken on the complex problem of linking (or coupling) models either within or across the disciplinary boundaries; an activity which is generally referred to as 'integrated modelling'. In recent years, however, there have been a number of informal meetings among modellers who either have an immediate need to study interacting processes or who have seen the bigger picture and its opportunities. From these meetings roadmaps have begun to emerge for progressing integrated modelling. Although the various roadmaps have originated from different disciplines, they are remarkably consistent in their conclusions. They all recognise that intra- and inter-disciplinary and national collaboration will be required to bring about the necessary conditions for the required culture and technology to grow and flourish.

This keynote talk will examine the challenges and questions which have given rise to the need for Integrated Environmental Modelling (IEM) and the forces which shape it. It will explore some of the technical and scientific aspects as well as discussing the effect of current ideas and initiatives. It will set out a vision of how integrated environmental modelling could contribute to meeting the environmental challenges we face as well as exploring some of the key ingredients of such a solution.

A Perspective of the USDA Watershed Erosion and Sedimentation Research

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Keywords: Soil conservation, Erosion prediction, Sedimentation, Soil erosion

Erosion and sedimentation related watershed research in the USA is for the most part traceable to the calamitous events during the "Dustbowl" of the 1930s. At that time, large areas in the Plain States of the USA (Oklahoma, Kansas, Western New Mexico, eastern Colorado, and western Texas) experienced serious wind storms which removed large amounts of surface soil from plowed-up and dried-out unprotected land. While this part of the USA suffered serious agronomic and ecological damage by wind and threatened and impoverished to a catastrophic degree the livelihood of the rural population, the south-eastern part of the USA suffered severe upland area erosion problems and gullies by water from rainfall and runoff especially during severe rainstorms on cultivated unprotected sloping land. In response to these conditions, the U.S. Congress, encouraged by President Roosevelt, set in motion the legal and technical framework to address these problems. The Soil Conservation Service (SCS), a U.S. Government federal agency, was established to perform research and to recommend and assist landowners and farmers with measures to control soil loss. The primary focus was on-site monitoring and quantifying soil loss from natural runoff plots on different soil types in different agricultural practices with sloping topography. Also, sediment movement into and within the stream system and channels of agricultural watersheds was of major concern as deposited soil caused severe siltation and flooding problems. The main goal of the SCS was to conserve the soil on upland areas, stabilize streams, and prevent flooding.

In the 1940s and 1950s SCS erosion and conservation research program was initiated to include in a limited way process oriented research and to arrive at predictive relationships for the effects of hydrology, topography, soil type, and agronomic and mechanical practices. During this period the well-known Universal Soil Loss Equation (USLE), a regression based factor relationship, was developed which had a major impact on soil conservation practices and recommendations, first in the USA but soon thereafter worldwide. This relationship, in particularly its updated versions, is today the main tool for conservation management programs. In 1954 the U.S. Government assigned the research component to a newly established Agency, the Agricultural Research Service. The SCS maintained its role of implementing conservation practices at the farm and watershed level. The research area focused in particularly on the relationship between the exogenic forces of rainfall and runoff characteristics (erosivity) and the soil response to these forces (soil erodibility).

In the 1960s the USLE underlying factor relationships were further improved. The physics of erosion processes became the subject of many research projects aided by the development of rainfall simulator equipment. This equipment could shortcut many of the long-term soil erosion studies and could evaluate in a relative short time the effectiveness of soil conservation practices.

In the 1970s soil erosion mechanics on upland areas, signifying process and analytical approaches to soil erosion research, became of major interest. Similarly, the advent of computer technologies for both statistical and deterministic analyses and calculations facilitated model development of complex erosion processes. At the same time, the USLE was improved, and remained the primary conservation tool for managing upland conservation practices and stream system stabilization measures in agricultural watersheds.

In the 1980s process erosion models such as WEPP (Water Erosion Prediction Project) were developed. The premise was that a better scientific basis for predicting and controlling soil erosion would be obtained for predicting soil erosion on upland areas and for conditions inadequately covered by the USLE. Processed based research and modeling research still continues.. The USLE was updated twice in 1978 and in 2008 and became the Revised Universal Soil Loss Equation (RUSLE) with the publication of Agricultural Handbook 703 in 1997. Since that time, the recently and scientifically improved 2008 version, known as RUSLE2 can be accessed on the Home page of the

National Sedimentation Laboratory. RUSLE2 has added capabilities. While the USLE can only be used in cases where erosion takes place and is not applicable when sediment deposition occurs. RUSLE 2 can be applied on upland areas with both erosion and sediment deposition problems. However, it does not address ephemeral or permanent gully erosion.

Work on channel erosion in the USDSA has not received as much emphasis as erosion on upland areas. However, substantial efforts have been made in sediment transport in the USDA. That work was mostly designed to obtain a better understanding of sediment movement in relation to flow regimes and sediment characteristics and to arrive at improved measurement techniques. Some research work was done on stream bank stability problems and protection, control structures, and sediment deposition in lakes and the stream system. Few transport relationships have been obtained. What is lacking is a better understanding of the sedimentary fluid mechanics in stream flow which appreciably may affect sediment movement as shown in shallow flow regimes on upland area.

In the 1990s and 2000nds , with digital computer technology, sophisticated numerical solutions and models have been developed that can predict to a very reasonable degree sediment movement in the stream system under complex flow regimes and geomorphic conditions. Of particular significance are the basic 1D-, 2D-, and 3D-NCCHE numerical computational models developed by the National Center for Hydro-sciences and Engineering at the University of Mississippi under the auspices of the Agricultural Research Service National Sedimentation Laboratory. These models can simulate the flow regime during dam failures of both a catastrophic (sudden collapse) or gradual nature. Likewise, these models can be used to project and determine sediment movement in the upstream and downstream sections of the stream system during and following the removal of functionally outdated dams. Of particular value in this era of climate change are the ability of these models to predict the flow regime in real time, the capability to predict the progression of flow waves in terms of height and velocity, and thus the capability of offering under certain circumstances the possibility of developing an early warning system in case of dam or levee failure. The usefulness of this capability is enhanced by the parallel development of geo-technical techniques by the National Center for Physical Acoustics of the Univ. of Mississippi to determine the stability conditions of earthen dams, to assess the potential for failure. The models also offer great potential in water quality research by following the movement of point and non-point pollutants through the watershed stream system, and estimating their abatement if combined with time dependent and natural decay rate processes. They are also very useful for Action Agency in devising policies regarding permissible discharges, evaluation of chemical hazardous conditions and spreading of pollutants in surface waters.

The weakest link in upland erosion and sedimentation research is an inadequate understanding of the effect of surface and subsurface flow on ephemeral gully and gully development. With the development of LIDAR technology, one can now accurately assess the contribution of gullies in the erosion and sedimentation processes though research on analytical methods and the underlying physico-chemical factors need far more attention than thus far has been recognized. Perhaps, the most limiting factors to progress in soil erosion and sedimentation research are the availability of well-trained personnel in the STEM (Science, Technology, Engineering, and Mathematics) subjects and budget limits. These aspects will be discussed as well.

Utility of Coastal Science

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For creating a framework to review the societal utility of science we suggest a list of categories of such utilities, and use examples from the practice of the HZG institute of Coastal Research In Geesthacht, Germany.

- “Making sense” refers to the scientific understanding of complex phenomena, and its use for supporting societal framing and decision making. Examples are consequences of eutrophication or the separation of the effect of different drivers, from global climate change to changing morphology. A significant constraint is that science is not the sole supplier of such understanding, but other knowledge brokers are active as well.
- “Marine Spatial Planning (MSP)” describes the “public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that have been specified through a political process”. MSP needs in particular contributions from social science for understanding structures, perceptions, interests and power balances of the involved actors.
- “Monitoring” aims at the assessment of the current status of the coastal environment and short term trends based on observation and related data analysis. This includes making data and assessments available for intermediate or final users. Examples refer to routine analysis and short-term forecasts of current environmental states.
- ”Hazard, risk and opportunities” assessments are needed for almost any kind of onshore and offshore operation. For the assessment of negative outlooks and positive perspectives comprehensive and homogeneous data are needed. Our example demonstrates how to prepare such assessments in cases when observed data are unavailable.
- “Scenarios” provide a useful tool in assessing consequences of possible future developments, sketching related uncertainties or identifying developments with predetermined properties. Our examples deal with the development of coastal protection or the expected impacts of climate change.Even though not independent, the different categories address different stakeholder groups; the first, “making sense” addresses mainly the general public, scientists, and media. In the other categories, numbers are produced, which may guide short term decisions.

Oral Presentations

Water Resources Planning and Management

A Real-Time Flow Muskingum Forecasting Model for Three Main Station of the Medjerda River (Tunisia)

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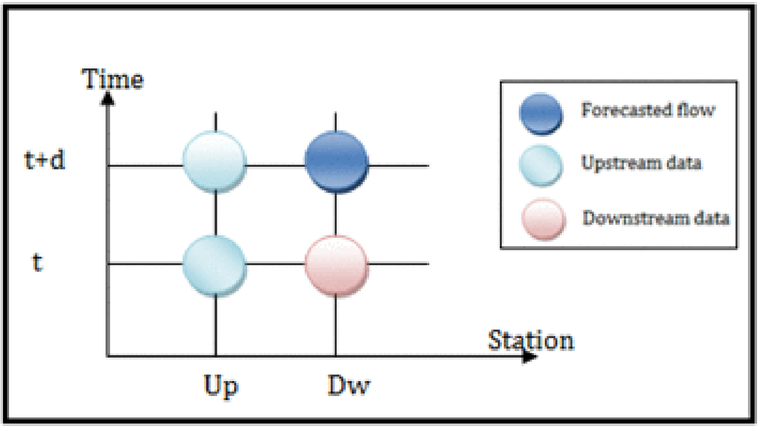
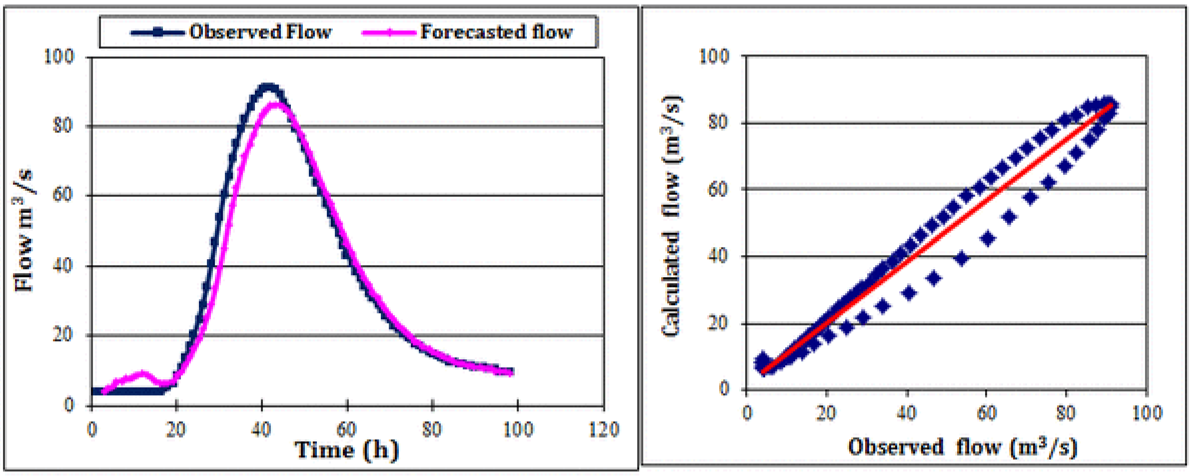
Keywords: Flood forecasting, Upstream basin of Medjerda, Muskingum

River flow forecasting has always been one of the most important issues in hydrology. Models of flood prediction are varied; there are a big number of algorithms from simple statistical receipt to the partial differential equations of Saint-Venant (Habaieb, 1992). In Tunisia, the flood problem arise the only perennial river, Medjerda, in particularly the plain of Ghardimaou-Jendouba-Bou Salem. The Muskingum model is the simple flood propagation model and is numerically equivalent to the Saint-Venant equations via the diffusion equation of a wave. In this research, Muskingum model is used to forecast 21 flood's hydrographs for three stations in Medjerda River. This model requires two data from the upstream station one on the present time and the second on the forecasting time and a data from the downstream station on the present time (figure.1). The delays of forecasting were 2, 4, 6 and 8 hours.



The forecasting operation consisted in choosing reconstitution coefficients by Muskingum model for a previous flood that belong to the same season and had a near humidity index.
To evaluate the quality of 252 forecasting operations, four numeric and three graphic performance measures were selected. The standard deviation error 'S' was chosen to assess the mean quality error. A big difference for the peak flow prediction offer more damage than the little flow in the beginning and the end of flood, for that the peak relative error 'S1' was calculated. The difference time between observed and forecasted peak have to be the minimum, so the peak time difference 'S2' was defined. Hydrograph flow, Error flow and correlation between observed and calculated flow were the graphic criteria selected in this application.
In the section Ghardimaou-Jendouba, the standard deviation error 'S' varied from 2 to 190 m^3/s, the peak relative error 'S1' had low value -35 and 23% and the peak time difference 'S2' 2 and 9 hours. While, for the section Jendouba-Bou Salem the value of the three criteria varied respectively from 2 to 236 m^3/s, -24 to 30 % and -2 to 11hours. For the last section Ghardimaou-Bou Salem, the three criteria ranges between; 2 and 225 m^3/s (for 'S'), -18 and 12% (for 'S1') and 2 and 10 hours (for 'S2'). These results are satisfactory for the three sections and all delay. That were confirmed by the mean flow error 'E' which where for the three section -2 m^3/s for the forecasting delay 2 hours, -3 to -4 m^3/s for

4 hours, -6 to -8 m^3/s for 6 hours and -8 to -13 m^3/s for 8 hours. The propagation model Muskingum gave adequate results for the flow forecasting.
The following figure (on the left) present an example of flow forecasting of 15/01/2010 flood after 2 hours, which is classified the second depending on 'S' and the eighth depending on 'S1' and the correlation between observed and calculated flow.



Modeling Investigation of the Underground Dam on Samui Island, Southern Thailand

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Keywords: Groundwater Flow Modeling, Underground Dam Design, Samui Island, Southern Thailand

Samui island in southern Thailand has become an ever-increasingly attractive tourist spot over the last decades. It is thus of no doubt that water deficit, mainly, during this tourist season – the main source of water is surface water stored in a few reservoirs across the island - has become more severe in recent years. Department of Groundwater Resources (DGR) has been aware of this problem and has thus initialized induced the project of underground groundwater dam to better manage the groundwater resources on Samui island which is supposed to impede the natural groundwater outflow towards the sea and so to increase the usable groundwater storage during the dry season. Based on results of a comprehensive hydro-geological field analysis that included geophysical surveys as well as drilling and piezometric monitoring, the aquifer system can be discriminated as a three-layer aquifer with, from top to bottom, i.e., (1) the sand-clay unconfined aquifer, (2) the sand-clay confined aquifer and, (3) the weathered granite-confined aquifer. The dam will be realized by two on a central impervious rock abutting low-permeability-, groundwater-flow-impeding walls that cut through the three layers of the aquifer system, down to a maximum depth of about 50 m. A top of the 2 m thick dam, which ends below the upper, unconfined aquifer layer, a vertical layer of high permeability will be set up, so that a "spillway-like" overflow of the groundwater is enabled, in order to not disturb too much the subsurface ecology downstream. According to above data, a 3D numerical groundwater flow and transport model with areal domain of 11.5 km x 7.5 km have been, respectively, conceptualized, set up and calibrated in both steady and transient mode. The computed head is good agreement with the observed head. In the subsequent modeling analysis the underground dam with the spillway characteristics as mentioned above has been embedded into the model by specifying the corresponding vertical curtains of low and high conductivity, respectively. Finally, groundwater pumps upstream of the underground dam have been included into the model. Simulations without and with the hydraulic structures have been performed to ascertain the differences with respect to both groundwater levels and degree of possible seawater intrusion and to evaluate the overall functionality of the underground dam. The results show that while the underground dam is able to raise groundwater levels, the amount of seawater intrusion is basically not affected. The budget analysis of the two simulation sets shows that the underground dam serves well its purpose, particularly, for long dry spells, as more groundwater can be pumped out of aquifer system than is possible without this hydraulic structure.

Uncertainties of Multivariate Derived Hydrological Design Values Under Non-Stationary Conditions

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Keywords: Non-stationarity, Copula, Uncertainty

Over the last decade the number of applications of copula functions for multidimensional modelling of hydrological and coastal parameters has significantly increased. However, almost all of the studies assume stationarity in the marginal distribution parameters as well as in the dependence structure of the variables. This is because the available time series are often too short for using a non-stationary multivariate model. Furthermore mostly the uncertainties of multivariate models are neglected. In this study we analyze the joint probability of the annual maximum peak discharges (Q) and volumes (V) of flood events based on a water level series of the Rhine River in Germany. The gauge provides 191 years of continuous data. We find significant positive trends in the marginal distribution parameters as well as in the dependence measure from analyzing 30-year moving time windows. Fitting time dependent marginal distributions and time dependent copulas to the data sets, and comparing the results with the stationary approach, shows the influence of the non-stationary behaviour of the variables. The results are illustrated by calculating the joint probability of the Q and V for four cases: i. considering all parameters as time dependent, i.e. the location, scale and shape parameter of the marginals and the copula parameter, ii. considering the location and scale parameter of the marginals and the copula parameter as time dependent, iii. considering the location parameter of the marginals and the copula parameter as time dependent, and iv. considering only the copula parameter as time dependent. The results highlight that the joint probability, illustrated by the isoline of a given exceedance probability, varies significantly over time when non-stationary models are applied. The uncertainties are illustrated on the 95% confidence level of the most likely design events. Here, we highlight the influence of the uncertainties of the marginal parameter estimation, the copula parameter estimation as well as on both.

A Trading-Ratio System for Waste Load Allocation in a Tributary River

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Keywords: Water Quality Management, Cost-effectiveness, Trading Discharge Permit, Tributary

One of the effective approaches for water quality management in river system is trading of discharge permits. In addition to reducing total treatment cost and maintaining water quality standards along the river, trading discharge permits can result in an equitable distribution of treatment costs among dischargers and dischargers would have economic motivation to participate in process of trading discharge permits. According to the fact that water flows to the lowest level unidirectionally, the Trading Ratio System (TRS) is utilized for water quality management in river systems. TRS considers the river assimilative capacity and provides the optimum trading pattern. In TRS, The trading ratios are set equal to the exogenous transfer coefficients among zones along stream flow and dischargers trade with each other based on the trading ratios. In the past researches, TRS has been designed for mainstream of river and the tributaries of river are not incorporated and considered. In this paper, the TRS is developed for considering tributaries of a river. TRS is used in a Monte Carlo Analysis to consider uncertainty in river, dischargers and simulation model parameters. The inputs of the Monte Carlo simulations are considered to be the pollution loads, upstream flow, DO and BOD concentrations in upstream flow, water temperature, rate of BOD removal and reaeration rates. As the existing water quality and quantity data in the study area are so limited, the PDF of the random input variables is considered to be Normal. In the proposed methodology, low water quality is also quantified as a fuzzy event and fuzzy risk of violating the water quality standards is estimated at checkpoints along the river. Results of applying the proposed methodology in the Pirbazar river in Gilan province of Iran, illustrate its efficiency as a cost-effective and risk-informed decision-making tool in river water quality management.

A Sequential Simulation-Optimization Model for Water Allocation from the Multi-Reservoir System in the Karkheh River Basin System, Iran

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Keywords: Simulation, Optimization, Reliability, Hydropower energy, Network Flow Program, MODSIM

Sequential Streamflow Routing (SSR) with a control on the reliability of meeting the energy demand is a common method for assessing the energy potential in practical hydropower projects' design and operation in Iran. This approach results in developing a Reliability-Based Simulation (RBS) model which is used for the design of single-reservoir hydropower projects. This method can be extended to multi-purpose multi-reservoir systems for the evaluation of other demands in an integrated system. This paper is about developing a simulation model, capable of assessing water resource development plans in the large-scale Karkheh river basin system in Iran. The system consists of seven dams that serve for hydropower generation, water supply and environmental purposes. The first step in the development of the RBS consists in the estimation of the production capacity of the power plants and the areas of irrigation systems under development, so that the target reliabilities in meeting the energy- and agricultural demands are achieved. This requires the use of the simulation model in a sequential scheme which iteratively adjusts the design variables of the power plant production capacities as well as of the irrigation areas, in order to arrive at the desired reliability levels. For this purpose, the MODSIM river basin decision support system has been used to simulate the system performance, in which sequential single-period Network Flow Programs (NFP) are employed to determine water amounts allocated to different uses, according to their priorities, for each set of design variables. Furthermore, using the custom coding facility, hydropower demands have been modeled and introduced to MODSIM to make it be capable of simulating specific operating policies relevant to the system's objectives. The finally resulting model has provided the possibility of comparing different scenarios of the operation of the Karkheh river basin multi-purpose, multi-reservoir system.

Modeling of Cascade Dams and Reservoirs Operation for Hydropower Energy generation

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Keywords: HEC-ResSim, Cascade dams & reservoirs, Omo Gibe river basin, Reservoir operation

Ethiopia is naturally endowed with one of the largest freshwater resources in sub-Saharan Africa but only small fraction of these potentials are annually utilized to achieving the national economic and social development goals of the country. However, now a days the Government of Ethiopia (GoE) has greatly committed to increase the utilization of these surface water resources by constructing dams in different river basins for example Awash, Tekeze, Omo Gibe, Blue Nile etc. for the purpose of hydropower energy generation, agricultural (i.e., irrigation and livestock), water supply, flood control, industry and other sectors.

The country has an immense renewable energy potential in the forms of hydropower, solar, and wind, as well as significant untapped geothermal resources. However, the per capita electricity consumption is among the lowest in the world. According to the GoE, only 15 percent of the population has access to electricity. The dependence on biomass energy causes increased deforestation, shortages of fuel wood, and degradation of rural ecosystems particularly in the Omo Gibe river basin. Deforestation in watersheds will contribute to high rates of siltation in the country's reservoirs, which limits the useful life of hydropower structures (and those used for municipal water supplies and irrigation as well). In addition to this loss of reservoir capacity will cause hydropower generation interruption, reduced water availability for irrigation, and reduced capacity to regulate the river, thereby exposing the river basin to general water shortages and to flooding which further increases the cost of modern energy in the country.

Therefore, development of priority for water infrastructures and improvements of water management have crucial and complementary roles in contributing to sustainable economic and social development goals of the country. One way of improving water management is through increasing the efficiency of reservoir operations. Reservoir operation is a complex task involving numerous hydrological, technical, economical, environmental, institutional and political considerations. There is no general algorithm that covers all type of reservoir operation problems. The choice for techniques usually depends on the reservoir specific system characteristics, data availability, the objectives specified and the constraints imposed.

Hence, in this study the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers reservoir simulation model, HEC-ResSim, was used to simulate the cascade dams and reservoirs operation in the Omo Gibe river basin to optimize the water for hydropower, flood management as well as environmental flows. For these purpose two scenarios were simulated via scenario one (2006-2013) and scenario two (2014-2031) based on the simulation period to incorporate the parameters that may influence flow requirements at a reservoir include time of year, hydrologic conditions, and simultaneous operations by other reservoirs in a system.

To set up and control the HEC-ResSim model, the output results of precipitation runoff model i.e., Soil Water Assessment Tool (SWAT) was applied as an input data for the model; and routing reaches representing the natural streams in the system, and the lag and attenuation of flow in a reach was computed by one of the available standard hydrologic routing methods, such as Muskingum routing method. Simulated unregulated flows without taking into account the effects of flood regulation (flood management) of reservoirs operation were used for calibration of the model by matching the simulated result with the observed streamflows. The daily time series plots of 2006-2013, as well as statistical measures, such as the coefficient of determination (R2) and the Nash-Sutcliffe efficiency (NS) parameter between observed and simulated streamflows are computed on daily time scales and both of them indicate a good performance of the final calibrated HEC-ResSim.

The model was attempted to represent the physical behavior of cascade reservoirs in the Omo Gibe river basin with its high speed hydraulic computations for flows through control structures, and hydrologic routing to represent the lag and attenuation of flows through the main and tributaries of the river. Hence, the model result indicates that the new reservoir operation rule selected for modelling of the cascade dams and reservoirs operation is the best for optimal average energy production which increase it more than 50% per year and for regulation of stream flows in the reservoirs compared to the targeted average energy production for each cascade hydropower plant designed by Ethiopian Electric Power Production (EEPCO).

The hydrologic flood simulation results also reveal that the operation of cascade hydropower plants with the new operation system will increase the water availability in the dry season and decrease flooding in the wet season. Overall the study has determined the new reservoir operation system will evenly allocate and release the available water in real time during day-to-day and emergency operations in the Omo Gibe cascade reservoirs throughout the year, and finally suggests that the modelling will solve the conflict of interest among the maximum power production of the government and the scarcity of the availability of water for the population in the lower Omo basin.

Construction Effects of the Karun 4 Dam, Iran, on the Groundwater in the Adjacent Karstic Aquifer.

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Keywords: Karun 4 dam, Water seepage, Karst, Hydrogeology

The Karun 4 concrete dam is with a maximum dam height above foundation of 230m the highest dam of Iran. It has been in operation since July 2011. It was constructed over a karst limestone and water leakage has been, and continues to be, one of the most important problems of this dam. The geological formations around the dam site consist of carbonate layers of the Asmari formation and marlstone and marly limestone of the impervious Pabdeh formation, upstream of the dam site. The object of this study is to determine the dam construction effects on the groundwater levels in the adjacent aquifer. Thus, before the dam construction, the natural groundwater levels at both banks were recorded to be 5-8m higher than the river stage. This indicates that the natural groundwater gradient at that time was from the banks towards the river, i.e. the latter was an effluent stream before the construction of dam. At that time no important springs were identified at the dam site., other than a minor spring with a discharge <5 Lit/sec that emanated at the contact interface between the permeable Asmari- and the impermeable Pabdeh formation (perching aquifer conditions) on the left bank, upstream of the dam. A Lugeon test that was carried out at that time indicated that the permeability of the adjacent limestone is high, as it varies from 25 to 55 Lu in the layers above the river level, but it decreases gradually to 3 Lu in the formations below. After dam impounding, some changes in the borehole's water levels were observed. Thus it has been found, in particular, that the leakage from the reservoir has induced groundwater level rises between 12 to 17 meters.

References

Jeannin, P.-Y., 2001. Modeling flow in phreatic and epiphreatic karst conduits in the Holloch Cave (Muotatal, Switzerland). Water Resour. Res., 37, 191-200.

Kamali, M. and Ashjari, J. (2012). Determination of efficiency of grout curtain of Karun 4's Dam by dye tracing test. Report to IWPC (Iran Water & Power resources development Company), 124 p.

Keeler, R.R. and Zhang, Y.K., (1997). Modeling of groundwater flow in a fractured-karst aquifer in the Big Springs Basin, Iowa. GSA Abs. with Programs, 29, 4, 25.

Kiraly, l. (1998). Modeling karst aquifers by the combined discrete channel and continuum approach. Bulletin du Centre d'hydrogeologie, Neuchatel, 16, 77-98.

Sauter, M., (1992) Quantification and forecasting of regional groundwater flow and transport in a karst aquifer (Gallusquelle,Malm,SW Germany): Tübinger Geowissenschaftliche Arbeiten, Ser.C, 13, 150p.

Impacts of Reclaimed Water Irrigation on Heavy Metal Distribution in Soil Properties and Crop

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Keywords: Wastewater reuse, Lettuce, Heavy metal

Reuse of treated wastewater for irrigation purposes have been accepted as the most effective ways for conserving the limited resources of freshwater. Treated wastewater reuse for irrigation purposes offers many advantages however; it may still pose various risks. The possible accumulation of trace elements and toxic organic contaminants over soil and plants should be investigated in detail. This study was conducted to analyze quality criteria of the wastewater treatment plant's effluents and possible accumulation of heavy metals in agricultural soils and plant in case of reuse for irrigation. To observe the heavy metal accumulation in soil a lab-scale lysimeter setup is constructed. In order to examine the effects of reuse water on soil and lettuce plant (Lactuca sativa), irrigation was tested by using three different effluents of domestic wastewater treatment plants in Istanbul (Secondary clarifier effluents of Pasakoy and Tuzla Biological Wastewater Treatment Plants (WWTPs) and effluent water of UV disinfection unit of Pasakoy WWTP). Under same conditions, four separate lysimeter setup were constructed and one of them was irrigated with tap water (as blank) and the others were irrigated with different effluents of wastewater treatment plants.
General wastewater characteristics of the effluents were analyzed before and during irrigation. Effluent characterization of water samples during eight months of application were shown in Table 1.

Table1. General characterization of treatment plants effluents

PARAMETERS	Unit	PASAKOY WWTP UV EFFLUENT	PASAKOY WWTP SECONDARY CLARIFIER EFFLUENT	TUZLA WWTP SECONDARY CLARIFIER EFFLUENT
		Average	Average	Average
NH_4-N	ppm	1,33	1,43	2,29
NO_2-N	ppm	0,06	0,07	0,08
NO_3-N	ppm	1,21	1,27	3,27
PO_4	ppm	5,15	6,27	4,64
DOC	ppm	8,00	8,60	11,71
COD	ppm	60,29	55,38	73,45
BOD	ppm	18,91	20,01	20,64
MLSS	ppm	4,93	5,36	11,42
pH	ppm	7,16	7,14	7,19
Cl^-	ppm	93,5	116,8	1345,9
EC	µs	912,7	921,8	5890,1
TDS (mg/l)	ppm	584,2	589,9	4712,0

Inhibition in the growth of lettuce was observed after 30 days of irrigation with secondary clarifier effluent of Tuzla WWTP. However, any signs of retardation in growth were not observed for the lettuce which was irrigated with secondary clarifier and UV disinfection unit effluent of Pasakoy WWTP. Saline water may result in the reduction of crop yield, while high value of sodium adsorption

ratio (SAR) leads to deterioration of the physical properties of the soil with consequent reduction in plant yield. Results show that highest TDS and chloride concentration was measured for the Tuzla WWTP effluent, therefore high salinity and specific ion toxicity (Cl-) might influence adversely the growth of lettuce for this lysimeter setup.
The concentration of heavy metals in soil and water samples which include, Zn, Cu, Cr, Cd, Pb, As, B, Ni etc. , were determined using Agilent 7500 Inductively Coupled Plasma Mass Spectrometry(ICP-MS). The mean concentrations of each heavy metal in the samples were compared with the permissible levels of international standards. Heavy metal concentrations of water and soil samples were shown in Table 2 and Table 3, respectively. Irrigation sources were found to affect heavy metal distribution in soil. In future studies, for different harvest time accumulation of heavy metal in the soil will be monitored and heavy metal transfer from soil to plant will be investigated.

Table2. Heavy metal concentrations of effluent waters

Sample ID		Li (ppb)	B (ppb)	Al (ppb)	V (ppb)	Cr (ppb)	Mn (ppb)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Se (ppb)	Mo (ppb)	Cd (ppb)	Pb (ppb)	SAR (meq/l)
Pasakoy WWTP UV Effluent	Average	2,17	81,02	106,11	0,60	24,74	182,17	0	67,85	4,83	81,80	1,40	0,21	9,72	0	2,03	4,74
	Max.	6,44	94,51	593,20	4,59	247,60	350,80	0	79,00	17,39	175,88	4,18	3,29	15,82	0	13,75	4,98
	Min	0	68,63	0	0	0	40,11	0	50,49	0,00	42,41	0,00	0,00	3,86	0	0,00	3,65
Pasakoy WWTP Secondary Clarifier Effluent	Average	2,92	79,10	64,39	0,39	20,68	231,22	0	71,96	6,19	88,37	1,21	0,07	9,12	0	1,18	56,67
	Max.	14,46	90,52	352,40	4,62	231,60	272,50	0	93,87	22,09	347,30	2,93	1,12	11,89	0	12,52	159,78
	Min	0,00	66,82	0,00	0,00	0,00	91,27	0	56,93	0,00	50,73	0,00	0,00	4,98	0	0	3,34
Tuzla WWTP Secondary Clarifier Effluent	Average	18,34	489,91	53,31	1,39	20,38	166,55	17,99	84,34	39,12	209,55	2,56	4,44	14,39	0,03	1,96	24,31
	Max.	27,92	625,50	303,10	4,50	39,16	384,30	284,70	360,60	51,51	423,80	5,48	8,55	21,87	0,43	13,85	29,24
	Min	10,65	322,50	0	0	6,39	11,29	0	29,48	19,11	36,79	0	0,58	9,93	0	0	17,36

Table3. Heavy metal concentrations of soils

Sample ID	Li (mg/kg)	Be (mg/kg)	B (mg/kg)	Al (mg/kg)	V (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Co (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Se (mg/kg)	Se (mg/kg)	Mo (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Lysimeter1	11,11	0,61	16,47	0	33,74	31,51	491,88	6,20	28,54	19,91	44,86	4,83	0,55	4,33	0,31	8,65
Lysimeter2	12,91	0,70	16,80	0	38,28	36,77	539,62	7,51	31,99	73,81	40,93	5,84	0,66	4,55	0,10	9,59
Lysimeter3	11,37	0,65	15,86	0	33,26	30,60	486,92	6,25	26,86	13,51	48,58	4,22	0,46	4,22	0,03	9,95
Lysimeter4	14,58	0,82	19,79	0	41,26	36,64	644,50	8,63	36,98	17,55	55,90	4,61	0,60	5,45	0,36	13,04

Mapping of Meteorological Drought Patterns Using SPI and Different Interpolation Methods

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Keywords: Drought Mapping, Standardized Precipitation Index SPI, Spatial Interpolation

Drought is a normal part of climate and occurs in virtually all regions of the world. It is one of the major weather related disasters which is likely to continue for months, possibly years. It can affect large areas and may have serious environmental, social and economic impacts. Drought monitoring is an essential component of drought risk management. Drought indices, which are functions of precipitation records showing the severity of dryness during a particular time period, are often used for monitoring purposes. These indices may only be calculated originally at a limited number of sites where observations records on climate variables are available. However, what is required for monitoring and mapping is to estimate the spatial distribution of drought severity over larger areas. The paper demonstrates the implementation of different spatial interpolation techniques into meteorological data analysis from stations to large areas. The frequency of drought events is calculated using the Standardized Precipitation Index (SPI). Using daily precipitation records, the SPI is calculated for 1, 3, 6, 9, 12, and 24 months at 40 climatic stations covering the period 1972- 2009 in Germany. A software package has a friendly Graphical User Interface (GUI), was developed for operational drought monitoring and mapping in Germany using several interpolation methods. This software generates maps showing the frequency isolines of moderate, severe and extreme droughts as well as of droughts in all classes.

Integration of Data-Driven Modeling and Stochastic Modeling for Multi-Purpose Reservoir Simulation

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Keywords: Data-Driven Modeling, Stochastic Modeling, Reservoir operation, Drought, Standardized Precipitation Index SPI

In reservoir management practices, a simulation model can be used as a valuable planning tool to evaluate the impact of changes to the system's configuration or operational objectives. The desired generation or release scheduling can be checked using inflow forecasting in order to satisfy the entire set of operational constraints. At real-time operation stage, a simulation tool can be used to quickly check operational alternatives due to emergency events or planning and real-time incongruence. In this paper, an integration of data-driven modelling, which is based on computational intelligence and machine-learning methods, and stochastic models for reservoir operation and simulation was presented. Adaptive network-based fuzzy inference system (ANFIS) provides a method for fuzzy modeling to learn information about the data set that best allow the associated fuzzy inference system to trace the given input/output data. The applicability and capability of the ANFIS model were investigated through the use of a set of data in the Ruhr reservoirs system, Germany. The historical data included inflow, reservoir storage, Standardized Precipitation Index (SPI) and reservoir release. Neural Networks, ANFIS, Thomas-Fiering model, and Hidden Markov Model (HMM) were integrated in a simulation model. The set of input included the time of the year, storage, inflow and Standardized Precipitation Index (SPI). The target output was the reservoir release. Predicted release values and observed release values are evaluated using several common evaluation criteria. Results of model performance showed that the ANFIS and the proposed stochastic models provided reliable reservoir release prediction. Results showed also that the proposed approach could be a good tool for the evaluation of release for a specified month and could be also a helpful reference guide to the operator during making decisions.

Grey Fuzzy Optimization of Total Nitrogen Load Allocation to Nonpoint Sources in Watershed

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Keywords: Water quality, Nonpoint source, Watershed, Optimization, Fuzzy,Uncertainty, GIS, Decision-making

Water quality deterioration in Lake Kasumigaura, the second largest lake in Japan, has been a serious problem. One of the main causes of the problem is too much loading of pollutant from agricultural areas to the lake. Since various pollutant sources affect the lake water quality and they are distributed throughout the large basin of the lake, it is not straightforward to determine allowable loads from pollutant sources considering self-purification for water quality management by effluent control. Therefore, as an improvement over our previous study, we have developed an optimization model for allowable total nitrogen (TN) load allocation in a watershed with the aid of GIS (Geographic Information System).

Three key elements should appropriately be expressed in the optimization model for effluent control, which are (1) mechanism of self-purification, (2) uncertainty in model parameters, and (3) conflicting goals of stakeholders. Regarding nonpoint pollutant sources, (1) paddy field, (2) upland crop field, and (3) residential area are considered in this study. A study area, or a watershed of a water body, is divided into uniform cells. Cells of paddy field, upland crop field and residential area are specified as land management units (LMUs) in optimization. Discharged TN load from each LMU is delivered to a water body of interest, along with surface runoff, baseflow, river flow, etc. In order to represent self-purification through the transport of the load, the traditional first-order decay with respect to distance is assumed. Since the self-purification coefficients embodied in the decay equation are highly uncertain, the concept of interval number is applied. An interval number is a closed and bounded interval with lower and upper bounds. Employing the method that uses interval numbers in order to express model uncertainty is more practical in reality than other stochastic methods, because the former never requires determination of the occurrence probability of events.

Conflicting goals of water quality management authorities and pollutant dischargers are defined as grey fuzzy goals using interval numbers. The authorities are supposed to wish the transported TN load to the outlet of the watershed to be minimized for water quality conservation of the downstream water body. On the contrary, a discharger wants to gain the maximized allocated value of allowable TN load because it corresponds to high yield or little wastewater treatment cost. Those goals are represented with piecewise-linear membership functions in the fuzzy decision. We overcome vagueness of threshold values in the membership functions by introducing interval numbers in the grey fuzzy optimization framework.

Since the goals of the authorities and dischargers related to the LMUs are in conflict, harmonized decision-making should be conducted under uncertainty at a watershed level. Zimmermann's minimum operator is employed as fuzzy decision, and an overall satisfaction level, expressed as an interval number as well, is used as an objective function in optimization. Additionally, the goals mentioned above are converted into linear inequality constraints. The grey fuzzy optimization model is developed as a maximization problem of the overall satisfaction level under the constraints. Finally, fragmented sets of linear programming problems are formulated to solve the grey fuzzy optimization model.

The optimization model developed is applied to the Seimei River watershed, which is a sub-watershed of the Lake Kasumigaura basin. In the Seimei River watershed (25.6km^2), 4,496 cells at a resolution of 50m × 60m are specified as LMUs using ArcGIS 10.2. Values of parameters such as self-purification coefficients, discharge of river flow, and permissible and desirable levels regarding goals for the authorities and dischargers, etc. are determined with observed data in 2013 and the literature. Flow length, i.e., length of route where TN load issued from a LMU is transported, is estimated by the steepest gradient method with surface elevation and land-use data in the GIS. By solving the linear programming problems for TN load allocation to LMUs using the simplex method, a satisfactory range of allowable load at each LMU is procured, which could be used as a target interval for effluent control.

Numerical Prediction of the Efficacy of Treated Wastewater Recharge to Impede Seawater Intrusion in the Coastal Aquifer of Gaza-Palestine

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Keywords: Gaza coastal aquifer, Seawater intrusion modeling, SEAWAT, Artificial recharge

The ongoing depletion of the coastal aquifer in the Gaza Strip due to overexploitation has led to the process of seawater intrusion, which has continually becoming a serious problem in Gaza over recent decades, as the seawater has invaded deeply inland at many sections along the coastal shoreline.
In this context, prediction of the future behavior of the seawater intrusion process in the Gaza aquifer is thus of crucial importance to safeguard the already scarce groundwater resources in the region. To that avail, the coupled three-dimensional density-dependent groundwater flow and solute transport SEAWAT- model, as implemented in Visual MODFLOW, is applied to the Gaza coastal aquifer system to simulate the location and the dynamics of the saltwater–freshwater interface in the aquifer between the periods 2000-2010. A very good agreement between simulated and observed TDS salinities with a correlation coefficient of 0.902 and 0.883 for both steady-state and transient calibration is obtained.
After successful calibration of the solute transport model, various future groundwater management scenarios for the Gaza aquifer are studied. This includes, in particular, the analysis of the effects of artificial recharge, planned in the Gaza strip already for some time, to forestall, or even to remedy, the presently existing adverse aquifer conditions, namely, low groundwater heads and high salinity by the end of the target simulation period, year 2040. To that avail, the calibrated transient SEAWAT-model is applied to examine numerous management scenarios within the target period 2011-2040.
In the first, pessimistic scenario, it is assumed that pumping from the aquifer continues to increase in the near future to meet the rising water demands, and there is not further recharge to the aquifer than what is provided by natural precipitation.
The second, optimistic scenario assumes that treated surficial wastewater can be used as a source of additional, artificial recharge to the aquifer which, in principle, should not only lead to an increased sustainable yield of the latter, but could, in the best of all cases, revert even some of the adverse present-day conditions in the aquifer (i.e. seawater intrusion). This scenario has been simulated using three distinct variants of the artificial recharge implementation that differ by the way how the injection wells are located and grouped across the Gaza strip.
The results obtained with the first (do-nothing) scenario indicate that there will ongoing negative impacts on the aquifer, which induced the propensity for strong seawater intrusion into the Gaza aquifer. This scenario illustrate that at the end of simulation period, year 2040, comparing with the baseline model at year 2010, the amount of saltwater intrusion into the coastal part of the aquifer increases by about 35%, meanwhile the saltwater-polluted (salinity) will be increased by 34%.
In contrast, all three cases of the second (artificial recharge) scenario group can partly revert the present seawater intrusion. From the water budget point of view, compared with the first (do nothing) scenario, for year 2040, the additional water to the aquifer by the artificial recharge reduces the amount of water entering the aquifer by seawater intrusion by 81%, 77 and 72%, for the three recharge cases, respectively. Meanwhile, the saltwater-polluted (salinity) in the Gaza aquifer reduces by 15%, 32% and 26% for the three cases, respectively.
Finally, one may note that the results of the numerical modeling of the various artificial recharge scenarios indicate that there is some success of aquifer recovery, as the presently existing saltwater intrusion is partly been reverted by the end of simulation period in year 2040.

Long-Term Navigation Optimal Operation of Cascaded Reservoirs

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Keywords: L*ong-term, Navigation optimal operation, Dynamic clustering method, Artificial immune system, Cascaded reservoirs*

Establishment of cascaded reservoirs greatly improved hydraulic conditions of navigation channel. However, in the dry season, the backwater zone of reservoir restores to its natural state with low water level that is not navigable. Therefore, navigation optimal operation of cascaded reservoirs is employed to improve the hydraulic condition which can enhance the freight volume of channel. Since the flood control and power generation is the main task of reservoir usually(Ahmadi, M., Haddad, O.B., et al 2014; Arunkumar, R., Jothiprakash, V., 2013.), few literatures focus on the long-term navigation operation. In recent decades, the navigation objective is considered as constraints by some scholars (Rao, G. S. 1999; Ackermann, T., Loucks, D. P., et al.2000; Wang, J., Zhang, Y., 2012), and is discussed often in short-term reservoir operation. However, long-term navigation operation is an important way to enhance the benefit of water resources especially for cascaded reservoirs whose main task are shipping, and are not taken into account reasonably in the aforementioned studies.

Long-term navigation optimal operation of cascaded reservoirs aims at determining optimal operation scheme of cascaded reservoirs to achieve maximum freight volume for 1 or more years while meeting all kinds of hydraulic and electric system constraints. This paper intends to present a novel optimal approach based on pattern recognition for the optimizing navigation problem. Due to different channel width and depth, which are determined by hydraulic condition, corresponding to different dead weight tonnage for the ship, pattern recognition (Theodoridis, S. Koutroumbas, K. 2009) is introduced to distinguish between different operating patterns with different navigation capacity. Under different states of operating pattern, the fuzzy relation matrix for navigation flow conditions is set up, which can be identified by a reasonable threshold. Then, through identifying the water level and discharge flow by the fuzzy relation matrix, the freight volume can be obtained synchronously. Finally, based on the results of the navigation capacity recognition, operation scheme of cascaded reservoirs is continuously adjusted to obtain the maximum freight volume through the solving method, artificial immune system (M., B. 2011). Meanwhile, the hydraulic and electric system constraints are handled effectively by designed heuristic strategies.

The proposed approach is applied to cascaded reservoirs in the lower Jinsha River. The simulation results obtained are feasible and very close to the optimal one, which shows that it has advantages in dealing with this navigation optimal problem. Furthermore, it can also apply to other optimization problem with high-dimensional and nonlinear characteristics of reservoir dispatching.

References

Ackermann, T., Loucks, D. P., Schwanenberg, D., and Detering, M. 2000. Real-time modeling for navigation and hydropower in the river Mosel. J. Water Resour. Plann. Manage., 126(5): 298–303.

Ahmadi, M., Haddad, O.B., Marino, M.A., 2014. Extraction of Flexible Multi-Objective Real-Time Reservoir Operation Rules. Water Resources Management28, 131-147.

Arunkumar, R., Jothiprakash, V., 2013. Chaotic Evolutionary Algorithms for Multi-Reservoir Optimization. Water Resources Management27, 5207-5222.

M., B., 2011. Artificial immune system for fixed head hydrothermal power system. Energy36, 606-612.

Theodoridis, S. Koutroumbas, K. Pattern Recognition, Fourth Edition. 2009.

Rao, G. S. 1999. Influence on navigation of the flood-releasing and sedimentation of the Three Gorges Reservoir. River Sedimentation: Theory and Applications: 537-542.

Wang, J., Zhang, Y., 2012. Short-Term Optimal Operation of Hydropower Reservoirs with Unit Commitment and Navigation. Journal of Water Resources Planning and Management-Asce138: 3-12.

Optimization of Cultivation Pattern for Maximizing Farmers' Profits under Land- and Water Constraints by Means of Linear-Programming: An Iranian Case Study

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Keywords: Linear Programming, Optimum cultivation pattern, Net profit, Water consumption

The pattern of agricultural cultivation has an important effect on the water consumption and the soil ecology, both of which, in turn, determine the agricultural productivity. Finding the optimal cultivation pattern in agricultural development projects for maximizing the net economical profit under several environmental and logistical constraints such as available water, area of the farms and etc., is complicated and usually requires the use of methods of constrained optimization.
The study area are 100 hectares of farm land near Kermanshah City - located in the western Iran - that is cultivated by 8 major crops (wheat, barley, corn, sunflower, soybean, alfalfa, canola and forage corn) and which are irrigated by groundwater extracted from seven wells.
For the optimization procedure mathematical Linear Programming (LP) is employed, with the objective to maximize the net profit of cultivation wherefore the net profit is the difference between gross income (selling price of the product on the market) minus costs (irrigation, fertilizer, farm rent, transportation of the crops). As for the constraints, these are the limitations on the soil area and the groundwater available. The LP- model has been developed within the WINQSB- environment. During the LP-execution process a sensitivity analysis of the variables with respect to changes on the right hand side (RHS) of the constraints has also been conducted.
The results of the LP- constrained maximization indicate that, compared with the present status of cultivation, an 11.4 percent annual increase of the economic benefits can be gained when using this optimum cultivation pattern. The sensitivity analysis test shows further, that even with this increased net income with the optimum cultivation pattern, 52878m3 of water - equal to 11.9 percent of the total available water - can be saved per year.

Refrences

Kipkorir, E.C., Raes, D., Labadie, J., 2001. Optimal allocation for short-term irrigation supply. Irrigation and drainage systems. 15(3): 247-266.
Kumar, C.N., Indrasenan, N., Elango, K. 1998. Nonlinear programming model for extensive irrigation. Journal of irrigation and drainage engineering. 124(2):123-126.
Kuo, S.F., Merkley, G.P., Liu, C.W. 2000. Decision support for irrigation project planning using a genetic algorithm. Agriculture water management. 45: 243-266.
Zhiliang W., Zhenmin Z, 2004. Optimization of water allocation in canal systems of Chengai irrigation area. Nature and Science, 2(1): 89-94.

Experimental and Computational Hydraulics

Simulation of Flow and Transport Processes in a Brazilian Reservoir

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Keywords: N*umerical modeling, Parameter study, TELEMAC*

Introduction

This contribution presents various simulations of flow and transport processes for the Itaparica reservoir in northeast Brazil, addressing water quantity and quality. Gunkel and Sobral [2] determined that the reservoir is confronted with massive eutrophication problems since the São Francisco river was dammed up in the 1980s. The basis for the development of possible adjustments for this area is the comprehension of the flow and transport processes in the river. Previous studies from Özgen et al. [4] were mainly focused on the Icó Mandantes Bay. This contribution extends the study site to the whole reservoir, in which the Icó Mandantes bay is located. A two-dimensional mesh was generated for the considered area. On this basis, mean flow conditions as well as draughts and flood cases were simulated. The influence of the friction on the flow was analyzed in parameter studies. The spreading of a contaminant in different areas and under different flow conditions and the impact of the diffusion was investigated.

Material and methods

The bottom topography was determined through 93 elevation measurements in the reservoir which were reported by Cirilo [1]. Due to the lack of further measurements, suitable idealized channel profiles were assumed at the 93 measurement points in form of parables. The bathymetry was generated by interpolating between these parables. The result is shown in Figure 1 (top). The maximum water depth is 42.8 m. The generated mesh is unstructured and consists of 30986 triangular elements with element lengths between 7.7 m and 632.1 m. The mean water elevation in the reservoir is 302.8 m and the mean discharge is 2060 m^3/s [2]. These values were used for the simulation of mean flow conditions in the reservoir. Statistical analyses of daily measured discharge data for the years 1989 to 2010 [3] were carried out. The statistical as well as the empirical recurrences of flood events and draughts were calculated. A flood event with a statistical recurrence of 10 years corresponds to a discharge of 11159 m^3/s. To represent a realistic case, the flood event between 14.12.2009 and 03.02.2010 with a maximum of 12194 m^3/s was used for a flood simulation. The simulations were carried out with the TELEMAC-2D model, solving the depth-averaged two-dimensional shallow water and transport equations with a finite element method.

Results and discussion

The results indicate that the stream in the main river dominates the flow field. Figure 1 (left) shows the velocity field under mean flow conditions. The flow velocities in the bays are comparatively small. The maximum velocity is around 0.59 m/s for a Strickler roughness coefficient of 50 m1/3/s. For the flood event with a maximum discharge of 12194 m^3/s, velocities up to 1.50 m/s were calculated. To analyze the influence of the friction, the Strickler roughness coefficient was varied from 10 m1/3/s to 75 m1/3/s for the flood case. The simulations showed a considerable impact of the friction coefficient on the flow. A relative difference of 170 % in the maximum velocities in the main stream was determined for a change in the roughness coefficient from 10 m1/3/s to 75 m1/3/s. The transport simulations showed that there is almost no exchange of water and matter between the main river and its bays under mean flow conditions. Figure 1 (right) shows the result of tracer concentration at

t = 17 d. Transport simulations with diffusion coefficients from 0 m^2/s to 0.1 m^2/s were carried out. For an increased diffusion coefficient the spreading of the tracer increases.
Additionally, a tracer was injected at the inflow boundary for a discharge of 12194 m^3/s. Due to the higher velocities, the advective spreading is much faster and the diffusion is of minor importance.

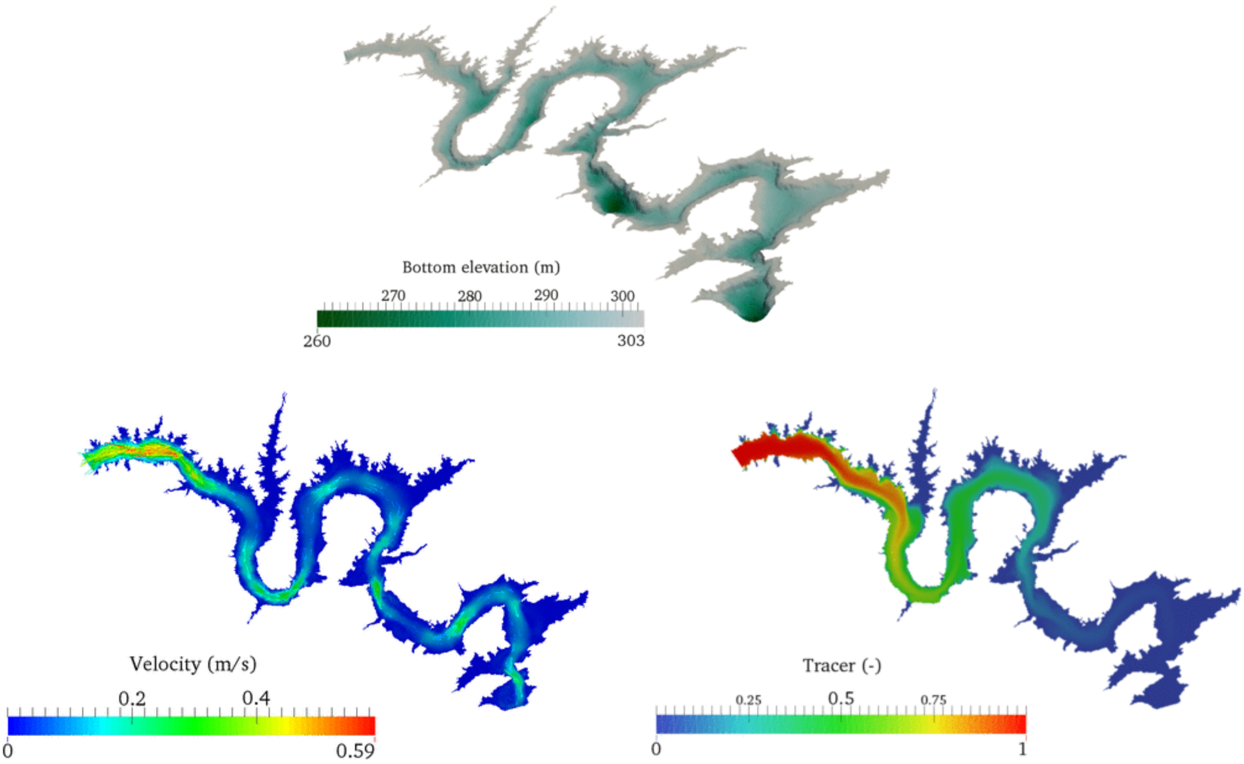

Figure 1. (Top) Bottom elevation, (Left) velocity field under mean flow conditions, (Right) tracer distribution in the reservoir at t = 17 d for a diffusion coefficient of D = 10^{-3} m^2/s.

Acknowledgement
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References
[1] Cirilo, J. A., Análise a dos processos hidrológico - Hidrodinâmicos a na bacia do Rio São Francisco, Ph.D. thesis, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil (1991).
[2] Gunkel, G., Sobral, M., Re-oligotrophication as a challenge for tropical reservoir management with reference to Itaparica Reservoir, São Francisco, Brazil, Water Sci. Technol. 67(4), 708-714 (2013).
[3] Operador Nacional do Sistema Elétrico. http://www.ons.org.br/ (accessed: 16-08-2012).
[4] Özgen, I., Seemann, S., Candeias, A. L., Koch, H., Simons, F., Hinkelmann, R., Simulation of hydraulic interaction between Icó-Mandantes bay and São Francisco river, Brazil, in: Gunkel, G., Silva, J., Sobral, M. (eds.) Sustainable Management of Water and Land in Semiarid Areas, Editora Universitaria, Universidade Federal de Pemambuco (2013).

Mathematical Formulations of Shallow Water Models with Porosity for Urban Flood Modeling

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Keywords: Urban flood modelling, Porosity, Representative Elementary Volume

Worldwide, floods are responsible for more than half of the victims and about 40% of the casualties due to natural disasters. In 2012, hydrological hazards caused 65 million victims and 26 billion US$ of damages (CRED, Annual Disaster Statistical Review 2012). Due to climate change and other environmental changes such as growing urbanization, floods are expected to become more frequent and severe in the future. However, the magnitude of these changes remains highly uncertain. This calls generally for the analysis of a high number of scenarios and, therefore, many runs of the numerical models are necessary.
Simultaneously, high-resolution topographic data have become widely available. The typical grid spacing of data is as fine as 1 to 5 m. Consequently, the present need is mainly for high performance computational models which take toll benefit of the available detailed data, combining thus accuracy and high efficiency. One way to meet this challenge is the development of subgrid models.
Subgrid models are enable to decrease the computational time while preserving information from the detailed topographic data. Shallow water models with porosity are typically applied with a computational cell size of one or two orders of magnitude higher than the size of the available detailed topographic data. Within each computational cell, the topography is represented by isotropic or anisotropic porosity parameters, which constitute a specific example of subgrid modelling.
To derive the shallow water equations (SWE) with porosity, the local equations of motion are integrated over control volumes. The main approaches followed for this integration are summarized by the works of Sanders et al. (2008) and Velickovic (2012).
As depicted in Figure 1, the integral form can be derived either from a macroscopic balance or by the mathematical integration of the local 3-D Reynolds-averaged Navier Stokes equations over a control volume (CV). In turn, the latter developments differ depending on whether the integration is first performed.
From the integral form, Sanders et al. (2008) deduced directly a discrete form by defining discrete variables. These discrete variables represent flow properties averaged over the control volume. This direct approach enables the rigorous definition of anisotropic porosities, accounting for the anisotropic effects of topography distribution inside the control volume.
The conversion of the integral form of the equations to continuous equations requires the definition of the so-called representative elementary volume (REV). The REV is defined at each local point as the smaller control volume for which the porosity of the urban area is independent of the control volume size. The continuous form of the equations can only be derived under the assumption that the size of the control volume exceeds the size of the REV. This assumption turns the porosity into a parameter independent of the size of the control volume.
Guinot (2012) analysed the REV sizes for theoretical periodic Cartesian street networks. Further analyses have been realized in the scope of the present research on real case studies for New-York city and Liege, in Belgium. Figure 2 shows that, compared to the scale of an urban area, the REV size is very large, of the order of the kilometer. This challenges the standard assumption generally accepted to derive the continuous form of the equations. Moreover, the definition of a REV is even not feasible in cases where the topography of the urban area is highly variable spatially.
Anisotropy was introduced by Lhomme (2006) in the continuous form of the continuity equation. However, the weakness of this approach is the lack of definition for the anisotropic porosity. In contrast, Sanders et al. (2008) takes into account anisotropy by properly defining discrete anisotropic porosity parameters in the discrete form of the equations.

Velickovic (2012) uses only isotropic porosity in the continuity equation and introduces the anisotropy in the momentum equation through the velocity deviations due to the presence of the obstacles.

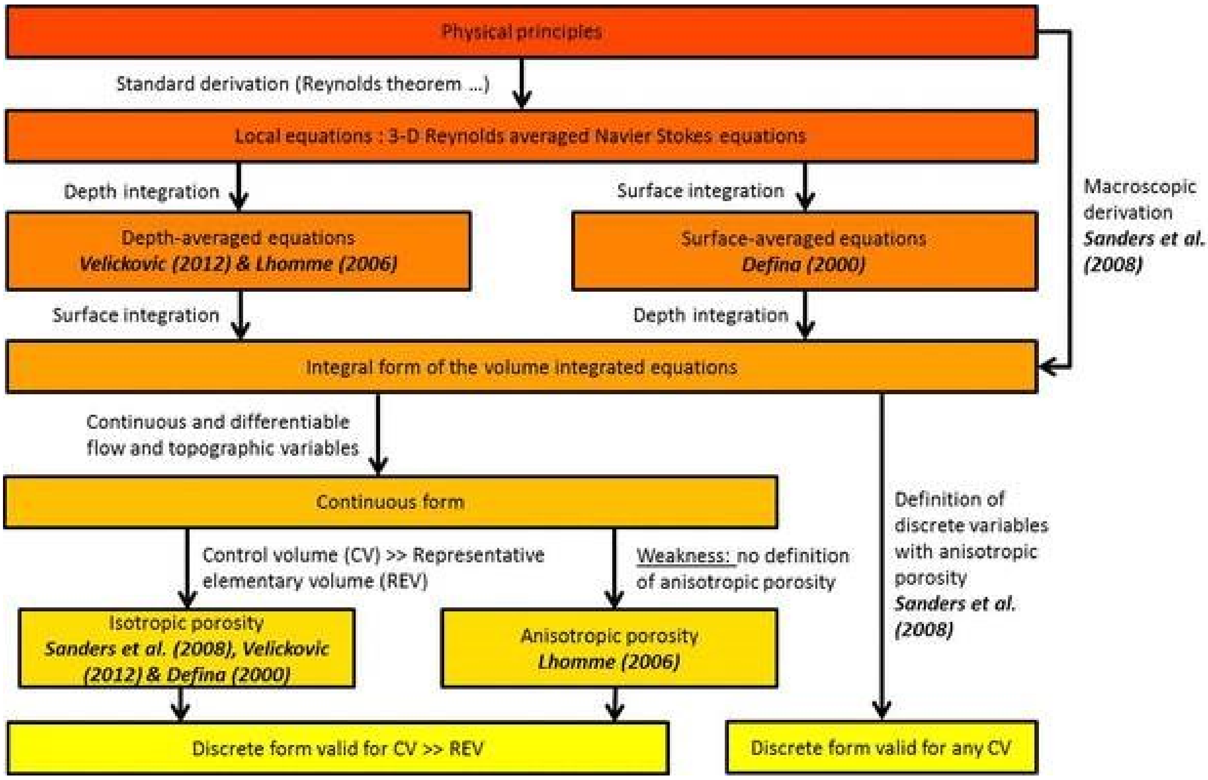

Figure 1. Derivations and forms of the volume integrated shallow water equations with porosity.

The approaches followed by Lhomme (2006), Sanders et al. (2008) and Velickovic (2012) assume a depth-independent porosity. The developments of Defina (2000) considerer depth-dependent porosity but is limited to isotropic porosity and the purpose of application was not specifically urban flood modelling. In this research, we develop a generalized 2D fully dynamic shallow water model with depth-dependent anisotropic porosity. This research will also investigate multi-layered approaches (Chen et al. 2012) to reflect the flow phenomena when a building bisects a coarse cell and creates within the cell two independent flow regions. This will guarantee applicability the model for a much wider range of real-world applications.

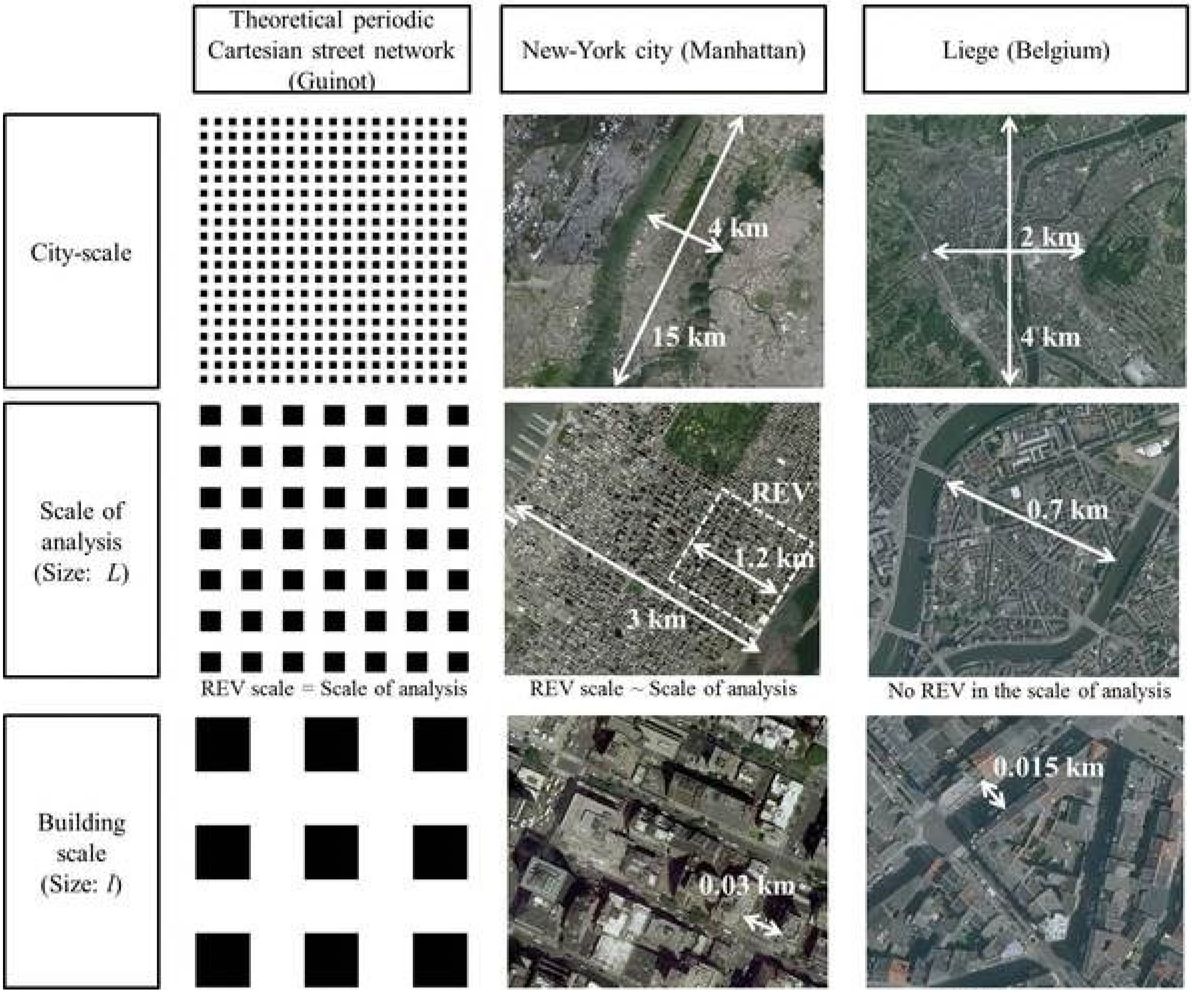

Figure 2. Orders of magnitude of the scales.

References

Chen, A. S., B. Evans, S. Djordjević and D. A. Savić (2012). "Multi-layered coarse grid modelling in 2D urban flood simulations." Journal of Hydrology 470–471(0): 1-11.

Defina, A. (2000). "Two-dimensional shallow flow equations for partially dry areas." Water Resources Research 36(11): 3251-3264.

Guinot, V. (2012). "Multiple porosity shallow water models for macroscopic modelling of urban floods." Advances in Water Resources 37: 40-72.

Lhomme, J. (2006). Modélisation des inondations en milieu urbain : approches unidimensionnelle, bidimensionnelle et macroscopique. PhD Thesis, Université de Montpellier II.

Sanders, B. F., J. E. Schubert and H. A. Gallegos (2008). "Integral formulation of shallow-water equations with anisotropic porosity for urban flood modeling." Journal of Hydrology 362(1-2): 19-38.

Velickovic, M. (2012). Macroscopic modeling of urban flood by a porosity approach, PhD Thesis, Université catholique de Louvain (UCL).

A Numerical Wave-Structure-Soil Interaction Model with Application to Monolithic Breakwaters Subject to Breaking Wave Impact

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Keywords: CFD-CSD, OpenFOAM®, Caisson breakwaters, Breaking wave impact, Soil liquefaction, Cyclic mobility

A one-way CFD-CSD coupled model system is developed within the OpenFOAM® framework to provide a tool for numerical analysis of coastal structures (e.g. vertical breakwaters). This tool is intended to work in parallel with physical experiments to extend the range of testing conditions and give better insight into the processes involved with wave-structure-soil interaction. This numerical tool can be used for optimizing and analyzing innovative coastal structures and designing physical wave-structure-soil interaction experiments.
The numerical model system is used to regenerate large scale experiments of a caisson breakwater, subject to wave attack, from the large wave flume (GWK) in the coastal research centre in Hanover (Kudella et al., 2006). Hence, the model is used to extend the results' spectrum to assist developing a simplified model for foundation response underneath caisson breakwaters subject to breaking wave impact.
The hydrodynamic model is a multiphase (water and air) Navier-Stokes model, which uses the volume of fluid method to track the water-air interface. Porous media are introduced as a fixed matrix that attenuate the fluid flow according to the volume averaging principle (e.g. Hsu et al. (2002)) with the Lin and Karunarathna (2007) seepage law (as explained in Lin (2008)). Waves' generation and absorption is done using relaxation zones via the waves2Foam (Jacobsen et al., 2012) toolbox. Compressibility is introduced to the model by adding an additional term to the continuity equation that calculates the fluid volume change (directly) due to its pressure change through an interpolated fluid bulk modulus based on the fluid phase fraction and degree of saturation of porous media. The addition of fluid compressibility enhances the breaking wave impact (Fig. 1).

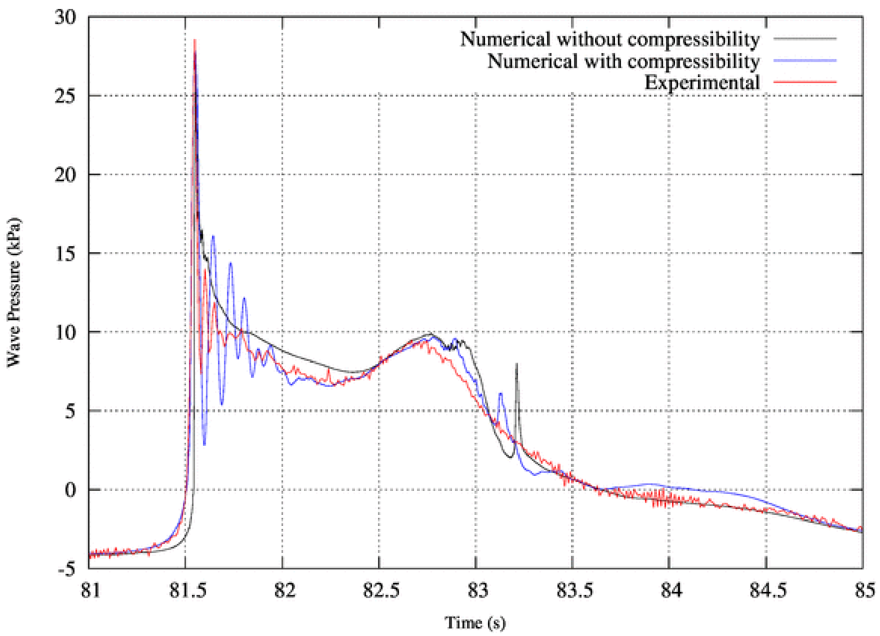

Figure 1. Breaking wave impact on a caisson breakwater for a single event; numerical (with and without fluid compressibility) versus measurements.

The Computational Structural Dynamics (CSD) model is developed using the finite volume method for the fully dynamic, fully coupled Biot equations (Zienkiewicz et al., 1999). The fully coupled poro-mechanical analysis is handled in a segregated approach in which the skeleton displacement, the pore fluid pressure and the pore fluid velocity (relative to the skeleton) are decoupled at the iteration level. The pore fluid pressure-velocity coupling is resolved using the PISO (Pressure Implicit with Splitting of Operators) algorithm, which is used for solving the Navier-Stokes equations in unsteady CFD problems. Two simplifications to the porous media formulations were introduced: (1) neglecting convective acceleration of pore fluid and (2) fully neglecting acceleration of the pore fluid (the u−p approximation). A frictional contact model is implemented to model soil-structure interaction.
The structural model allows for the introduction of various material constitutive models in different zones of the domain. A multi surface plasticity model with the Drucker-Prager failure criterion is introduced to model the behavior of sand foundations under cyclic load posed by wave action on the caisson breakwater (Elgamal et al., 2003).
The structural model is verified using analytical solutions of benchmark problems: (1) Terzaghis one-dimensional consolidation problem, (2) one-dimensional loading by fluid problem (Fig. 2) and (3) two-dimensional response of seabed to wave action. The validation of the CSD model with the large scale experiments is conducted using the one-way coupled system.

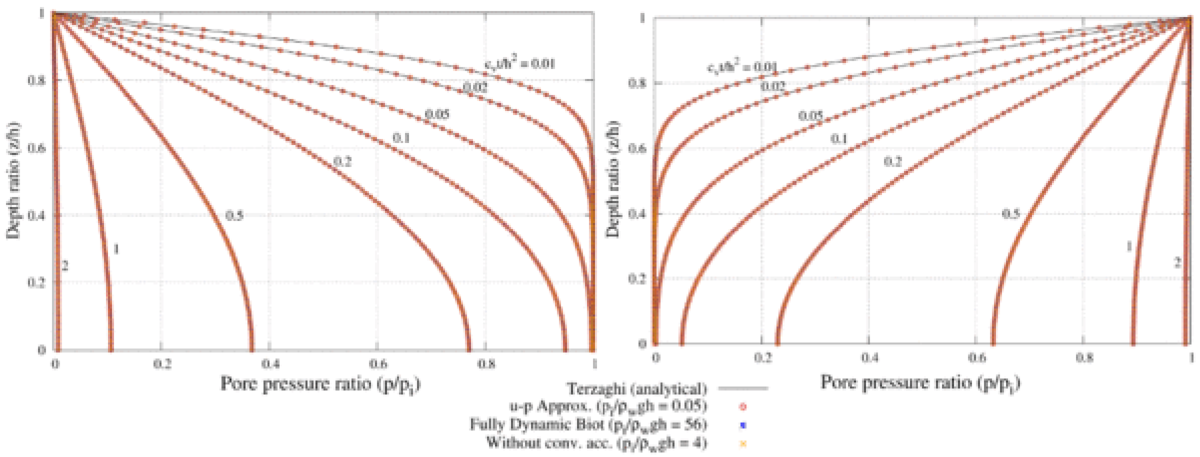

Figure 2. Comparative analysis of the three approaches with Terzaghis 1D consolidation model (S = 98.83%): (a) Consolidation of a soil layer and (b) Loading by fluid.

Interface utilities between both solvers are developed to collect output from the CFD solver and feed it as an input to the CSD solver. However, no feedback from the CSD is communicated to the CFD solver. This one-way link approach is convenient and sufficient for monolithic breakwaters and allows better focus on different hydrodynamic and hydro-geotechnical processes independently. Nevertheless, the limitations thereof are discussed (i.e. inaccurate results for uplift pressure on a caisson breakwater).
It was found that considering the fluid compressibility in the CFD model enhances breaking wave impact on caisson structures. For the CSD model, it was found that neglecting the convective acceleration of the pore fluid is not computationally advantageous (for the model at hand) and therefore is not recommended. The u−p approximation was found to be much faster than the fully dynamic formulation and should be used whenever appropriate.
Using the PISO algorithm, to resolve pore fluid pressure-velocity coupling, for the geotechnical model to solve the fully dynamic fully coupled Biot’s equations provides means to solve the pore fluid momentum balance equation instead of being considered implicitly in the mass conservation equation similar to other approaches. Hence, the PISO based model calculates the total pore pressure instead of calculating the excess pore pressure in other approximations. It is further observed that for the fully dynamic model the generation/dissipation of excess pore pressure is affected by the ratio of the excess pore pressure to the hydrostatic pore pressure. Further, the air content in the pore fluid (fluid compressibility) significantly affects the results. The model is capable of reproducing generation and dissipation of pore pressure in sandy soils.

References

Elgamal, A., Yang, Z., Parra, E., and Ragheb, A. (2003). “Modeling of cyclic mobility in saturated cohesionless soils.” International Journal of Plasticity, 19(6), 883 – 905.
Hsu, T.-J., Sakakiyama, T., and Liu, P. L.-F. (2002). “A numerical model for wave motions and turbulence flows in front of a composite breakwater.” Coastal Engineering, 46(1), 25 – 50.
Jacobsen, N. G., Fuhrman, D. R., and Fredsøe, J. (2012). “A Wave Generation Toolbox for the Open-Source CFD Library: OpenFOAM® . Int.J.N umerl.M eth.F luids, 70(9), 1073 −1088.
Kudella, M., Oumeraci, H., de Groot, M., and Meijers, P. (2006). “Large-scale experiments on pore pressure generation underneath a caisson breakwater.” Journal of Waterway, Port, Coastal, and Ocean Engineering, 132(4), 310–324.
Lin, P. (2008). Numerical Modeling of Water Waves. Taylor & Francis.
Zienkiewicz, O., Chan, A. H. C., Pastor, M., Schrefler, B. A., and Shiomi, T. (1999). Computational geomechanics with special reference to earthquake engineering. John Wiley.

A Hybrid 2D-3D CFD Model System for Offshore Pile Groups Subject to Wave Loading

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Keywords: CFD, OpenFOAM®, Pile groups, Wave loading, Focused waves

A hybrid 2D-3D CFD model is developed for studying water wave loads acting on a pile in a pile group. In the hybrid model approach, a one-way link is established between a model for the far-field and another for studying the (local) fluid-structure interaction phenomenon. For this study, the far-field is considered as a 2D incompressible Navier-Stokes multiphase solver for proper reproduction of phase-focused (freak) waves produced in physical experiments. The near-field model is a multiphase 3D CFD model that utilizes compressible Navier-Stokes equations to enhance simulation of entrapped air compressibility effects during breaking wave impact on structures. Both models use the Volume-Of-Fluid (VOF) method to capture the air-water interface. An overlap zone is introduced to both models, in which fluid kinematics and surface elevation are sampled from the far-field model and introduced via a relaxation function to the overlap zone in the near-field model. In the 3D model, the use of a relaxation approach provides absorption for reflected waves from the structure. Further, a procedure is outlined to achieve/enhance the 3D model convergence. This is necessary in case of development of artificial high velocities at water-air interface at the end of a short overlap (relaxation) zone for wave inlet (or near the boundary if only a wave inlet boundary con- diction is considered). The model system is developed using the OpenFOAM® framework. The overlap zone is implemented as an extension to the waves2Foam toolbox (Jacobsen et al., 2012).
The hybrid 2D-3D model system consists of three main parts:

- A 2D wave flume (without any structure present) with a moving piston (dynamic mesh) wave maker, extending for a long distance before the position of the structure (i.e. similar to the Large Wave Flume, GWK) in order to properly simulate wave-wave interaction needed to construct phase-focused (rouge) waves,
- Linking utilities to sample the data from the 2D model and to introduce them to the 3D model inside an overlap zone using a relaxation function. The linking utilities are equipped with interpolation and mapping capabilities to ensure independence of time and space discretization of both the 2D and the 3D models.
- A small 3D wave basin with inlet and outlet boundaries close to the structure with a relaxation zone for the generation and absorption of waves. The structure is modelled in this do-main.

The procedure for using the hybrid 2D-3D CFD model system is as follows:

- Prepare the 2D flume and provide positions for velocity probes and wave gauges inside the overlap zone in the 2D flume
- Run the 2D model to simulate each wave condition
- Use the linking utilities to prepare probed velocities and water surface data for use as input in the 3D model
- Prepare the geometry (and mesh) for the 3D model for each structural configuration, starting at the overlap zone
- Run the 3D model for each combination of structural configuration and wave conditions

In Fig. 1, a sketch is given for the dual domains used in the hybrid model system with illustration of system components.

Large-scale physical experiments in the Large Wave Flume (GWK) in Hanover (Sparboom, and Oumeraci, 2006; Bonakdar, and Oumeraci, 2012) are used for validation of the 2D-3D CFD hybrid model system.
Fig. 2 illustrates the capability of the 2D model of reproducing focused waves (without a structure) that compares very well to measurements. In Fig. 3, the inline moment exerted on the fixation point of a single pile (in the 3D model) is compared to the measurements. The model is capable of reproducing the maximum moment. Nevertheless, the structural vibrations due to wave impact on the pile are not reproduced. This is not possible without considering the coupling with a structural model.

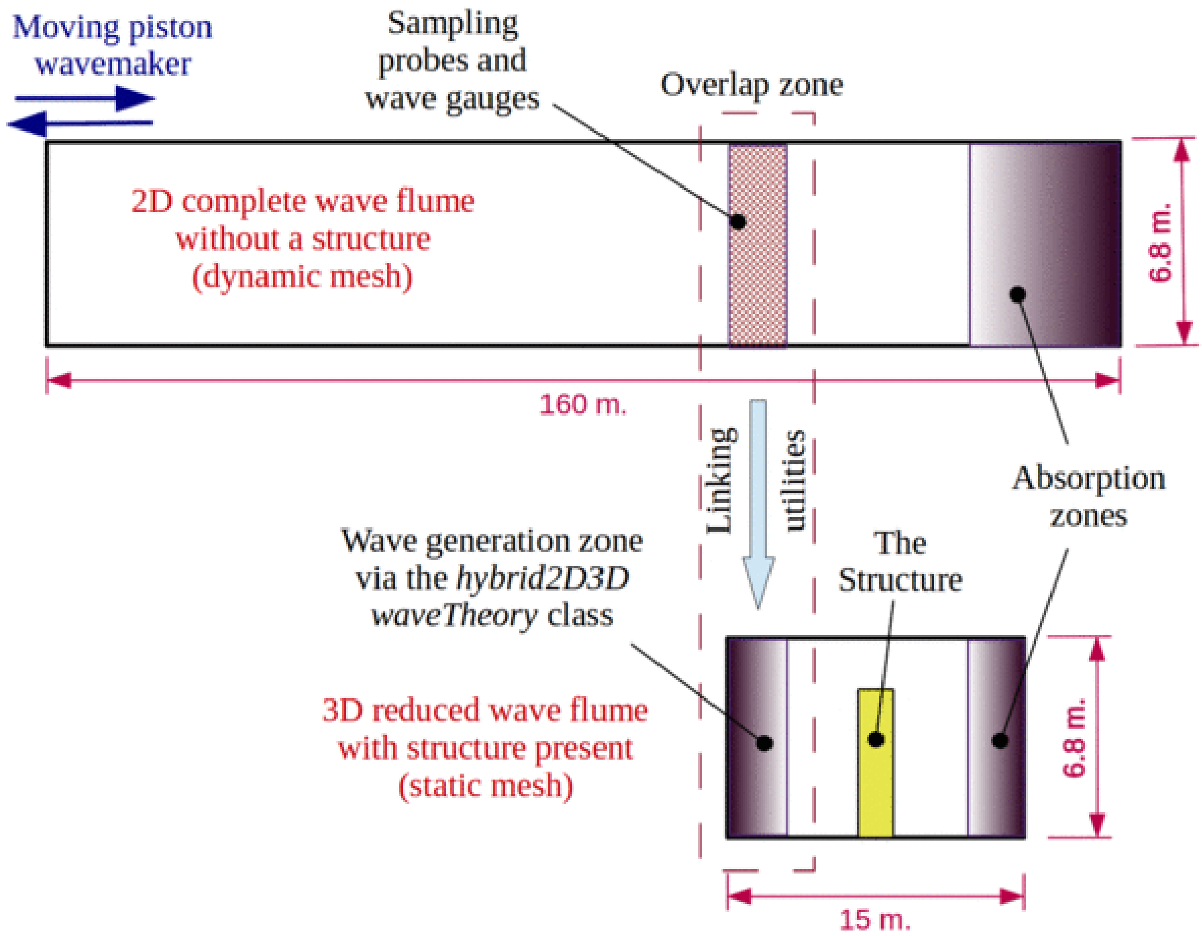

Figure 1. Sketch of the dual domains used for the 2D-3D hybrid model system with the linking utilities.

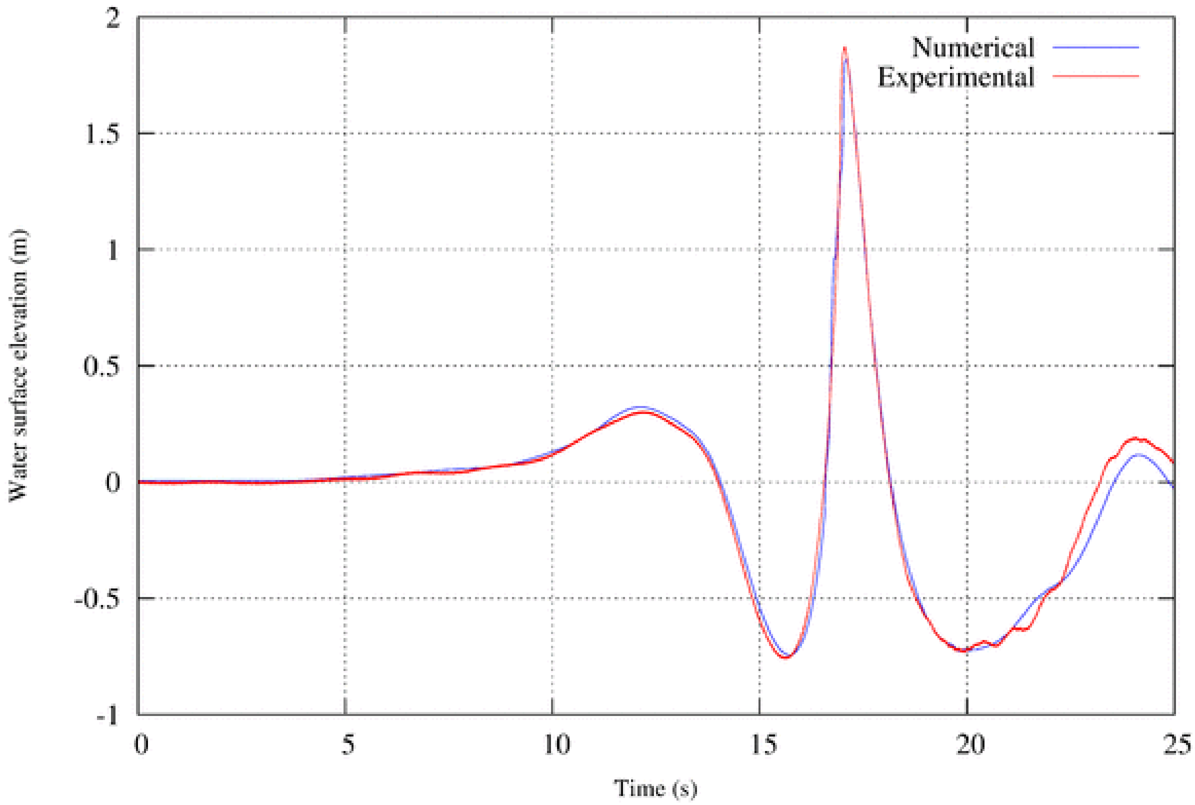

Figure 2. Water surface for phase-focused waves 2.6 m. before position of the structure (2D model).

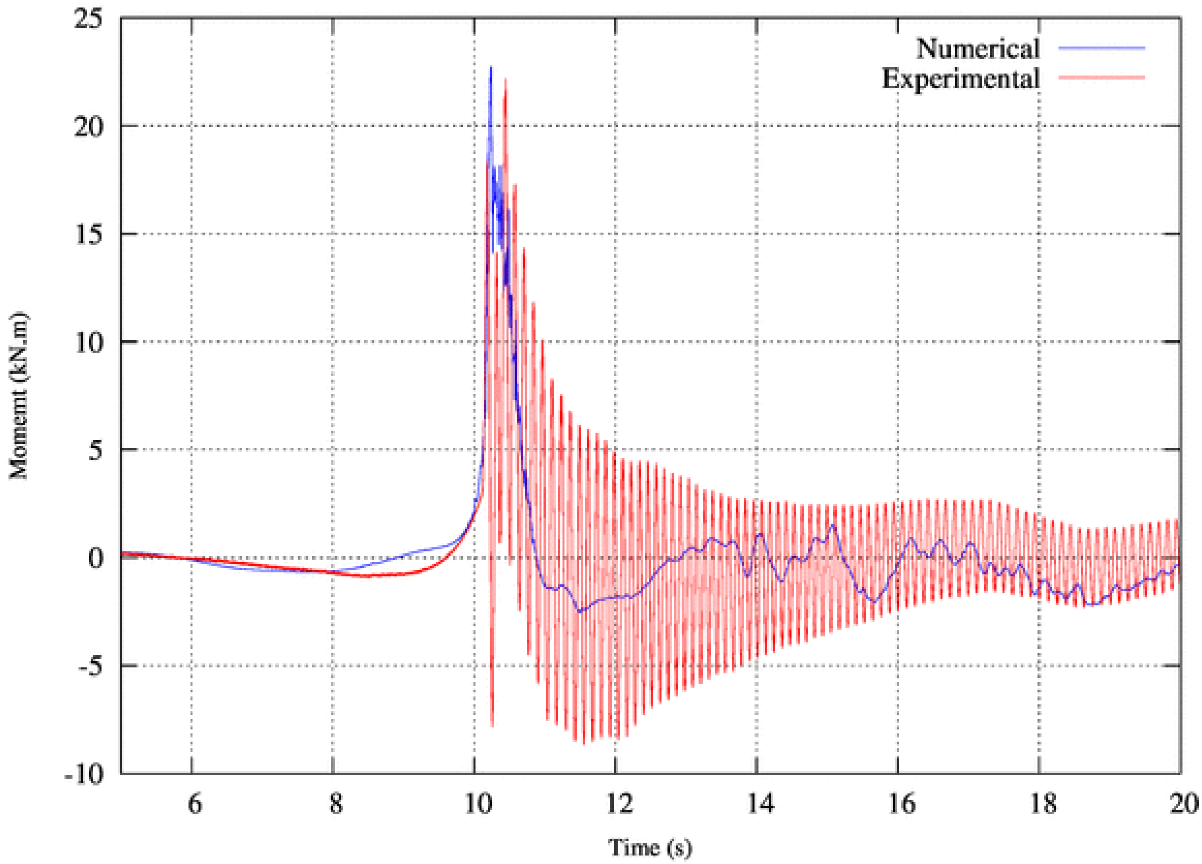

Figure 3. Inline moment on the top of a single pile for a Gaussian wave packet that focuses 103 m. away from the wave-maker (3D model).

In the final version of this publication the validation of the numerical model for two pile group configurations will be presented against measurements from the Large Wave Flume (GWK) in Hanover.

Acknowledgment
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References

Jacobsen, N. G., Fuhrman, D. R., and Fredsøe, J., 2012. “A Wave Generation Toolbox for the Open-Source CFD Library: OpenFoam® ”. Int. J. Numerl. Meth. Fluids, 70(9), pp. 1073–1088.

Sparboom, U., and Oumeraci, H., 2006. “Wave loads of slender marine cylinders depending on interaction effects of adjacent cylinders”. Proc. 25th OMAE, Hamburg, Germany, Paper No. 92626.

Bonakdar, L., and Oumeraci, H., 2012. “Interaction of waves and pile group-supported offshore structures: A large scale model study”. Proc. 22nd ISOPE, Rhodes, Greece.

Fully Coupled Numerical Modelling of Wave-Current-Mud Interaction by Finite Volume Method

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Keywords: Wave-Current-Mud Interaction, FVM, Bingham Equation, ALE, Projection Method

Introduction

In the presence of fluid mud, waves are attenuated by mud and the wave force results in mass transport of fluid mud layer. While waves are erosive over mud, currents transport suspension of mud in the coastal and estuarine waters (Zhao et al., 2006). Complex interactions occur among waves, currents, and mud in turbid coastal and estuarine settings. Interaction of wave, current and mud has been supported by a small number of investigations reported in literature. For instance, An (1993) presented a multi-layered water-fluid mud model based on linearized Navier-Stokes equations which was verified by laboratory measurements. In a numerical model presented by Zhao et al. (2006), eddy viscosity models for wave and current were separately proposed to close the equation of wave or current motion in a combined flow.

The interaction between wave, current and mud bed has been studied herein. The numerical wave-mud interaction model of Hejazi et al. (2013) is modified here by implementing the current velocity in water layer. An ALE 2DV numerical model has been utilized to simulate the hydrodynamics of the fully coupled N-S equations in water and mud bed layers. Application of the model in a system of combined wave and current over the mud-fluid bed shows good agreements in determining velocity profiles of current, free surface wave heights and wave lengths compared to the experimental data. The wave attenuation increases in the opposing current and decreases in the following current. The opposing current has more significant effects on the wave height attenuation rate than the following current.

Numerical Solution

The numerical model uses a structured non-orthogonal curvilinear staggered mesh and is capable of simulating non-homogeneous, gravity stratified flow fields. Projection method has been deployed for solving the Finite Volume Method non-hydrostatic Reynolds-averaged Navier–Stokes equations. The pressure gradient terms are omitted from the momentum equations, and the unsteady equations are advanced in time to obtain a provisional velocity field. The provisional velocity is corrected by accounting for the pressure gradient and the continuity constraint. The water elevation is computed through the solution of free surface equation obtained from the application of normal and tangential dynamic boundary conditions, and the integration of the continuity equation over water depth. The interface elevation is obtained by the application of the integration of the continuity equation over mud layer depth and the kinematic boundary conditions at bed and interface. Gridding is then updated in mud and water layers independently. In the mud layer, grid geometry is computed and updated according to the interface and bed levels, whereas in the water layer, the grid is updated according to the interface and free surface levels.

Results and Discussion

To validate the model, the experimental measurements conducted by An (1993) have been used. The experiments were carried out in a flume with a length of 17 m. The still water surface was at 0.263 m above the mud surface and the mud layer thickness was 0.08 m. The reported incident wave height of H0 = 0.045 m and the wave period of T = 1.01 s have been applied for numerical simulations. A constant viscosity was assumed for the bottom fluid mud layer and the mud specific gravity was 2.67. Fig. 1 shows the comparison of the numerical simulations and laboratory measurements of two velocity profiles on the mud layer in two directions of current flow. The simulated and measured values of wave height and wave length variation are compared for various current speeds in Fig. 2.

The effect of the currents on the wave attenuation coefficient (ki) is illustrated in Fig. 3, for numerical prediction and measured values, which show good agreements.

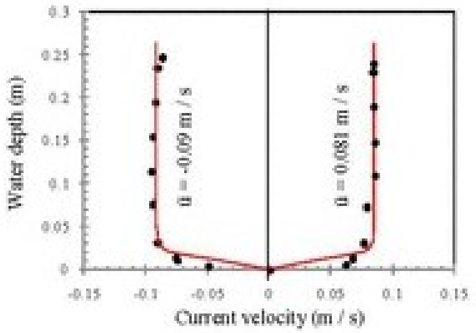

Fig. 1 Velocity profiles of currents in opposite directions.

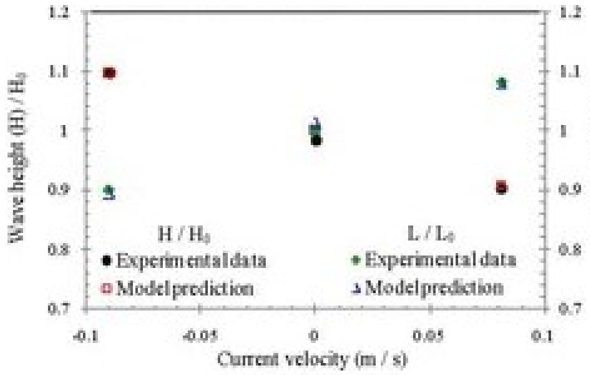

Fig. 2 Wave length and wave height variation due to current on the mud layer.

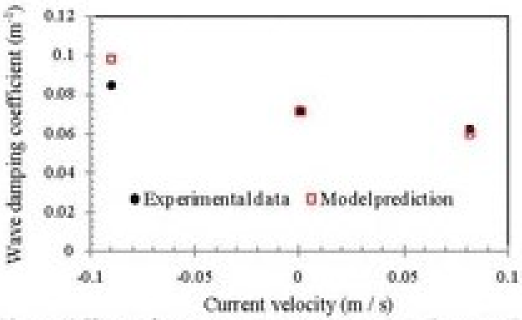

Fig. 3 Effect of currents on wave attenuation on the mud layer.

Conclusions

A 2DV FVM numerical model has been utilized to investigate the interaction of wave, current and mud. Simulated results in accordance with measured values suggest that the wave length decreases in the opposing current and increases in the following current, while the wave height variations reveal an inverse tendency. This trend is also valid for rate of wave attenuation in which ki is greater in the opposing current and less in the following current. It may be seen that the opposing current has more significant effects on the rate of wave height attenuation than the following current.

References

An, N.N. (1993) Mud mass transport under wave and current, Ph.D. dissertation, Department of Civil Engineering, Yokohama National University,135 p.

Hejazi, K., Soltanpour, M. and Sami, S. (2013) Numerical modeling of wave-mud interaction using projection method, Ocean Dynamics, (2013) 63:1093–1111

Zhao, Z-D., Lian, J-J. and Shi, J.Z. (2006) Interactions among waves, current, and mud: Numerical and laboratory studies, Advances in Water Resources, 29, 1731-1744.

A CFD Based 3D Numerical Wave Tank to Investigate Wave Interaction with Rectangular Cylinders

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Keywords: CFD, Rectangular cylinders, Wave force, Numerical wave tank, REEF3D

Offshore constructions are commonly composed of cylindrical elements with circular cross-section. A lot of research has been carried out to understand wave interaction with circular cylindrical structures for example by Morison [1], Keulegan and Carpenter [2], Sarpakaya[3] and Mo et al. [4]. Cylinders with rectangular cross-sections have also found increasing application in the design of offshore structures due to the ease in manufacture and transport in comparison to circular elements. Rectangular sections can also be seen in the design of tension leg platforms and floating production units. The force coefficients for a cylinder of rectangular cross-section is different from those for a circular cylinder due to the presence of sharp corners [5]. The fluid flow problem is changed due to introduction of asymmetry and aspect ratio of a rectangular cross-section which influences the flow regime. So it is interesting to gain more knowledge about the hydrodynamics of the flow around a rectangular cylinder. Understanding the force acting on the cylinder is of practical interest.

A Computational Fluid Dynamics (CFD) model uses the Navier-Stokes equations to solve the fluid flow problem. It represents most of the flow physics accurately. A large amount of data can be extracted to study the various flow parameters without obstructing the fluid flow. A photo-realistic visualisation of the problem is obtained. This provides an opportunity to gain more insight into the flow physics. The flow around the edges including separation and vorticity in the flow can be visualised using CFD simulations. The forces acting on the cylinder and its correlation with the flow regime can be explored. This can further the knowledge in the design of rectangular sections in the offshore and marine civil engineering industry.

This paper investigates the interaction of regular waves with a truncated rectangular cylinder using a CFD model. The influence of the aspect ratio of the cylinder with respect to the incident wave direction is investigated. The force experienced by the cylinder under different geometries is evaluated. The numerical results are compared with the experiments carried out by Vengatesan et al. [6]. The flow field behind the rectangular cylinder and the vorticity in the flow is visualised. The effect of the depth of immersion on the force experienced by the cylinder and the variation of the force over the depth is investigated.

The numerical model used in this study employs a fifth-order conservative finite difference Weighted Essentially Non-Oscillatory (WENO) scheme [7] for convection discretization. This higher-order scheme provides the accuracy required to study free surface flows. Time advancement is carried out by a TVD third-order Runge-Kutta [8] scheme. The level set function is used to describe the free surface. This function is smooth over the interface and provides a sharp representation of the free surface. Chorin's projection method [9] is used to obtain the Poisson equation for pressure which is solved using a preconditioned BiCGStab solver. The code is fully parallelized using the MPI library to improve the computational performance of the code.

References

[1] Morison, J. R., O'Brien, M. P., Johnson, J. W., and Schaaf, S. A., 1950. "Force exerted by surface waves on piles". Journal of Petroleum Technology, 2, pp. 149–154.

[2] Keulegan, G. H., and Carpenter, L. H., 1958. "Forces on cylinders and plates in an oscillating fluid". Journal of Research of the National Bureau of Standards, 60, pp. 423–440.

[3] Sarpakaya, T., 1976. In-line and transverse forces on smooth and roughened cylinders in oscillatory flow at high Reynolds numbers, Report No. NPS-69SL76062. Naval Postgraduate School, Monterrey, California.

[4] Mo, W., Irschik, K., Oumeraci, H., and Liu, P., 2007. “A 3D numerical model for computing non-breakingwaveforcesonslenderpiles”.JournalofEngineeringMathematics, 58,pp.19–30.
[5] Bearman, P. W., Graham, J. M. R., and Singh, S., 1979. “Forces on cylinders in harmonically oscillating flow”. In Proc. Symp. on Mechanics of Wave Induced Forces on Cylinders, Bristol, (UK), pp. 437–449.
[6] Vengatesan, V., Varyani, K. S., and Barltrop, N., 2000. “An experimental investigation of hydrodynamic coefficients for a vertical truncated rectangular cylinder due to regular and random waves”. Ocean Engineering, 27, pp. 291–313.
[7] Jiang, G. S., and Shu, C. W., 1996. “Efficient implementation of weighted eno schemes”. Journal of Computational Physics, 126, pp. 202–228.
[8] Shu, C., and Gottlieb, S., 1998. “Total Variation Diminishing Range Kutta schemes”. Mathematics of Computation, 67, pp. 73–85.
[9] Chorin, A., 1968. “Numerical solution of the Navier-Stokes equations”. Math. Comput., 22, pp. 745–762.

Reynolds Stress Modeling of Flow in Compound Channels with Vegetated Floodplains

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Keywords: Vegetation, Compound channel, Secondary flow, Shear stress, Turbulence models

In natural rivers, vegetation grows on floodplains, generating complex velocity field within the compound channel. Due to the velocity difference and the momentum exchange between the vegetated and non-vegetated area, strong shear layer and vortices occur. Therefore, knowledge of the mechanism of momentum exchange between the main channel and the vegetated floodplain is significant due to the effect on the discharge capacity of the channel, on erosion processes and on biological and issues.
In the present study three dimensional computations of the VARANS (Volume-Averaged Reynolds-Averaged Navier-Stokes) equations, in conjunction with a Reynolds Stress (RS) model, are performed for a non-symmetrical compound channel of a trapezoidal main channel and a vegetated floodplain, corresponding to the experimental setup of Yang et al. (2007). The drag effect of the vegetation on the current is taken into account through additional terms in both the momentum and the RSM equations based on a vegetation dynamics approach according to Ayotte et al. (1999). The additional terms are related to the drag coefficient C_d and the plant density α, defined as the frontal area per unit volume (m^{-1}). The results are compared against the experiments of Yang et al. (2007) shown in Figure 1. Moreover, the analytical method of Shiono and Knight (1991) is applied for the depth-averaged velocity, together with simple Manning calculations.
The effect of the relative depth Dr, defined as Dr=(H-h)/H, with H=total depth flow, is investigated together with the effect of floodplain vegetation on the mean velocity and turbulent characteristics of the flow. Therefore, three different runs are performed for Dr=0.15, 0.30 and 0.56, for vegetated floodplain and for free floodplain. Figure 2 shows the velocity distribution (made dimensionless with the average cross-sectional velocity U_{mean}) at different locations for Dr=0.56 and non-vegetated floodplain. The numerical results are in quite good agreement with the experimental data of Yang et al. (2007) which seem to follow the distribution of the law of the wall.

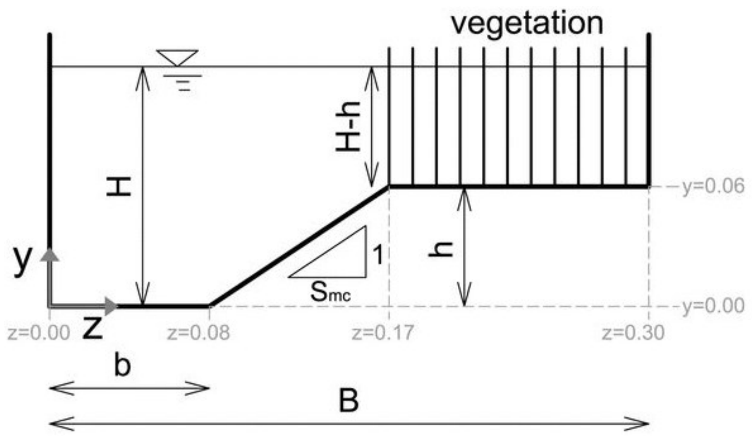

Figure 1. Cross-section of the compound channel with vegetated floodplains.

The numerical and analytical depth-averaged velocity profiles, made dimensionless with the cross-sectional velocity U_{mean}, are shown in Figure 3 for the free and vegetated floodplain together with experimental data of Yang et al. (2007) for Dr=0.56 (vegetated floodplain). It appears that the SKM overestimates the velocities in the main channel for all cases, and also exhibits a sharp edge in the maximum velocity at the beginning of the side slope, which is not the case for the numerical results.

For the vegetated cases the distribution of numerical velocities is in good agreement with the experimental data.

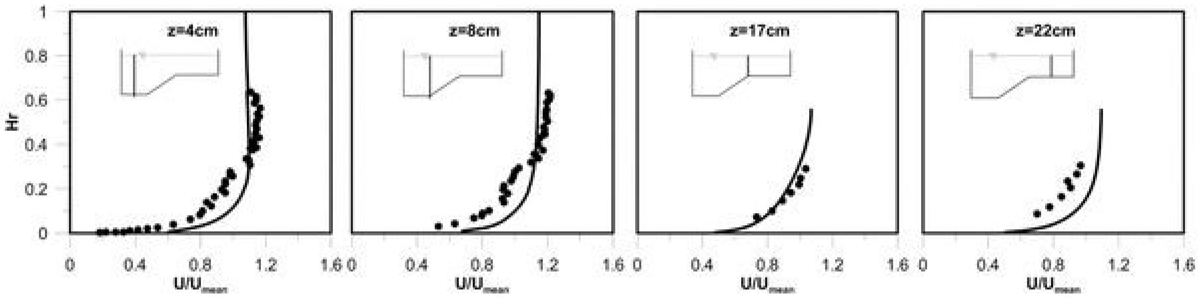

Figure 2. Vertical distribution of velocity (U/Umean) at different locations for Dr=0.56 and free floodplain for numerical (solid line) and experimental data of Yang et al. 2007 (dots).

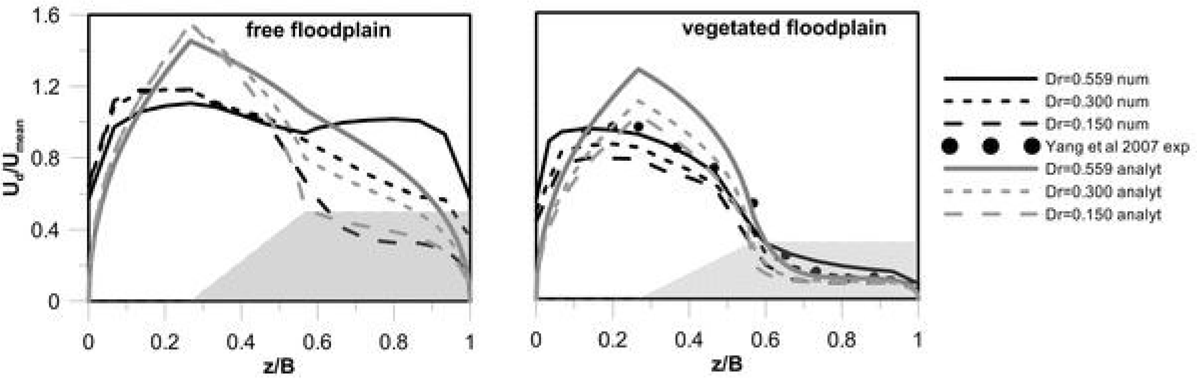

Figure 3. Distribution of depth averaged velocity (Ud/Umean) for all cases with (a) free and (b) vegetated floodplain.

The main conclusions from the numerical study of Reynolds stress modeling of flow in compound channels with vegetated floodplains can be summarized in the following:

- The turbulence penetration through the vegetation interface is evident with increased stresses and turbulence anisotropy near the vegetation interface, due to the momentum exchange between main channel and floodplain.
- The secondary flow is considerable especially in the main channel near the vertical interface with the vegetated floodplain (~8% of U_{mean}). The numerical model is able to reproduce the evolution of vortices with the stronger one found in the interface region. The vortical pattern is in accordance with the experimental findings of Yang et al. (2007).
- The analytical SKM method overestimates the mean velocities of such channels and the depth averaged velocity profiles is not efficiently reproduced near the vertical interface due to the weakness of the model to describe accurately the momentum exchange between the main channel and the vegetated floodplain.
- Regarding the Manning calculations, the separate channels method, based on the vertical interface, estimates better the mean velocity, in comparison with the numerical one, for the lower relative depths (Dr=0.15 and 0.30), while for the higher one (Dr=0.56) the simple channel method estimates better the mean velocity.

References

Ayotte, K.W., Finnigan, J.F., Raupach, M.R. (1999). A second-order closure for neutrally stratified vegetative canopy flow. Boundary Layer Meteorology, Vol. 90, pp. 189-216.

Liu, Ch., Luo, X., Liu, X., Yang, K. (2013). Modeling depth-averaged velocity and bed shear stress in compound channels with emergent and submerged vegetation. Advances in Water Resources, Vol. 60, pp. 148-159.

Shiono, K., Knight, D. (1991). Turbulent open-channel flows with variable depth across the channel. Journal Of Fluid Mechanics, Vol. 222, pp. 617-646.

Yang K.J., Cao S.Y., Knight D.W. (2007). Flow patterns in compound channels with vegetated floodplains. Journal of Hydraulic Engineering, Vol. 133, pp. 148–159.

Sloshing Displacements of an Above Ground Cylindrical Liquid Storage Tank Subjected to a Near-Fault Earthquake Ground Motion

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Keywords: Sloshing, Near-Fault Earthquake Ground Motion

Aboveground liquid storage tanks are critical components of infrastructure systems which are widely used to store chemicals, fuel and water. Field reports from past earthquakes indicate that these structures are quite susceptible to earthquake related damages due to sloshing effects of the contained liquid and that their failure can result in catastrophic damages to the environment in addition to significant financial losses. Earthquakes can damage liquid storage tanks in several ways. Hydrodynamic forces and the overturning moments acting on the tank wall due to the impulsive component of the liquid motion can result in the failure of the tank wall and the tank foundation. Excessive sloshing displacements which are primarily due to the long period convective component of the liquid motion can result in the spilling of the contained liquid or induce damages to the tank roof. This paper focuses on the sloshing response of a liquid storage tank subjected to near-fault earthquake strong ground motions with large displacement and velocity pulses which can be particularly destructive for structures with long vibration periods. In this study, the maximum sloshing displacements of a liquid storage tank subjected to a horizontal base excitation of a near-fault earthquake ground motion were analyzed with the ANSYS/Fluent and the CFD analysis results were post-processed with the help of Matlab image processing tools. Temporal variation of the sloshing displacements obtained from the CFD analysis was compared with the sloshing displacement time-histories obtained from the mass-spring equivalent models which are widely used in the design of liquid storage tanks.

Numerical Wave Tank Modelling of Hydrodynamics of Permeable Screen

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Keywords: Permeable screen, Reflection, Transmission, Numerical wave tank

Breakwater is an artificial structure used to protect the harbour, anchorage or marina basin from the attack of waves. In addition, breakwaters enable safe navigation of vessels inside the harbour and provide the clam water zone inside the harbour to loading and unloading of ships. Depending upon the requirement, breakwater structures can be permeable, which is advantageous for the development of marinas and small craft facilities, where a certain amount of wave transmission into the sheltered area is accepted. Basically, the classification of breakwaters depending upon the wave climate and degree of tranquillity require, and their design depending upon the hydrodynamic behaviour of ocean waves. Permeable barriers or screens are thin vertical breakwaters consisting of holes of desired diameter at discrete intervals to represent certain porosity. Permeable screens allow certain wave energy to pass through and to reflect, based on the porosity.

This present study describes the hydrodynamic performance of single permeable screen in terms of reflection coefficient (*Kr*) and transmission coefficient (*Kt*). A numerical wave tank model has been developed for wave interaction with a single vertical permeable screen. This numerical model use Volume Of Fluid (VOF) method, which allows to computationally simulate the waves, close to reality. An appropriate porous boundary condition defines the permeable screen along the numerical wave tank. The dimensions of numerical wave tank are 50m long and 1m deep. The permeable boundary condition is considered in the middle of the numerical wave tank. A special boundary condition, to represent the piston type wave maker, is used to generate the waves at one end of the numerical wave tank. Similar to physical wave tank, a numerical wave absorber, in terms of slope bed (1:5), is adopted at other end of the tank to dissipate the incident wave energy. Inside the wave tank, optimized grid is generated of ΔX=0.05m and ΔY=0.05m, having total number of elements 19790. The wave generation inside the wave tank is also validated with linear wave theory. The complex reflected and incident wave characteristics are measured based on three probe method of Mansard and Funke (1980). On the leeward side of the permeable screen, another single point is chosen for the measurement of transmitted wave characteristics. Permeable screens, with porosities varying from 5 to 20%, are subjected to different wave periods, heights and water depth.

In another experimental parametric study, the physical models of permeable screens are tested under similar wave and water depth conditions. Typical results comparing the results obtained from physical and numerical wave tank studies, for 10% porosity is shown below. The results of numerical and physical wave tank experiments are compared and discusses in this paper. The effect of various porosities on the hydrodynamics characteristics is discussed in the paper.

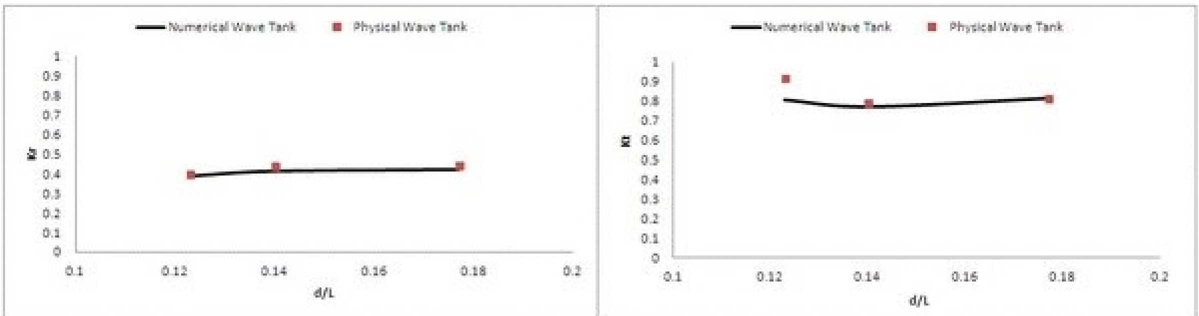

Figure 1. Variation of Kr and Kt with d/L for d=0.5m, H=0.1m and P=10%.

A Gas-Kinetic Model for Shallow Water Flows in Presence of Wet/Dry Fronts.

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Keywords: Lattice Boltzmann Method, Gas Kinetic Method, Shallow Water Flows

Recently the single relaxation time Lattice Boltzmann Method (hereinafter LBM) has considerably spread in Computational Hydraulics. The LBM consists of a mesoscopic representation of the flow, whose description is made in terms of a finite number of probability distribution functions, each one giving the probability to find a fluid particle in a given position and with a given velocity. The main reason for the diffusion of the LBM in Computational Hydraulics is that the corresponding numerical algorithm is much simpler than the usual ones derived from "classical" hydraulic models (such as e.g. the Shallow Water equations). The simplicity of the standard LBM lies on the discretization of the velocity space: i.e. lies on the fact that even a rather low number of velocities (9 in the standard LBM-based model of the Shallow Water equations) permits a satisfactory description of subcritical Shallow Water (hereinafter SW) flows. The main drawback of the standard LBM-based model of the SW equations is that it cannot simulate transcritical and supercritical SW flows, which always occur in realistic situations.
Such a serious drawback depends on the low number of lattice velocities usually adopted in standard LBM-based models of SW equations. If the number of lattice velocity is arbitrarily increased (i.e. an infinite number of lattice velocity is adopted), numerical simulations of transcritical and supercritical SW flows are possible. This is the basic idea of the Gas Kinetic Method (hereinafter GKM), recently extended to the simulation of SW flows.
A reliable and versatile numerical tool aimed to the simulation of realistic SW flows must own the capability of handling wet/dry fronts. SW equations do not account for this phenomenon automatically. Under strict mathematical point of view, wet/dry fronts are moving boundaries and should be treated just like that. On the other hand, the approach employing a moving boundary can become extremely cumbersome and many possibilities have been proposed and adopted in the recent past as remedies within numerical SW models.
The aim of this work is to assess the ability of the finite volume formulation of the GKM recently proposed in literature by Ghidaoui et al. (2001) and Liang et al. (2007) when simulating SW flows in presence of wet-dry fronts. The assessment is performed through a comparison with a considerable number of benchmark cases, both theoretical and experimental, both 1D and 2D, in order to consider some of the main critical aspects of the SW numerical modeling. Results are promising. Some of the preliminary ones, aimed to the assessment of the correctness of the proposed numerical implementation of the GKM-based model for SW flows, are shown in Fig. 1, which shows several 1D steady SW flows over smooth bottom profiles. In the left panel depth profiles are shown, in the right panel velocity and Froude number profiles are shown. "Sub" and "Sup" stands for Subcritical and Supercritical regime respectively. Continuous traces are analytical solution. The ability in satisfactorily reproducing the hydraulic jump is evident in the left panel.
Finally a qualitative idea on the ability of the proposed GKM model in simulating SW flows in presence of wet-dry fronts is given in Fig. 2, where the well-known experimental CADAM test of Hiver (2000) is shown. In the left panel the blue line represents a propagating wet-dry front, the position of the latter being highlighted by the circle, while the red dots represent the Froude number of the flow. In the right panel the comparison between experimental and GKM numerical results is given at x=19.5 for a time interval of 40 seconds. The agreement is quite good.

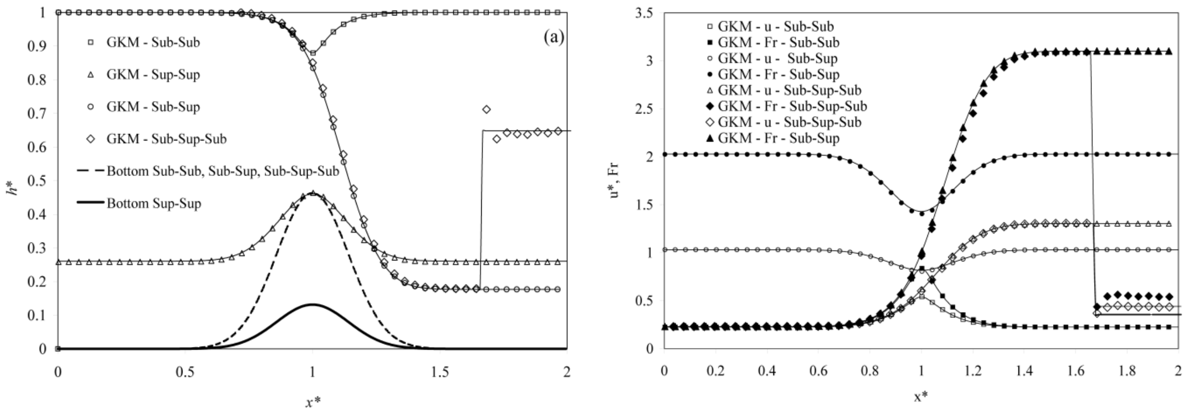

Figure 1. Steady motion over a smooth bottom profile. a) Flow depth profiles. b) Velocity and Froude number profiles. "Sub" and "Sup" stands for Subcritical and Supercritical regime respectively. Continuous traces are analytical solution.

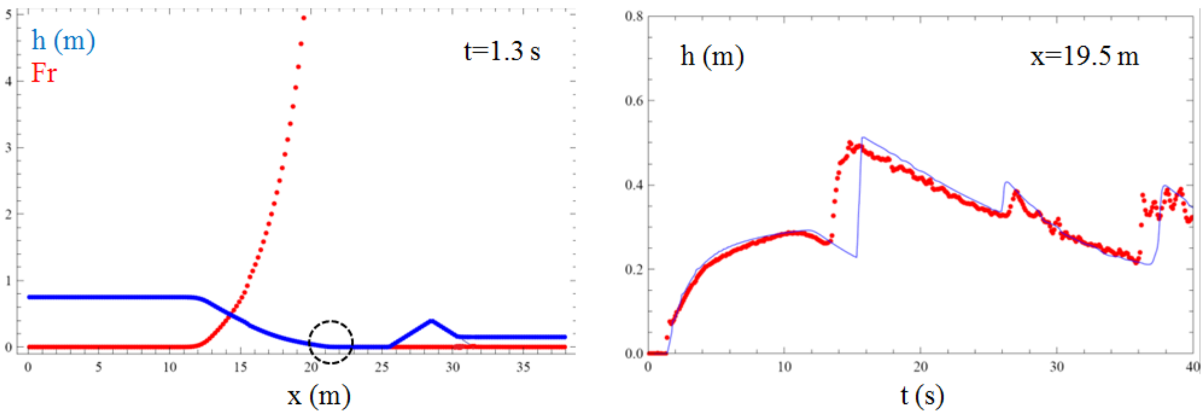

Figure 2. CADAM test of Hiver (2000). Left: GKM numerical flow depth and Froude number profiles along the channel. Right: time history of the experimental (solid line) and GKM numerical flow depth (red dots) at x=19.5 m.

References

Ghidaoui MS, Deng JQ, Gray WG, Xu K. 2001. A Boltzmann based model for open channel flows. Int. J. Numer. Meth. Fluids; 35: 449–494.

Hiver JM. Adverse-slope and slope (bump). Proceedings of "Concerted Action on Dam Break Modelling: Objectives, Project Report, Test Cases". Université catholique de Louvain, Civ. Eng. Dept.,Hydraulics Division, Louvain-la-Neuve, Belgium, CD-ROM. 2000

Liang JH, Ghidaoui MS, Deng JQ, Gray WG. 2007. A Boltzmann-based finite volume algorithm for surface water flows on cells of arbitrary shapes. Journal of Hydraulic Research; 45: 147–164.

Hydrodynamic Coefficients of Yawed Square Cylinder in Oscillating Flow

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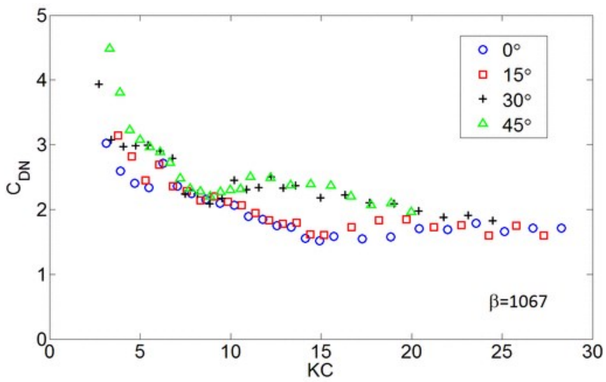
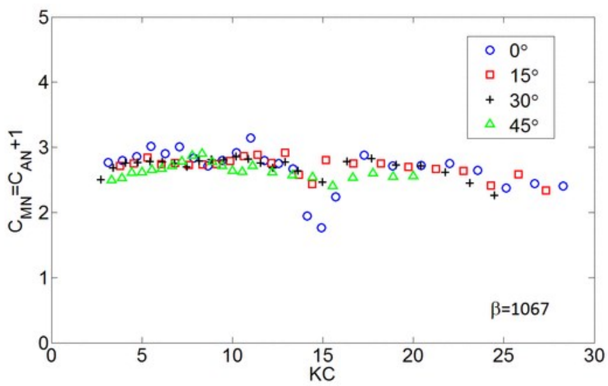
Keywords: Yawed square cylinder; Hydrodynamics; Oscillating flow

This study investigated the effect of yaw angles on the hydrodynamic force for a yawed square cylinder oscillating in still water. The yaw angle (α) is defined as the angle between the flow direction and the plane which is perpendicular to the cylinder axis. The independent principle (IP), which is generally applicable for steady currents, was examined in the oscillating flows. The application of the experiment setup was verified by the results from a circular cylinder, which agrees well with that from previous studies. The hydrodynamic forces on a square cylinder with α = 0°, 15°, 30° and 45° were measured with a 3-dimensional load cell in the oscillating flow at different periods and amplitudes. Quantitative comparisons were made regarding the hydrodynamics coefficients between these two types of cylinders.

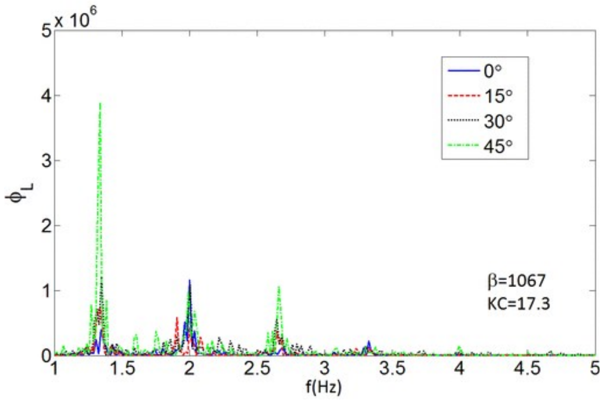
The force coefficients are demonstrated as the function of Keulegan-Carpenter (KC) numbers and frequency parameters (β). The normalized drag (C_{DN}) and inertia (C_{MN}) coefficients were evaluated with the least square method by minimizing the difference between measured in-line force and the theoretical value predicted by Morison equation. In terms of the energy spectra, fundamental frequency and the root mean square (rms) value of lift force coefficient (C_{Lrms}), more information of the cylinder yaw angle effect on a oscillating square cylinder were present in the present study.

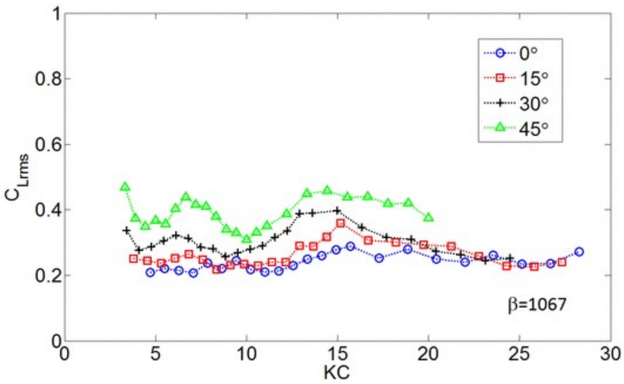
Generally the magnitude of C_{DN} increases as the yaw angle increases for the yawed square cylinder. The most significant difference are observed in the range KC = 8~20, where C_{DN} of α = 45° is about 50% higher than that of α = 0° (Figure 1). This result is opposite to that of the yawed circular cylinder, from which a smaller at α = 45° is found than the other angles (Sarpkaya, 1982; Sundar, 1998). The dramatic increase of for the yawed square cylinder, as well as the decrease of for the yawed circular cylinder, are absent within KC 8~20, indicating the invalid of IP. In addition, the generally larger value of for a square cylinder, corresponding to a lower vortex shedding frequency, indicates the less intensive vortex shedding behaviour. The inertia coefficient C_{MN}, on the other hand, decreases with the increase of the yaw angle, thought the difference is not significant (Figure 2). However, attentions should be drawn to the range of KC 10~18, where the sudden drop of is found to be absent for α = 45° and the magnitude of C_{MN} at α = 0° is the smallest. While for the yawed circular cylinder, the significant difference still exists in the KC range of 8~20 and C_{MN} keeps a trend of increase as α increases (Sarpkaya, 1982). The deviation of C_{DN} and C_{MN} observed from different angles in the range KC = 8~20 is attributed to the disruption of the transverse vortex street.





The lift force spectrum, obtained through Fast Fourier Transform (FFT), is shown in Figure 3. The peak on the spectrum becomes higher as the yaw angle increases. The fundamental lift frequency, corresponding to the peak on the lift force spectrum, however, is almost the same for all the angles. The magnitude of the peak on the spectra reflects the vortex shedding energy. Unlike the results of yawed circular cylinder (Cotter et al., 1984), from which the reduction of the vorticity structure due to the yaw angle was found, the increase of α may intensify the vortex shedding process behind a yawed square cylinder. The rms value of lift force coefficient increases with the increase of yaw angle for the square cylinder (Figure 4). As C_{Lrms} is also closely related to the vortex shedding and the motion history, the increasing trend corresponds well to the fundamental lift frequency.





References

Cotter, D and Chakrabarti, S (1984). "Wave Force Tests on Vertical and Inclined Cylinders," J Waterway, Port, Coastal and Ocean Engineering, 110: 1-14.

Sarpkaya, T (1982). "Wave Forces on Inclined Smooth and Rough Circular Cylinders," 14th Annual Offshore Technology Conference, Houston, Texas, OTC4227.

Sundar, V, Vengatesan, V, Anandkumar, G and Schlenkhoff, A (1998). "Hydrodynamic Coefficients for Inclined Cylinders," Ocean Engineering, Vol 25, pp 277-294.

Simulating Water Flow into a Soil Matrix and a Cylindrical Macropore

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Keywords: Macropore flow, Infiltration, Discrete model concept, Two-phase flow in porous media, Numerical model

Introduction
Fast water infiltration in macroporous soils was exptected to be responsible for fast pressure reaction in a multi-layered alpine hillslope thus being a possible trigger for deformation processes and even the initiation of a landslide (Hinkelmann et al. 2011). In order to better understand macropore infiltration it was decided to carry out controlled experiments in the laboratory and then to model the infiltration.

Materials and Methods

Experiments
Based on the requirement to design a very simple macropore experiment, the idea of a single vertical artificial macropore along the centre line of a cylinder was develop. Assuming radial symmetrical flow distribution from the centre position, a bisected cylinder was built (Fig. 1, top). The half cylindrical container experiment had a high of 120 cm, a diameter of 100 cm. The container was homogeneously (porosity ≈ 0.31) filled with fine-sand. An artificial 1 cm macropore is emplaced vertically at the centre of the glass pane. To measure the capillary heads in the experiments, 24 tensiometers were installed in six levels, each level containing four tensiometers in distance of 2, 6, 14, and 30 cm, respectively, from the macropore axis.
The upper surface area is open to the atmosphere. Hence, with exception of the top boundary, all boundary conditions are no-flow. The macropore is open at the top and bottom for the water injection and free outflow through the bottom plate. Only direct injection of water into the macropore is shown here. The water injection was held constant throughout the injection period. In this research 2 experiments are presented labelled as Q166 and Q375. The respective numbers represent the injection rate in cm^3/min. The injection time was 484 min for Q166 and 317 min for Q376. The distribution of water in the porous material was photographically documented through the glass pane with digital camera in interval modus.

Numerical Model
MUFTE-UG is a numerical software toolbox for simulating multiphase flow and transport processes in porous media (Helmig *et al.* 1998). The two-phase flow module of MUFTE-UG is used to simulate the soil matrix of the executed experiments. As mentioned before, flow in the macropore is described with a simple cascade model which was coupled with the soil matrix. The numerical software toolbox MUFTE-UG applies a local mass conservative box-method for the spatial discretization. The mobility at the integration points is therefore computed with a fully upwinding scheme. A fully implicit adaptive time stepping is used for the discretization in time. The resulting non-linear systems are linearized with the Newton-Raphson method and solved with a BICGstab solver using a multigrid preconditioning.
A mesh with overall 2484 nodes and 1170 elements with a resolution of 46 nodes in the vertical direction is used for simulation. For the given setup it is convenient to use a P_n/S_w formulation. For both phases, we defined Neumann no-flow boundary condition (BC) on the cylinder surface. At the top we set atmospheric pressure for the gas phase (Dirichlet BC) and a Neumann no-flow BC for the water phase. However, it is also necessary to define a Dirichlet BC for the second primary variable, the water saturation. To minimize the influence of this BC the water saturation was set near to the

initial condition at the outer edge at the top. The surface between matrix and cascade is a crucial part. Here, we chose a Neumann BC for the water phase since the cascade model serves like a sink/source term and a Neumann no-flow BC for the gas phase.

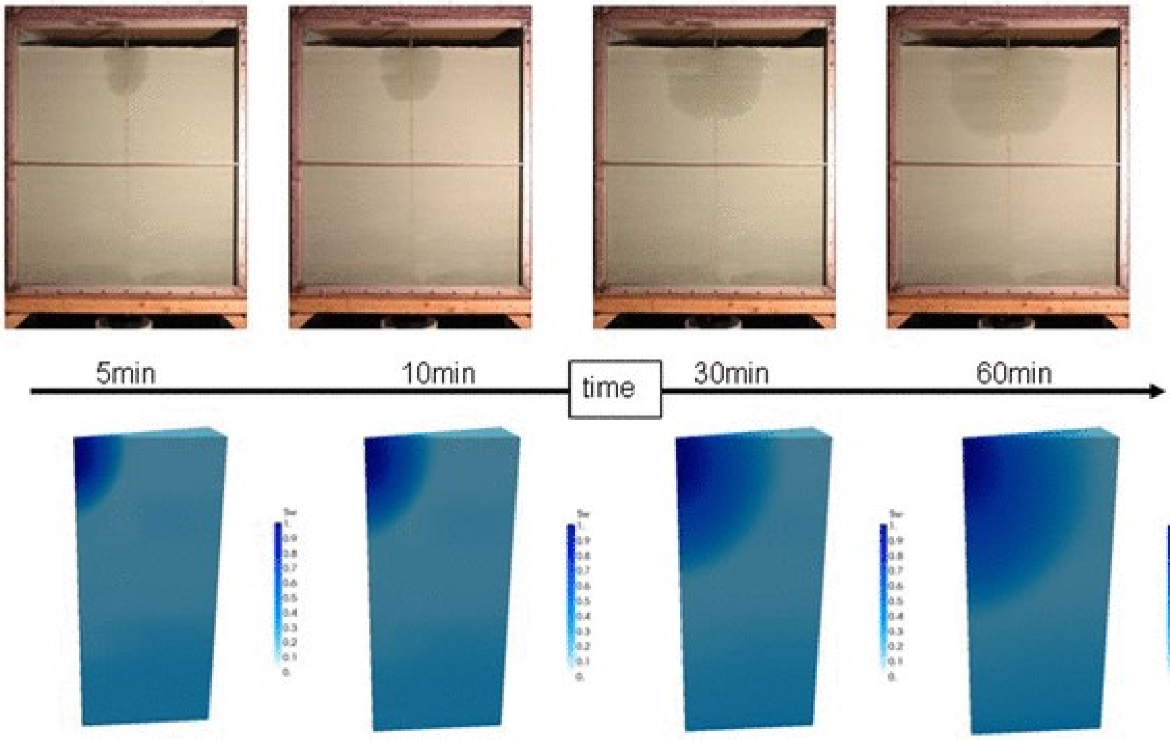

Figure 1. Infiltration during Q166: Laboratory experiment (top); numerical modeling (bottom).

Results

The combination of an experimental design and the extension CASCADE for the two-phase flow module of MUFTE-UG were developed to determine water transfer rates between macropore and its surrounding soil matrix. This concept was used to analyse the water transfer for fine sand with strong capillary suction, where the capillary suction of the matrix dominates the system. Based on the model calibration we obtained reasonable agreement between computations and experiments. We are able to simulate the water infiltration and to determine the water transfer between macropore and soil matrix. The detected water transfer was much higher than expected. However, the results are plausible and show that very high water transfer can occur during macropore flow. The numerical simulation was time expensive since small time step size was necessary for the solution. The combination of our experimental design and numerical model can be used to analyse the water exchange systematically for other soils. Furthermore, the artificial macropore can be adapted to account for more natural like soils. The usage of the simple concept should be further extended in order to consider air flow inside the macropore and air exchange with the matrix. The determined water transfer rates might be valuable for the estimation of exchange parameters for double-continuum models (Stadler *et al.* 2012) which are generally used on large scale.

Acknowledgements

The research was carried out in the Research Unit "Natural Slopes (Großhang) – Coupling of flow and deformation processes for modeling the movement of natural slope" which is funded by the Deutsche Forschungsgemeinschaft. For further information see www.grosshang.de. We thank Dr. Andre Peters of TU Berlin for measuring the soil parameters of the GEBA sand.

References

HELMIG, R., CLASS, H., HUBER, R., SHETA, H., ERWIG, J., HINKELMANN, R., JAKOBS, H. & BASTIAN, P. (1998): Architecture of the Modular Program System MUFTE-UG for Simulating Multiphase Flow and Transport Processes in Heterogeneous Porous Media, Mathematische Geologie, Vol. 2, pp. 123-131.

HINKELMANN, R., ZEHE, E., EHLERS, W. & JOSWIG, M.: Special Section on Landslides: Setting the Scene and Outline of Contributing Studies. Vadose Zone J. 10:473,476, doi:10.2136/vzj2011.0032, 2011.

STADLER,L., HINKELMANN,R. & HELMIG,R.: Modeling Macroporous Soils with a Two-Phase Dual-Permeability Model. Transport in Porous Media: Volume 95, Issue 3, Page 585-601, Springer Verlag, DOI: 10.1007/s11242-012-0064-3, 2012.

Simulation of Wind-Induced Flow and Transport in a Brazilian Bay

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Keywords: Wind-induced flow, 2D shallow water model, Parameter study

1. Introduction

Wind-induced flow was investigated in Icó Mandantes bay, a branch in the São Francisco river, Brazil. Aim of the study was to analyse the effects of the wind on the water body and on the interaction between the São Francisco river and the bay, for different scenarios and different wind conditions. Two different approaches to calculate the wind shear stress were investigated. Additionally, a tracer was injected at different locations in the area to simulate the spreading of a contaminant.

2. Motivation

The Icó Mandantes bay is located in the Itaparica reservoir, a reservoir built for multiple uses of the water such as power generation, irrigation agriculture, abstraction of drinking water, fishery and aquaculture. As pointed out by Gunkel and Sobral [1], the bay faces a severe eutrophication problem. Özgen et al. [2] showed that no significant exchange of water and matter between the bay and the São Francisco river occured for mean flow conditions, which suggests that the influence of the main stream on the flow in the bay is small. The water inside the bay is almost stagnant. However, wind was not taken into account. Therefore, it was necessary to investigate the influence of wind on the flow field in the area.

3. Material and methods

For the computational domain, the same bottom topography as in [2], which showed good agreement with recent measurements reported by Selge and Gunkel [3], was used in this study. The mean water elevation is 302.8 m [1] and the maximal water depth in the study site is around 34 m. Wind data from May 2002 until May 2013 was provided by a weather station with an approximate distance of 30 km to the study site. A mean wind velocity of 5.5 m/s and a maximal wind velocity of 20 m/s were determined through statistical evaluation of the data. On the Beaufort scale the mean wind velocity corresponds to a gentle breeze and the maximal wind velocity is listed as a gale. The most frequent wind direction was determined as 140° from the existing data. Wind shear stress was calculated with Flather's approach in favour of safety, because it returned higher values than Smith-Banke's approach. The simulations were carried out with the Hydroinformatics Modelling System (HMS), which is a java-based framework to solve the two-dimensional shallow water and transport equations with a finite volume method, presented by Simons et al. [4]. The domain is discretized with an unstructured mesh of about 40000 triangular cells. An average element length is 100 m.

4. Results and discussion

The simulations were conducted for different flow and wind scenarios. Mean and extreme wind cases were considered both for mean flow and for a moderate flood, with several wind directions, varying from 30° to 315°. The results showed a significant increase of the flow velocities inside the bay when wind was taken into consideration. An example of the flow field for extreme wind conditions with an angle of 140° is shown in Figure 1(*Left*). High velocities at the boundaries were observed, which are related to the small water depths in these parts of the domain. The change of the flow velocity inside

the bay is from almost stagnant water, when the wind is neglected [2], to 0.04 m/s for the most frequent wind direction of 140°, until 0.19 m/s for a wind direction of 210°.
A circulation of the water in the bay occured. The influence of the wind on the flow is stronger for mean flow conditions than for a flood event.

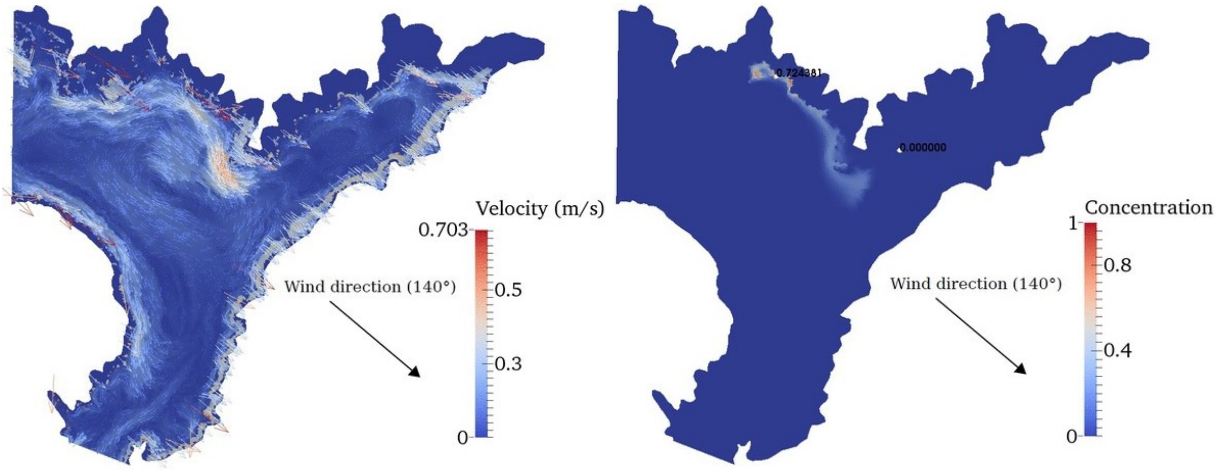

Figure 1. Results of a simulation for extreme wind conditions. (Left) Flow velocity, (Right) Tracer concentration.

Additionally, the spreading of the tracer at different locations in the area was simulated considering the most frequent wind direction of 140◦. An example of it is shown in Figure 1(*Right*). An increase of tracer exchange between the river and the bay was observed.

Acknowledgement
This work was funded by the Federal Ministry of Education and Research (BMBF) in the framework of the research project ’Interplay among multiple uses of water reservoirs via innovative coupling of substances in aquatic and terrestrial ecosystems’.

References
[1] Gunkel, G., Sobral, M., Re-oligotrophication as a challenge for tropical reservoir management with reference to Itaparica Reservoir, São Francisco, Brazil, Water Sci. Technol. 67(4), 708-714 (2013).
[2] Özgen, I., Seemann, S., Candeias, A. L., Koch, H., Simons, F., Hinkelmann, R., Simulation of hydraulic interaction between Icó Mandantes bay and São Francisco river, Brazil, in: Gunkel, G., Silva, J., Sobral, M. (eds.), Sustainable Management of Water and Land in Semiarid Areas, Editora Universitaria, Universidade Federal de Pemambuco (2013).
[3] Selge, F., Gunkel, G., Water reservoirs: worldwide distribution, morphometric characteristics and thermal stratification processes, in: Gunkel, G., Silva, J., Sobral, M. (eds.), Sustainable Management of Water and Land in Semiarid Areas, Editora Universitaria, Universidade Federal de Pemambuco (2013).
[4] Simons, F., Busse, T., Hou, J., Özgen, I., Hinkelmann, R., A model for overland flow and associated processes within the Hydroinformatics Modelling System. J. Hydroinform., (HIC2012 Special Issue), 1–26. doi:10.2166/hydro.2013.173 (2013).

Rainfall Simulator RS-TUHH - Planning, Construction and Use

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Keywords: Rainfall simulation, Intensity, Drop size, Drop velocity, Rainfall runoff model

The growing impact of climate change due to constantly raising CO2-Emissions caused by mankind requires intense research in several sectors. Extreme weather events like droughts and heavy rains can result in rising erosion and flood risk, damage of structures, injuries and fatalities, and extensive economic losses (IPCC, 2012). In this context, flood management plays an important role in adapting to climate changes. Recent approaches integrate decentralized measures such as SUDS and multipurpose spaces to reduce flood risk. To analyze the efficiency of adaptation strategies, numerical as well as physical models are required.

In this paper the development and construction of a rainfall simulator (RS-TUHH, figure 1) is described. On a testing area of 1m² different drop forming measures have been analysed before the simulator was constructed. However, instead of using spraying-nozzles for circular shaped plots the RS-TUHH uses 1650 droplet-nozzles (figure 2) with a grid space of 6 cm and an underlying drop-splitting net. The combination of measures ensures a naturalistic distribution of drop sizes and a uniform distribution of rainfall over the testing area.

Figure 1: RS-TUHH in use, without net

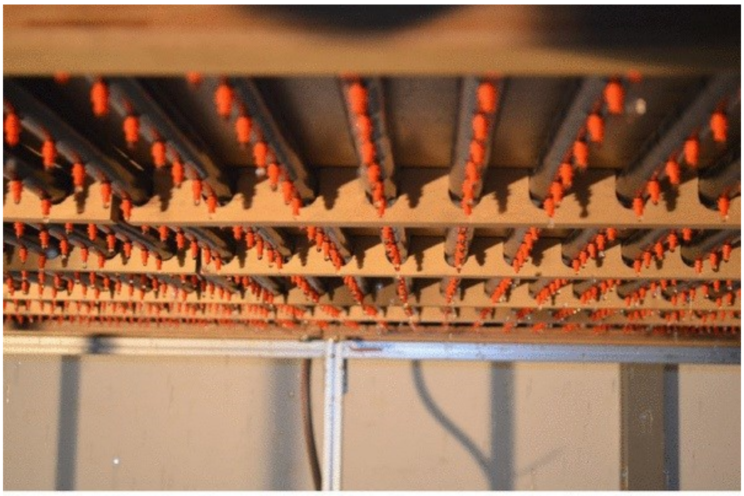

Figure 2: drop forming measure (Gardena Endtropfer 13-4020)

The simulator consists of four elements: the pipe pressure and water distribution control module, the aluminum structure, the irrigation system and the drop splitting net. As it is built, the shaped plot area of 6 m² can be divided into 3 sectors of 2 m². The main intention is to imitate natural heavy rain events by reproducing parameters like rainfall velocity, intensity and duration, as well as drop size, amount and distribution. Experimental parameters of are measured with laser-precipitation-monitor (by Thies Clima) and rain collectors.

Exemplary results for heavy rains with low intensity of ca. 3 mm/h on graphs for drop-amount/diameter and drop-amount/fall velocity are shown in figure 3 and figure 4. Due to the height of fall (2m) the average fall velocity in the simulated rain is slow (1.8 m/s) compared to the measured natural rain (2.7 m/s). On the other hand, the generated average drop diameter of 0.523 mm is close to the measured natural average diameter of 0.573 mm. The droplet size distribution for the used net configuration varies between 0.125 - 5 mm. The distribution of fall velocities varies between 0.2 - 6 m/s which are both in the range of natural rain events (0.5 - 5 mm and 2 - 9 m/s). In this experiment the RS-TUHH features a variation of spatial rainfall distribution of 3% over the plot area of one plate with droplets.

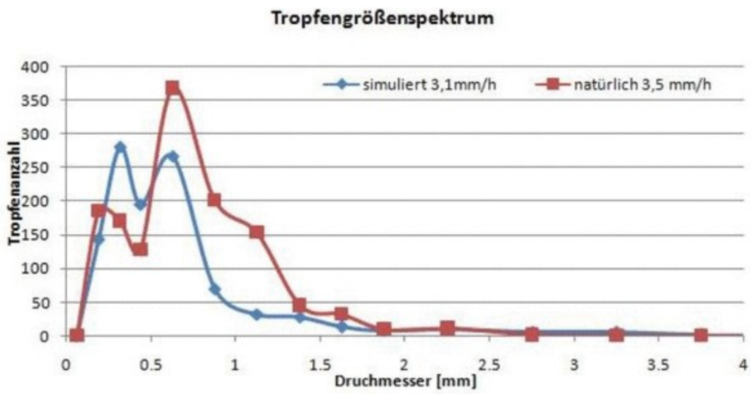

Figure3: distribution of dropsize

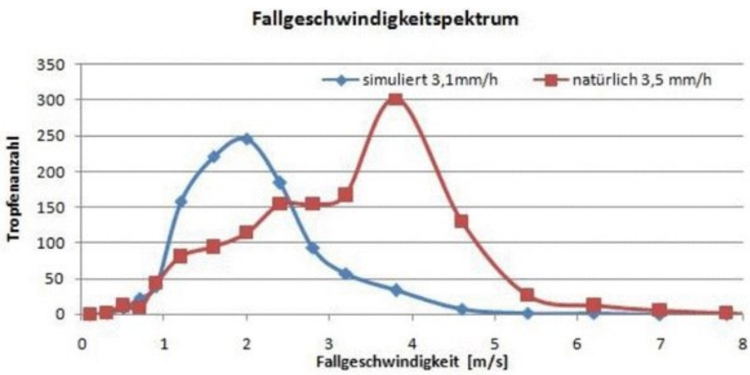

Figure4: distribution of fall velocities

In summary the RS-TUHH is able to imitate natural heavy rainfall events of different intensities from 3 to 200 mm/h on three sizes of plot areas with any duration. Intensity and duration are pre-set on the control module. The drop size distribution is depends on the used net grid space as well as the drop amount. Spatial distribution is homogeneous over the plot area. Fall velocities are low compared to natural rain.

The further objective is to set the intensity and duration of rainfall with the RS-TUHH to irrigate (small-scale) physical urban models under realistic extreme conditions. Besides illustrating the behavior of decentralized rainwater management measures (SUDS), the optimization of measures combination will be analyzed by evaluating surface runoff, flow paths, transpiration and infiltration. In this paper the functionalities of the RS-TUHH and the first steps of development of the physical urban model will be shown.

Acknowledgement
The work described in this paper was made possible through support by a grant from the German Ministry for Education and Research (Bundesministerium für Bildung und Forschung) as part of its KLIMZUG initiative. The authors gratefully thank for this support.

References

IPCC (2012) Managing theRisksof Extreme Events andDisasterstoAdvanceClimate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.
Iserloh T. Dissertation: Niederschlagssimulationen mit kleinen mobilen Beregnungsanlagen - Tropfenerzeugung, Regnervergleich, windbeeinflusster Niederschlag, Universität Trier, 2013. - S.58 ff, S. 62 Table 1.

Modelling the Holtenau Ship Lock with SPH

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Keywords: Ship lock, SPH, CFD, GPU Computing, GPUSPH

The large ship locks of the Kiel-Canal will undergo a significant renovation and it is planned to adopt a through-the-gate filling system. The Waterways Engineering and Research Institute (BAW) was commissioned to evaluate the filling and emptying times of the new filling system and its impact on the forces acting on the ships, which might undermine the safety of the transit.
In [1] a scaled physical model and a purely numerical approach are used to simulate the filling and unfilling of the lock. The numerical model used a Volume-Of-Fluid (VOF) eulerian approach and was is acceptable agreement with the laboratory measurements. The relative movement of the ship with respect to the lock chamber was simulated by grid-morphing or by defining an extra mesh containing the vessel and moving the latter with respect to the background one. The study concluded underlining the relevance of the transversal forces acting on the ships for the planning of the schedule of the valves, especially in extraordinary load conditions. However, it is stated that the most complete way to simulate the behavior of a lock is still a scaled physical model, as the numerical modelling showed several difficulties in respect to the movement of the ship.
In this paper we tackle the same problem with a different numerical method, namely Smoothed Particle Hydrodynamics (SPH). SPH is a meshless lagrangian model: the fluid is discretized as a set of particles which are free to move with respect of each other. The motion of the particles is driven by the actual equations of motion, in our case by the Navier-Stokes equation. SPH is a highly flexible method and it has been used to model single-fluid problems, multi-fluid, thermal problems and fluid/structure interactions.
For our simulation we rely on GPUSPH [2,3], an implementation of SPH that exploits the high-performance parallel computing power of modern Graphic Processing Units. GPUSPH supports a variety of SPH formulations and can distribute computations across multiple GPUs, on the same as well as across multiple machines in a network, which allows the simulation of large scale problems at high resolutions. Particularly of interest for our application is the support for floating objects, which allows us to model the ship in the basin and its fully coupled interaction with the water during operation.

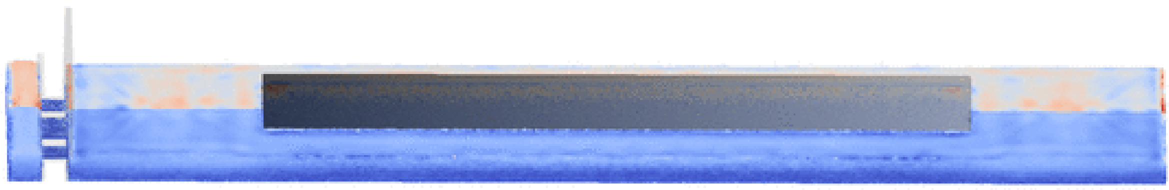

Figure 1. General view of a preliminary simulation of the ship lock model using GPUSPH on two devices; fluid particles are colored by velocity magnitude and by device.

The ship lock has been modeled in GPUSPH in 1:1 scale. The relatively small size of the valve culverts with respect to the complete domain presented the first technical difficulty, since it imposes a minimum size for the SPH particles with which we need to fill about 2·10^5 m³ of water. We need a number of particles close to 1·10^7 and this is not feasable on a single GPU device, so we used GPUSPH to simulate our ship lock model on a cluster of 16 GPUs.
The preliminary results show a good agreement with the previous tests. They also highlight the importance of the investigation of the longitudinal forces. The modeling was an important experience in the practical application of the SPH model on a real hydraulic engineering problem. Further

investigations are being performed to improve the accuracy of the simulation and to overcome the current memory limits and run the simulation at even higher resolutions.

References

[1] Thorenz, C., Anke, J.: *Evaluation of ship forces for a through-the-gate filling system*, Proc. Smart Rivers 2013, Liege (BE), Maastricht (NL), 23-27 September 2013

[2] Hérault, A., Bilotta, G., Dalrymple, R.A. (2010), *SPH on GPU with CUDA*, J. Hydr. Res. 48:74–79.

[3] Rustico, E., Bilotta, G., Hérault, A., Del Negro C., Gallo G. (2013) *Advances in multi-GPU Smoothed Particle Hydrodynamics simulations*, IEEE Transactions on Parallel and Distributed Systems, vol. 99.

SToRM: A Model for Unsteady Surface Hydraulics over Complex Terrain

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US Geological Survey, USA

Keywords: Flood hydraulics, Numerical model, Godunov scheme, Flood inundation, Flood modeling

This paper will provide a brief overview of SToRM, a System for Transport and River Modeling, being developed by the National Research Program of the United States Geological Survey (USGS). In its present state, SToRM is a computer model that solves the unsteady, depth-averaged, two-dimensional shallow water equations for environmental surface flows. The numerical discretization is accomplished using finite volumes with mixed, auto-switching Riemann and diffusive numerical fluxes, and using shock-preserving Runge-Kutta schemes to advance the solution in time. Employing unstructured triangular grids, SToRM is well adapted to compute the flow over complex topography by the combined use of local mesh refinement and coarsening. These techniques will be briefly outlined in the presentation, which will include descriptions of how moving wetting and drying fronts are computed, such as those encountered in flooding events; how the numerical flux computation switching algorithm deals with shock-capturing in hydraulic jumps and flow regime transitions; and other features of practical interest in the modeling of natural water bodies.
For modern day applications, however, special emphasis is placed in the effectiveness of the interaction between user and model. Tasks such as the manipulation of large bathymetric data sets, the generation and adjustment of computational grids, and the calibration of model parameters are usually the most time consuming and costly parts of a numerical modeling engineering project. As such, emphasis will be placed on the integration of SToRM in the iRIC graphical user interface. iRIC is a graphic user interface for pre-processing of data and post-processing of numerical results that was specially designed to work with surface water models. It provides a unified tool for free-surface modeling that incorporates several surface-water models from varied sources. These models are run from within a common interface, therefore allowing the use of different techniques on the same problem without the need to repeat the data pre-processing efforts, such as mesh generation and refinement. It will be shown how SToRM is integrated in iRIC, and the presentation will be illustrated with practical application examples, such as the one shown in Fig. 1.
This article will be useful to flow modelers interested in numerical modeling techniques; to project managers interested in tools to help decision making in water resources; and to scientists and engineers involved in projects in surface water hydraulics, who use (or might use) numerical modeling as a practical problem solving technique.
SToRM is the result of current efforts in the USGS to develop and distribute modeling tools for surface water problems. The model SToRM and the graphical user interface iRIC are available for free download at http://i-ric.org/en/.

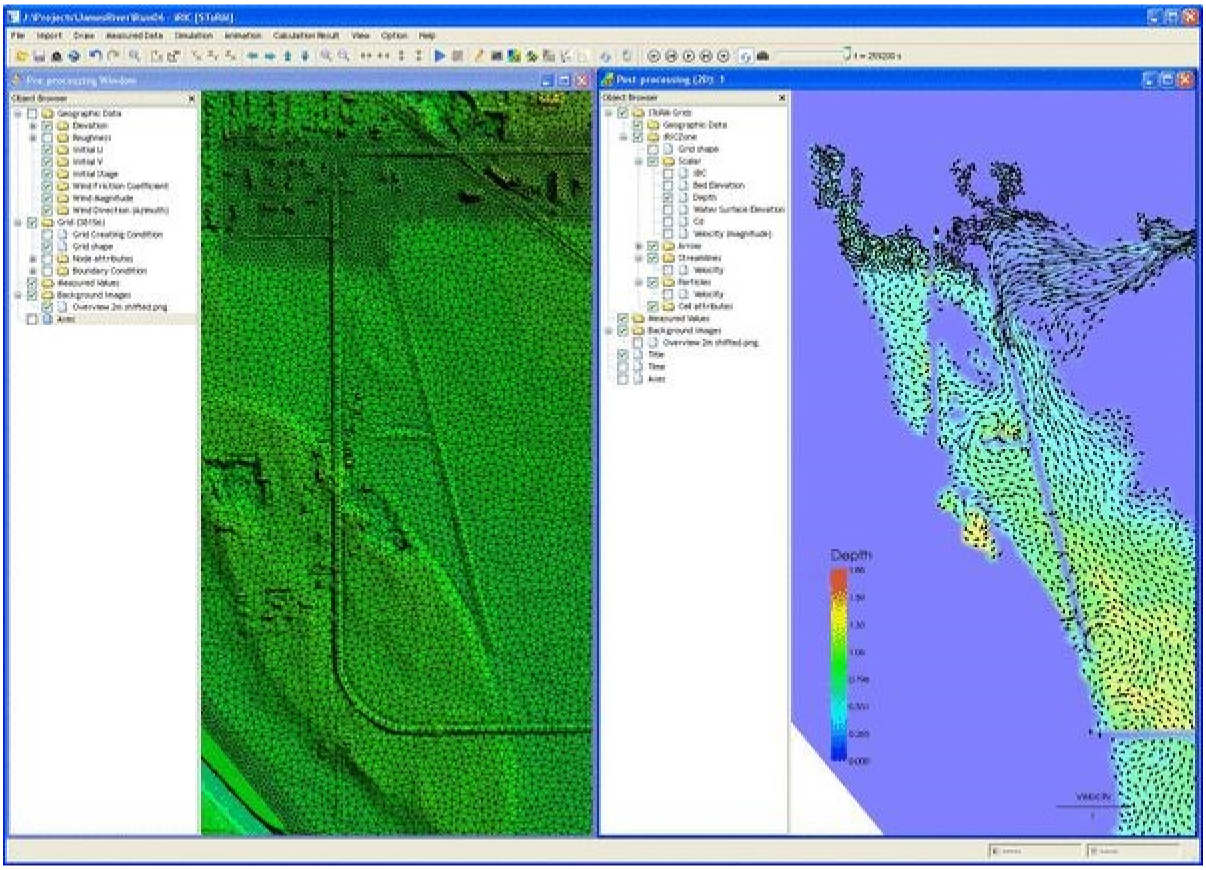

Figure 1. Flood inundation study of catastrophic flooding from dam overtopping in Twin Lakes, North Dakota, USA, as displayed in the iRIC graphical user interface. The plot on the left shows the computational grid and topography at the city of LaMoure, ND, located in the flood zone downstream from the spill. The plot to the right shows flood levels (water depth) and velocity vectors at the same location. The integration of SToRM in iRIC makes this type of projects easier and faster to accomplish, making it a viable tool to provide emergency managers with valuable information for flood mitigation plans.

Design of River Training Structures in a Tidal Channel

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Keywords: Spur dike, Tidal river, Stabilization, Levee erosion

Han river, a major river in south Korea, flows through Seoul metropolitan city and merges with the Imjin river before it flows into the Yellow Sea of Korean Peninsula. The total length of the river is about 514km and the design flood flow rate is about 37,000m3/s. The width of the lower river ranges from 1km to 2km and the average depth is about 7m to 10m. Pedestrian walkways and levee protection with hard structures are well developed along the river. Tidal effects are very strong at the mouth of the river due to the high difference between the rise and fall of the tide. The adverse flow velocity is approximately 3m/s when the river subject to tide effects. The bed materials of the lower river consist with silt-sand. The mean diameter of the bed material is less than 0.02mm.

The reach of Munbal IC, which locates 30km far from the river mouth, has suffering from the serious scouring at right side of levees. The roads and fences on levees were fallen down due to the scouring. Island in the river is developed near the Munbal IC for the last couple of decades so the river divided by two paths. Bank line intruded more than 60m so levee protection with large boulder was provided around Munbal IC in early of 2000 but to fail again. In this study the reasons of scouring were studied and the river training structures with spur dikes and vanes were designed with numerical simulation and physical hydraulic model.

It was found that the scouring was caused by both flood flow and tidal flow. The river bends to right with 110 degree angle at Junryu station which is 5km upstream from Munbal IC. The flood flow from upstream hits left levees at Junryu station and deflected to the right side. The flood flow goes through right channel of the middle island and hits right levees at Munbal IC. The upstream ward tidal boar turns to the right with almost 90 degree at the intersection with Injin river and hits right side of levees at Munbal IC.

It was concluded that the river training structures at Munbal IC should be designed to satisfy two flows, flood flow and tidal boar flow. This study suggests serial spur dikes and vanes finally. The serial vanes were provided at two points, one is at the beginning point of the island and another is at the end point of the island. The vanes could change the flow path far from right levees and major flow could be developed along left channel of the island. The serial spur dikes were also provided at Munbal IC with right angle. The vanes and spur dikes will be constructed in two years and monitoring program will be performed.

Study of Flow over Weirs Such as Pulteney Weir

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Keywords: Open channel flow, Labyrinth weir, Head-discharge relationship, Flow discharge, Weir, Sharpcrested, Rectangular weir, Oblique weir

The present research paper looks into the expression of a head-discharge relationship for Pulteney Weir, constructed in Bath in 1975 as a part of a flood protection scheme, and initiates research for the computation of its flow.
To achieve this, the study looks at the flow of three known shapes of weirs – a sharp-crested rectangular, a sharp-crested 45° oblique weir and a sharp-crested 60° oblique weir - and compares experimental and analytical expressions, to eventually test “Half” Pulteney and Pulteney Weir models.
The series of tests were conducted in the University of Bath’s Hydraulic Laboratory. For each experiment, upstream and downstream water levels were measured for different flow rates and boundary conditions.
Head – discharge relationships were established for all weirs tested. The results showed that for the sharp-crested 45° and 60° oblique weirs, the discharge coefficient is simply a function of H/P.
The derived equation for Pulteney Weir indicated that the impact of a serious flood situation in Bath could be predicted. Although the “Half” Pulteney experiments presented that the turbulent flow was not as symmetrical as it was expected to be.
All equations found, proved a very a good agreement with the experimental data.

Evaluation Method of Positive and Negative Retarding Storage Volumes for Unsteady Two Dimensional Flows and Propagation Mechanisms of Peak Discharge and Peak Water Level

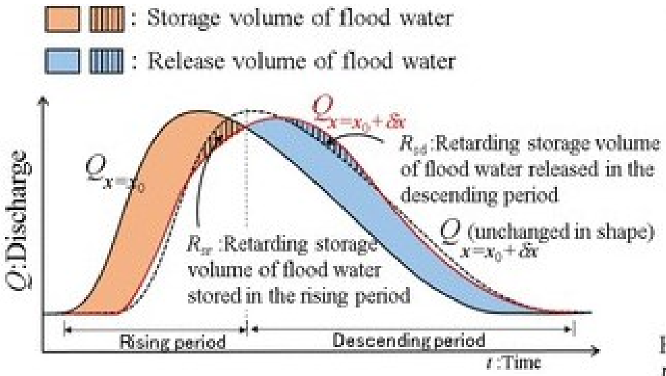
Yoshiharu Takemura, Shoji Fukuoka

Research and Development Initiative, Chuo University, Japan

Keywords: Flood propagation, Storage, Retarding storage, River geometries, Discharge hydrograph, Water level hydrograph, Valley

When a flood occurs in a river with compound cross-sections, channel areas are temporally filled with flood water during the rising period. They are gradually released back into watercourse during the descending period. Discharge hydrographs of flood flows transform through this process and peak discharge decreases in downstream reaches. In addition, it has been known that when large transformation occurs in the discharge hydrographs of flood flows due to the longitudinal difference of the storage volume of flood water in channels, distinct differences appear in propagation characteristics of the discharge and water level hydrographs (Takahashi, 1971) unlike in the case of the flood flow passing through uniform channels (e.g., Lighthill and Whitham, 1955; Hendeson, 1963). Therefore the transformation of discharge hydrographs will give a reasonable index to understand flood propagation mechanisms in river channels.

Some indexes were proposed by researchers to explain the attenuation ratio or propagation speed of flood waves passing through river channels (e.g. Chin, 1978; Mishra and Seth, 1997). However, they do not take into account the mechanism of the transformation of discharge hydrographs,: even though they are essential factors causing the attenuation and delay in propagation of flood waves. Figure 1 shows the discharge hydrographs at upstream and downstream ends of a certain reach of river channels. The discharge hydrograph transforms from the black broken line to the red solid line as it moves downstream. Colored areas surrounded by the discharge hydrographs are equal to the storage and release volumes in the rising period and descending period of the flood water, respectively. They have a certain value even in the case that the discharge hydrograph is unchanged as shown in Figure 1 because there is a difference between the arrival times of the upstream and downstream ends of the reach. It is difficult to evaluate the transformation of the discharge hydrographs quantitatively. In order to solve this problem, Takemura and Fukuoka (2012) characterized roles of the storage and release volumes of flood water that directly contribute to the transformation of discharge hydrographs as retarding storage volumes (shaded areas in Figure 1) and its evaluation method was proposed by deriving an advective equation for flood discharge (Equation 1). However, the evaluation method is not enough to evaluate the effects of the channel morphology on the transformation of the discharge hydrographs because it is made for the unsteady one dimensional flows. This paper shows the advective equation derived for flood discharge based on the unsteady two dimensional flow equations to make clear the physical meaning of right-hand side of Equation 1. We propose the new evaluation method of the retarding storage volume consists of Equations 2-4. The new method is applied to a 2007 flood in a valley of the Kitakami River, Japan.



Advective equation for flood discharge

$$\frac{DQ}{Dt}\left(=\frac{\partial Q}{\partial t}+U\frac{\partial Q}{\partial x}\right)=A\frac{\partial U}{\partial t} \qquad (1)$$

Evaluation method of retarding storage volume

$$\frac{dR_{sr}}{dt}=\int_{x_0-x_0+\delta x}\delta_1 \min\left(\frac{\partial A}{\partial t},-\frac{A}{U}\frac{\partial U}{\partial t}\right)dx \qquad (2)$$

$$\frac{dR_{sd}}{dt}=\int_{x_0-x_0+\delta x}-\delta_2\frac{A}{U}\frac{\partial U}{\partial t}dx \qquad (3)$$

$$\delta_1=\begin{cases}1 & (\partial U/\partial t\le 0)\\ 0 & (\partial U/\partial t>0)\end{cases},\ \delta_2=\begin{cases}1 & (\partial U/\partial t\ge 0)\\ 0 & (\partial U/\partial t<0)\end{cases} \qquad (4)$$

Here, Q: discharge, A: cross sectional area of the flow, U: mean velocity, δ_1 and δ_2: response functions.

Figure 1 Definition sketch of the retarding storage volumes of flood water in a certain reach of river channels and its evaluation method

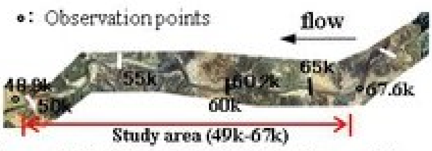


Figure 2 Study area and observation points

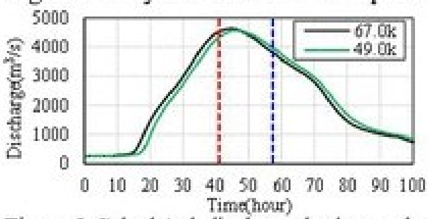


Figure 3 Calculated discharge hydrographs (67.0k and 49.0k sections)

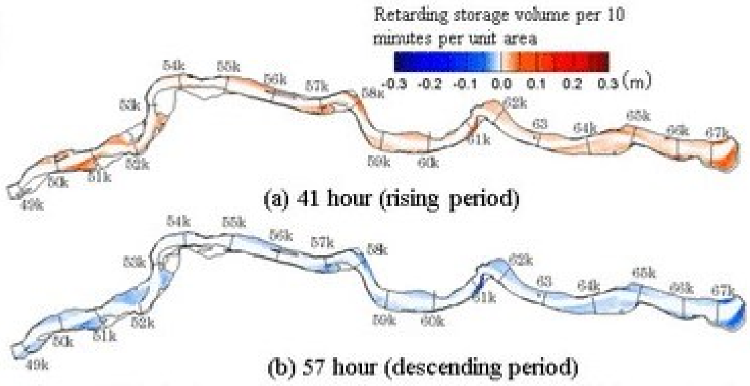


Figure 4 Distributions of the retarding storage volumes which are stored and released per 10 minutes in the rising and descending periods

Figure 2 shows the study area of this paper. In this area, the unsteady two dimensional flood flow analysis was already conducted for the 2007 flood (Takemura and Fukuoka, 2012). Figure 3 is the calculated discharge hydrographs at upstream and downstream ends of the study area. We investigate the temporal and spatial distributions of the retarding storage volumes during the flood from the results of the unsteady two dimensional flood flow analysis. It is clarified that the accumulated amount of the retarding storage volume during the rising period reaches about 2.5 million cubic meters. It is equivalent to about 20% of the flood control volume of the dam reservoir located on the upstream area of the Kitakami River system in this flood. Figure 4 (a) and (b) show the distributions of the retarding storage volumes which are stored and released in the study area per 10 minutes at the times indicated by the red and blue lines in Figure 3, respectively. Flood water are retarded at the red colored places in Figure 4 (a) during the rising period and they are released from the blue colored places in Figure 4 (b) during descending period. This mechanism transforms the discharge hydrograph of the flood flow passing through the valley of the Kitakami River. This paper shows that it is possible to evaluate the effects of river morphology on the transformation of discharge hydrographs quantitatively by investigating the temporal and spatial distributions of the retarding storage volumes in river channels. Moreover, we represent that the retarding storage volume is closely related to the difference of the propagation mechanism of the discharge and water level hydrographs.

References
Chin, L. Y.: Subsidence of peak flow in channels with storage area, J. Hydraulic Res., 16, No. 4, pp.309-326, 1978.
Lighthill, M. J. and Whitham, G. B.: On kinematic waves. I .flood movement in long rivers, Proc. Roy. Soc. A, pp. 281-316, 1955.
Mishra, S. K. and Seth, S. M., 1997: Use of hysteresis for defining the nature of flood wave propagation in natural channels, Hydrological Sci., 41:2, 153-170.
Takahashi, T. : Study on propagation characteristics of flood flows in river channels, thesis, Kyoto University, Kyoto, Japan, 1971.
Takemura Y. and Fukuoka S.: Effects of river morphology on propagation and transformation of discharge and water level hydrographs of flood flows through river valley, Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering), Vol. 68(2012) No. 1, pp. 35-54, 2012.
Henderson, F. M.: Flood wave in prismatic channels, J. Hydraulics Div., ASCE, HY4, pp. 39-67, 1963.

Groundwater Hydrology, Irrigation

A Hydro-Geochemical Evaluation of Groundwater Suitability for Irrigation and Domestic Purposes: A Case Study from Narmada Mahi Inter-Stream Region of Gujarat, India.

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Keywords: Geology, Groundwater, Geochemical, Total Dissolved Solids, Suitability

The study area constitutes a part of Mahi - Narmada inter-stream region of Gujarat state, India. It has a distinct hydro-physiographic boundaries; which is bordered by the Gulf of Cambay in the West, the rocky uplands in the East, Mahi River in the North and Narmada River in the South and sprawl in about 11,000 sq km. The area lies between 72º 30’ E and 73º 43’ E longitudes and 21º 40’ N and 22º 53’ N latitudes. The western and central part of the region, comprises huge thickness of marine, fluvial and aeolian sediments of Quaternary period. These sediments consist of intercalations of sand, silt, clay and gravel bands strongly calcretised. These Quaternary deposits are good repository for groundwater in unconfined, semi-confined and confined conditions. The Eastern part of the study area is covered by hard rocks consisting of Cretaceo-Eocene; Deccan trap- basalts, intrusive granite, basement gneisses followed by meta sediments; quartzite, phyllites, slate, schists and marble, etc.
In order to ascertain pre-monsoon and post-monsoon compositional variations in the groundwater under different6 aquifer conditions, water samples were collected covering. coastal plains, alluvial plains, piedmont zone and highlands. Samples were collected from shallow aquifer (hand pumps/dug well) and deeper aquifers (tube/bore wells). The average range of constituent ions in groundwater samples of pre and post monsoon periods indicate minute but noticeable change in their ionic content. The average difference indicate an overall decrease in pH, TDS, Ca, Mg and Sulphate whereas increase in total hardness, chloride and nitrate concentration from pre to post monsoon season.
Hydrogeochemical investigation has been carried out with a view to characterize groundwater for its domestic and irrigation suitability. As a part of irrigation suitability the review of Ec values have established that only 6% (Pre-monsoon, 2002), 57% (Post-monsoon, 2002), 18% (Pre-monsoon, 2003) and 17% (Post-monsoon, 2003) was found to be in fresh water category. The alkali hazards as Kelley’s Ratio, indicates 75% (Pre-monsoon, 2002), 43% (post-monsoon, 2002), 69% (Pre-monsoon 2003) and 69% (Post-monsoon, 2003) of the samples fall above the one ratio, indicating prone to alkali hazards. Evaluation of groundwater Permeability Index has established that bad category water is almost absent except one location at Rarod village (Karjan Taluka). About 57% (Pre-monsoon, 2002), 45% (Post-monsoon, 2002), 54% (Pre-monsoon, 2003) and 53% (Post-monsoon, 2003) of groundwater fall in excellent category. The abundance of carbonate and bicarbonate ions is denoted by residual Sodium Carbonate. Most of the samples are within the safe permissible limit with more numbers of samples having negative value, indicating that the concentration of Ca2+ and Mg2+ ions exceeds far more than Carbonate and Bicarbonate values. The Schoellar Index (SI) point to the possibilities of ion exchange reaction in groundwater. The SI index for about 70% (Pre-monsoon, 2002), 79% (Post- monsoon, 2002), 77% (Pre- monsoon, 2003) and 71% (Post- monsoon, 2003) samples are in chloro-alkaline disequilibrium whereas few samples are indicative of base exchange reactions. The adsorption of sodium by soil is measured as SAR (Sodium Adsorption Ratio). The SAR values indicate that only one sample in pre-monsoon 2002 and six samples in post 2002 fall in good water category while in pre and post monsoon year of 2003 none of the samples fall in good water category. Majority of the samples fall in bad water category i.e. C4-S4 to C3-S3. Owing to high ion concentration ground water is not fit for irrigation, especially in coastal and alluvial plain regions.
δ18 O isotopic concentration of groundwater sample shows considerable variation in stable isotopic values ranging between -3.16 to 1.06‰. The depleted values are indicating that the area is being recharged from surface water, while enriched values are from coastal plain area, which indicate salinity ingress. Pieper’s Trilinear plot has been used to determine the genetic classification of water.

The mean dominant cation in pre and post-monsoon 2002 and pre-monsoon 2003 in groundwater samples are in the order of Na^+ >Mg^{++} > Ca^{++} >K^+, while anion shows SO_4^{2-} > Cl^- > HCO_3^- dominance. Similarly in post-monsoon 2003 samples are in the order of Na^+ > Ca^{++} > Mg^{++} >K^+, while anions shows SO_4^{2-} > Cl^- > HCO_3^- dominance respectively.

Overall ground water facies in the study area is Na-Mg-Ca-K: SO_4-Cl-4CO_3 type. On the whole, groundwater quality tends to deteriorate from eastern hilly zone to western coastal plains which follow the ground water gradient direction. The groundwater movement direction as evident from reduced water level map indicates that highlands act as a recharge zone to the shallow and deeper aquifers. Some of these aquifers through lower aquitard layer are in hydraulic connectivity with the lower aquifers thereby gets recharged. Categorizing water in accordance with the drinking water standards has established that majority of samples have either one or two constituents in higher concentration making it unfit for drinking.

Under- Versus Overestimation of Aquifer Hydraulic Conductivity from Slug Tests

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Keywords: Slug test, Hvorslev, Bouwer and Rice, Hydraulic conductivity

Extensive examinations of hydraulic conductivities from calculated, simulated, and actual field slug and pumping tests reveal that the well-known Hvorslev- and Bouwer and Rice- slug test methods can underestimate the hydraulic conductivity K in such a test. This is in contrast to the usual overestimation of K that the classical theory underlying these slug-test methods - which omits the effects of the aquifer's storativity, and which may, so, be particularly problematic for unconfined aquifers - predicts. Numerical solutions of the exact equations describing a slug test have been carried out which corroborate this overestimation of K in an unconfined aquifer, but only for low conductivity values (K<1 m/day), and when the "first straight line segment" of the log (H/Ho) vs. time plot is used in the Hvorslev- or the Bouwer and Rice analysis. Although, theoretically, overestimation also exists for slug tests conducted in a high-conductivity aquifer, this is partly masked by the absence of early recordings of hydraulic head changes in the observation well as well as a mixture of saturated and unsaturated flow in a slug well after slug injection and so the "inadvertent" utilization of an “inherent” "late straight line segment" in the log H(t)/Ho plot often results, in fact, in an underestimation of conductivities in a high conductivity aquifer. Hydraulic conductivity estimation from both our computer simulations and field studies, where the results of slug- and pumping tests are compared, supports this conclusion of the underestimation of the hydraulic conductivity in a slug test for a moderate- to high-conductivity aquifer. Therefore, here it is suggested that for estimating the hydraulic conductivity from a slug test, “a late straight line segment” correction in the log H(t)/Ho plot may only be needed in a low-conductivity aquifer, whereas in a moderate- to high-conductivity unconfined aquifer, the early or “first possible straight line segment" in the log H(t)/Ho plot of a slug test is recommended, instead of the traditionally used “late straight line segment”.

Groundwater Vulnerability Assessment Using a Common Index Model Adapted to Urban Conditions

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Keywords: Vulnerability, DRASTIC, Groundwater, India, Urban, Index Model, Fuzzy Logic

Metropolitan areas of emerging and developing countries with their high and dense population are suffering from a large variety of intensive anthropogenic impacts. Many of the associated processes and structures, like sewer disposal, urban runoff, landfills, storage tanks, etc. pose contamination hazards to groundwater, as the effluent pollutants can be transported to the aquifer by surface infiltration. Therefore, groundwater protection strategies are urgently needed. However, for emerging and developing regions, in particular, remediation of aquifers, once they are contaminated, is time-consuming and costly, and the success is often also uncertain. Therefore, the application of sustainable prevention measures of groundwater contamination appears to be indispensable.

In this context, groundwater vulnerability models are established management tools, which can provide valuable information on the planning of appropriate measures to prevent further groundwater quality deterioration. Among the three basic model types (physical, statistical and index) used for vulnerability assessment, index models are the most widely used. Their advantage is the low-cost and straightforward approach to include complex hydrogeological properties in a rather comprehensible manner. Moreover, input data is relatively simple to obtain and the results from these models are easily interpreted and implemented in the subsequent decision-making process of land-use planners and water resources managers.

However, DRASTIC, (Aller et al., 1987) the most renowned index model, and SINTACS (Civita et al., 1997), are still being criticized for having too many input parameters, making the selection of the most important ones difficult (Merchant, 1994), as well as for some parameters being correlated to each other (Foster et al., 2002), or for lacking validation (Nobre et al., 2007) and enough quantitative studies for choosing the appropriate parameters (Garrett et al., 1989). It is then of no surprise that many hydrogeologists criticize the often unconsidered applications of these models because of oversimplification of complex geological conditions, hydrological processes or the neglect of human-caused changes of the land surface.

On the other hand, by some essential adoptions and improvements within these two index models, a more realistic approach to assess groundwater vulnerability can be achieved. Those modifications include the addition and removal of single input parameters or assigning them different ratings or weights (Bai et al., 2012).

In this study, a model based on DRASTIC and the related SINTACS is applied for groundwater vulnerability assessment in the highly urbanized area of Chennai City, India. In these adapted methods, empirical scores and weights are allocated to certain intrinsic, physical parameter defining the underground and the land surface with regard to their capability to protect the aquifer against surficial contamination. These parameters are, namely, 'Depth to water table', 'Groundwater recharge', 'Aquifer media', 'Soil media', 'Topography', 'Impact of vadose zone' and 'Hydraulic conductivity'. The single vulnerability scores of these parameters are overlain and result in one composite map which displays areas of certain vulnerability levels by different colors.

Different from numerous other DRASTIC vulnerability studies, the specific site conditions in the study area are considered, by adapting the input parameters and their scores and weights to obtain a more realistic spatial distribution of the groundwater vulnerability. Thus, firstly, the monsoon-driven rainfall pattern is considered, namely, its intensity and annual variations. This, in conjunction with the incorporation of the anthropogenic impacts on the groundwater system by abstraction wells, leakage of water and sewage pipes has provided a more accurate estimation of the parameter of 'Groundwater recharge'. Secondly, 'Soil media' is modified by considering the various land cover zones of an urban environment, besides the actual soil type itself. Furthermore, 'Impact of vadose zone' and 'Aquifer media' are combined to one parameter and this for several reasons: firstly, the study area is underlain

by a very thin vadose zone and, secondly, the groundwater surface heights permanently vary by several meters during the year, due to strong seasonal water table fluctuations and groundwater abstraction and, thirdly, as the two zones consist of the same alluvial material with properties that are suitable to attenuate contamination, they are associated with an identical vulnerability rating factor.
Additionally, aspects from the SINTACS model, which is the DRASTIC adaptation for Mediterranean climate conditions, have been incorporated in the model. Since dilution effects is considered in SINTACS, groundwater vulnerability decreases in general, when high groundwater recharge rates due to surface water infiltration are present. In fact, studies in Chennai show a decrease of solute concentrations after heavy monsoon rains, as the latter dilute the aquifer with fresh precipitation water (Shanmugam et al., 2007 ; Sathish & Elango, 2011). Thus, for a short time after such an event, it is assumed that this dilution effect outweighs the illuviation of contaminants.
In spite of these expedient modifications, uncertainties in the final groundwater vulnerability map concerning model assumptions, input data and numerical approximations remain. To further diminish these ambiguities, fuzzy-logic and statistical methods are used in combination with the index model to better approach the probability of groundwater contamination occurrence.

References

Aller, L., Lehr, J. H., Petty, R., Bennett, T., Hackett, G. (1987). DRASTIC: A Standardized System to Evaluate Ground water Pollution Potential Using Hydrogeologic Settings. Washington D.C.: U.S. Environmental Protection Agency.
Bai, L., Wang, Y., Meng, F. (2012). Application of DRASTIC and extension theory in the groundwater vulnerability evaluation. Water and Environment Journal , 26 (3), 381-391.
Civita, M., De Maio, M. (1997). SINTACS. Un sistema parametrico per la valutazione e la cartografia della vulnerabilità degli acquiferi all'inquinamento. Bologna: Pitagora Editrice.
Foster, S., Hirata, R., Gomes, D., D'Elia, M., Paris, M. (2002). Groundwater Quality Protection - a guide for water utilities municipal authorities and environment agencies. Washington, D.C.: The World Bank/The International Bank for Reconstruction and Development.
Garrett, P., Williams, J., Rossoll, C., Tolman, A. (1989). Are ground water vulnerability classification systems workable? Columbus: National Ground Water Association.
Merchant, J. W. (1994). GIS-Based groundwater pollution hazard assessment: A critical review of the DRASTIC model. Engineering & Remote Sensing , 60 (9), 1117-1127.
Nobre, R., Rotunno Filho, O., Mansur, W., Nobre, M., Consenza, C. (2007). Groundwater vulnerability and risk mapping using GIS, modeling and a fuzzy logic tool. Journal of Contaminant Hydrology (94), 277-292.
Sathish, S., Elango, L. (2011). Groundwater Quality and Vulnerability Mapping of an Unconfined Coastal Aquifer. Journal of Spatial Hydrology , 11 (1), 18-33.
Shanmugam, P., Neelamani, S., Ahn, Y.-H., Philip, L., Hong, G.-H. (2007). Assessment of the levels of coastal marine pollution of Chennai city, Southern India. Water Resource Management (06).

Evaluation of Automatic Irrigation System in Paddy for Water and Energy Saving and Environmental Conservation

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Keywords: Agricultural water use, paddy, nitrogen load, Inbanuma, Japan

1. Introduction

Agricultural water is essential for food production especially in paddy rice, and much water was withdrawn from water sources compare to other water use sector. In Japan, water delivery system for agriculture was highly-developed and managed by land improvement district. The 1st priority of irrigation is water supply to avoid the water stress, however, saving a labor input for agricultural land management such as weed control also the important factor. Therefore, farmers want to input much water for their paddy to save a labor cost. However, much irrigation water leads much energy consumption for pumping, as a result, water fee also increase. In addition, increase of drainage water cause a much nutrient load effluent to downstream water environment, because nitrogen load can be calculated by drainage water amount (m^3) times nitrogen concentration (mg/l). Historically, water delivery system in paddy agriculture has been supply-oriented system. However recent innovation of field monitoring or automatic regulation system will change it to demand-oriented system. In this study, the automatic irrigation system was evaluated to improve the water management system in paddy without the additional labor input. Kashima district, which was managed by Inbanuma land improvement district, was selected for the test site. Water amount and nitrogen concentration was monitored at Iino pumping station and paddy drainage pipe. Meteorological data were also observed at Iino pumping station for calculation of evapotranspiration. From the monitoring data, water balance and nitrogen balance was estimated. Then, by using the water management model, the effect of automatic irrigation system was evaluated in the view point of water and energy saving and nitrogen load mitigation.

2. Study Area

For the test site, Kashima district was selected which was managed by Inbanuma land improvement district and having 6.48 ha benefit area. All of these paddy fields were cultivated by same farmer group. Irrigation water was pumped up from Inbanuma lake, and water from paddy was drained to Inbanuma again flowing through Kashima river. In this paddy fields, open type drainage canal was not existed and subsurface drainage system was installed in all paddies so that all drained water, which was percolated through paddy soil layer and overflowed from paddy outlet, gathers to drain pipe. Inbanuma lake is closed water area and eutrophic lake. Therefore, drainage water from paddy fields was one of the pollution sources. Although drainage water from paddy have relatively low nutrient concentration compare to that from upland, drainage water amount is more larger. Therefore, nutrient load from paddy fields could not be negligible for the conservation of lake water environment.

3. Field Measurement

To evaluate the water balance, paddy water level was monitored in hourly basis at 2 paddies. Water quality at Iino pumping station and paddy drainage pipe was measured in daily basis (at noon) such as soil sediment (SS), total nitrogen (TN), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N). Meteorological data also measured at Iino pumping station for calculating evapotranspiration. Measured items were rainfall, solar radiation, wind speed, air temperature, relative humidity and atmospheric pressure. Rice variety was Momiroman which was not for human food but for livestock feeding. Observation period was from 2013/5/16 to 11/20. A questionnaire to the farmer also conducted to grasp the fertilizer input or land management practices.

4. Result and Discussion

Iino pumping station was operated until 9/1 so irrigation rate was zero after 9/1. At the monitoring paddy fields, 2045 mm water was pumped up for irrigation and 50.9% of supplied water was released by surface drainage from paddy outlet in current situation. Therefore there was still large possibility to save water by introducing elaborated water management system to reduce surface drainage water. In the conventional paddy field, 90-120 kg/ha nitrogen was recommended in food rice cultivation. However much nitrogen (154kg/ha) was fertilized in this monitoring paddy compared with conventional one. Because, in feed rice cultivation, farmers do not need to pay attention to a taste of rice, therefore much amount of fertilizer was input to increase the rice biomass. Estimated nitrogen load from paddy was 36 kg/ha, it was summation of surface drainage 26 kg/ha and percolation 10 kg/ha. In Inbanuma watershed, there are 7,370 ha paddy field so that about 265 ton nitrogen was flow into the Inbanuma lake from all paddy fields. The pollution load through surface runoff can be reduced by controlling the surface drainage water volume. Such water management leads water and irrigation cost saving, and pollution load to downstream water environment also can be reduced.

For saving water and farmer's labor input, automatic irrigation system was developed and introduced in some irrigation district.In this study, numerical simulation was conducted to evaluate the effect of this auto irrigation system on water saving and nitrogen load reduction. The water saving effect was about 1335mm (65.3%) and energy consumption for pumping also can be saved. As a result, farmer can save water fee which farmer pay to land improvement district for the maintenance and operation of water delivery facilities. Nitrogen load reduction was 24 kg/ha (66.7%), and about 177 ton in Inbanuma watershed. Especially, nitrogen load reduction of first growing stage (June, july) was 17kg/ha (47%), therefore application of auto irrigation system was relatively effective at that period.

Recently, feed rice paddy area is increasing under the governmental regulation policy. Therefore, water pollution in closed type lake may become worse if feed rice paddy spread widely. Auto irrigation system is effective to save irrigation water input and pumping energy consumption and to conserve the water environment without more farmer's labor input for water management. However even after farmers install auto irrigator to their paddies, they will go to see and check paddies almost in everyday. Because they afraid the some trouble in their paddy. In such case, auto irrigator is not so needed and not effective for them. Important point is that if farmer don't need to go to paddy and they can monitor their paddy in their house, for example by internet or using mobile phone, auto irrigator is very useful and effective. Recently, ICT technology in agricultural filed is developed and spread rapidly so that farmer will be able to manage their paddy at their house in near future. In addition, to motivate the farmer to save water, this kind of data should be informed to them and their merit of saving water fee and effect of water saving on environmental conservation also should be explained.

Studying the Effects of an Irrigation/Drainage Network on Groundwater Table Fluctuations Uusing 3D Groundwater Flow Modeling

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Keywords: Miandarband plain, Groundwater, Irrigation/drainage network, MODFLOW, Water logging

The Miandarband plain is one of the most fertile plains of the Kermanshah province, Iran, as it is endowed by ample surface and ground water resources. With the construction of irrigation and drainage networks and the reduced use of ground water resources, the ground water table has risen and caused water logging, followed by salinization of the arable soils in the plain. Environmental deterioration and economical losses have been the consequence. From this the importance of a study of the fluctuations of the water table levels in response to the construction of irrigation and drainage network in the Miandarband plain becomes clear. In this study the fluctuations of the groundwater table have been simulated in both steady-state and transient regimes using the 3D groundwater flow model MODFLOW within the GMS 6.5 environment. For the set-up of the conceptual model, the meteorological, geological, hydrological and hydrogeological parameters, pertinent to the Miandarband area, were studied and implemented into the model. Based on the geological composition of drilling log cores, the aquifer is divided vertically into 11 horizontal layers. The groundwater surface measured in April 2007 is used to carry out the steady-state calibration and employed, at the same time, as initial condition for transient simulation with head measurements taken between May, 2007 and March, 2009. For model verification the heads measured in the subsequent month, April, 2009 is used. A very good agreement between simulated and observed groundwater heads with a coefficient of determination R2 of 0.99 is obtained. In the next step the transient effects of the operation of the irrigation and drainage network on the ground water table is analyzed, whereby the simulations are started with initial conditions as they have existed prior to the operation of the irrigation/drainage network. In addition, to satisfy the needs of the proposed cropping pattern with the recommended surface irrigation, an annual water volume of 176.2 MCM is transferred from the Gavshan dam to the Miandarband irrigation and drainage network. It is assumed that 25% of this irrigation water infiltrates into the aquifer as recharge. With these parameters ground water levels for times of 1, 5 and 10 years after the start of the network operation are calculated. The results show that after 1 year the groundwater table in the center of the plain has risen about 1.8 m, but going up to 3.2 and 5.2 m for 5 and 10 years, respectively. Moreover, after 1 year, 6.59% of the plain's areas are waterlogged, a value which goes up to 37.91% and 56.28% after 5 and 10 years, respectively. In conclusion, by using a transient groundwater flow model it is possible to control the ground water levels and, so, to prevent the occurrence of detrimental water logging events in irrigated agricultural areas.

1. Introduction

Changing hydrological conditions occurring, for example, in the wake of future climate change (IPCC, 2007) by alterations of temperatures and precipitation will have detrimental effects on the surface and groundwater resources in many areas of the world (e.g. Koch, 2008; Fink and Koch, 2010). This holds particularly for regions and countries which are already nowadays affected by water scarcity, such as the Middle Eastern region, including Iran. There, responding also to the needs of a strongly increasing population, rising water withdrawals have already caused drastic changes in the surface flow regimes and severe drops in groundwater levels in many basins of that country.

Responding to all water demands and converting weak points and threats to this resource to new capabilities and opportunities necessitates the use of appropriate water resources management strategies more than ever before. Therefore, finding suitable methods and models for conjunctive use

of water resources, that have maximum efficiency, is one main priority in water resources management. (e.g. Bejranonda et al., 2009).
One particularly water-affected region in the west of Iran is the Miandarband plain, where groundwater serves as the main source of irrigation. The construction of the Gavoshan Dam's irrigation and drainage network is a national project in Miandarband plain that is supposed to be realized in the near future. Although the main goal of this project is the agricultural development in the basin, some of its effects could also be undesirable, due to a lack of effective water resources management. In fact, after the construction of such a modern irrigation and drainage network, the groundwater withdrawal could be reduced significantly, so that the groundwater table level could rise, and water logging may occur subsequently. This phenomenon is prevalent in artificially irrigated, agricultural areas in many arid regions across the globe, where it causes then numerous economic and environmental losses, due to, among other factors, increases of the soil salinity (Rhoades and Loveday, 1990). Therefore, one key to understand water logging and to develop measures, to prevent it, such as proper drainage (Ritsema, 1994), is an analysis of the groundwater table fluctuations in the region affected. This can be done efficiently by the use of numerical groundwater flow models (Mahmudian Shoushtari, 2010).
Several groundwater modeling studies deal with groundwater flow in regions of Northern China, where many areas are facing water resources shortages and/or the named pollution problems which, eventually, have already adversely affected the agricultural productivity (e.g. Wang et al, 2008; Xu et al., 2011 Xu et al., 2012).
In the present study, groundwater flow in the Miandarband plain will be studied and then the effects of the construction of the Gavoshan Dam's irrigation and drainage network on the groundwater resources in the region will be simulated, using the MODFLOW groundwater flow model in the GMS6.5 environment (USACE, 2008).

2. Conclusions

Using the 3D groundwater flow model MODFLOW within the GMS 6.5 environment, the fluctuations of the groundwater table in the Miandarband plain have been simulated. After calibration and verification of the model, the possible effects of the future construction of the Gavoshan Dam's irrigation and drainage network on the groundwater table are simulated. The results show that after 10 years irrigation operation more than 50% of the plain's surface will be waterlogged. Therefore, an effective water resources management strategy is required to prevent this imminent waterlogging problem. One well-suited policy approach to that regard would be the application of optimally managed conjunctive surface-groundwater operations, the set-up of which will, however, require further quantitative groundwater management simulations

References

Bejranonda, W., M. Koch and S. Koontanakulvong (2009), Improving traditional conjunctive Use Management with Surface Water and Groundwater dynamic Interactions Modeling, International Symposium on Efficient Groundwater Resources Management (IGS-TH 2009) , Bangkok, Thailand, February 16-21, 2009.
Fink, G. and M. Koch (2010) Climate Change Effects on the Water Balance in the Fulda Catchment, Germany, during the 21st Century, In: Proceedings of the Symposium on "Sustainable Water Resources Management and Climate Change Adaptation", Nakhon Pathom University, Thailand, June 16-17, 2010.
IPCC (2007) Summary for policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge,UK.
Koch, M (2008) Challenges for future sustainable water resources management in the face of climate change, The 1st NPRU Academic Conference, Nakhon Pathom University, Thailand, October 23-24, 2008.
Koch, M., P. Arlai, P. and A. Lukjan (2012) Modeling Investigation of the future permissible Yield in the upper Chiang Rai Aquifer System, Procedia Engineering, 32, 69–76.
Mahmudian Shoushtari, M. (2010). Groundwater flow hydraulics, Chamran Univers. Publ.. Ahvaz, Iran.(in farsi)

Ritzema, H.P (ed.) (1994) Drainage Principles and Applications. International Institute for Land Reclamation and Improvement (ILRI), Publication 16, Wageningen, The Netherlands.
Rhoades, J.D. and J. Loveday (1990), Salinity in irrigated agriculture. In: Stewart, B.A., Nielson, D.R. (Eds.), Am. Soc. Civil Eng., Irrigation of Agricultural Crops. Am. Soc. Agronomists, Madison, WI, p. 1089–1142.
USACE (2008), U.S. Army Engineer Research and Development Center., Groundwater Modeling System (GMS)
Wang, S., J. Shao, X. Song, Y. Zhang, Z. Huo and X. Zhou (2008). Application of MODFLOW and geographical information system to groundwater flow simulation in North Plain, China, Environ Geol, 55, 1449-1462
Xu, X., G. Huang, Z. Qu, and L. Pereira (2011). Using MODFLOW and GIS to assess changes in groundwater dynamics in response to water saving measures in irrigation districts of the upper Yellow River basin, Water Resour. Manage.. doi:10.1007/s11269-011-9793-2.
Xu, X., G. Huang, H. Zhan, Z. Qu and Q. Huang (2012). Integration of SWAP and MODFLOW-2000 for modeling groundwater dynamics in shallow water table areas, Journal of Hydrology, 412–413, 170–181.

Integrating Spatial Multi Criteria Decision Making (SMCDM) with Geographic Information Systems (GIS) for Determining Suitable Areas for Artificial Groundwater Recharge

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Keywords: Shabestar plain, SMCDM, Artificial recharge, AHP, Spreading basins.

The Shabestar plain is a semi-arid area that is located in northwest Iran. Increasing population, agricultural development and, coming with it, illegal well pumping, have increased the exploitation of groundwater resources in that area tremendously over the past decades. This phenomenon, along with some seasonal droughts that have occurred in recent times, has led to a severe decrease of the groundwater levels in the Shabestar aquifer system. In order to reduce this crisis, the establishment of groundwater artificial recharge projects can be a suitable option. One of the typical climate characteristics of semi-arid areas are stormy rainfalls that can produce considerable runoff. Using this runoff-water for artificial recharge spreading basins is a great opportunity to avoid further decreases of the groundwater table. An important tasks in preparing such projects consists in the determination of suitable areas for their implementation.
In this study, spatial Multi Criteria Decision Making (SMCDM) is used in combination with a Geographic Information System (GIS) to determine suitable artificial recharge areas, based on their potential to store water and the appropriate properties of several GIS-data layers. For the latter, seven main hydro-geological parameters including land slope, soil hydrologic groups, alluvium thickness, quaternary formation, groundwater level are considered as main layers, while pasture land and water drainage network are considered as efficient layers in locating suitable artificial recharge areas. The data layers for each these groups are supplied by GIS. The ranges of changes of the five main layers are then classified in accordance with their importance in locating these areas. Afterwards these data layers are assessed relative to each other, applying the Analytical Hierarchy System (AHP) and finally set up in the GIS environment. As mentioned, the presence of pasture areas and water drainage network is a major criteria in the decision making process.
Based on the results of the SMCDM process, seven separate regions, measuring a total area 124.32 km2 (10.42% of the total flood plain area) have been chosen as the most appropriate places for the implementation of artificial recharge spreading basins. Based on the annual potential of runoff production, that has been calculated by the Justin method, these areas have then been prioritized. The results show that the third region, with an area of 38.63 km2 is best for artificial recharge, as is provides a potential runoff of 7.65 million cubic meters (MCM) per year. Following in ranking are the second and first region.

References

ArcGIS9.3 desktop help- interpolate to raster with spatial analyst.
Asano, Takashi. 2004. Artificial recharge of groundwater, California states water resources. pp – 69 – 96.
Bouwer, H. 2002. Artificial recharge of groundwater: hydrogeology and engineering. Hydrogeol, J: 10:121–142.
J.ghayoumian , M.Mohseni sarvi , S.Feiznia , B. Nouri , A.Malekian . 2006. Application of GIS techniques to determine areas most suitable for artifical groundwater recharge in a coastal aquifer in southern Iran.
Jana Kaklcikova and Pavel tucek. 2008 . Evaluation and setting of parameters in interpolating methods by modeling of different types of georelief.
Kumar B and Kumar U,2011. Ground water recharge zonation mapping and modeling using Geomatics techniques, Int.J. Environmental Sciences Volume 1, No 7

Maroju.Suman. 2007 . Evaluation of Five GIS Based Interpolation Techniques for Estimating the Radon Concentration for Unmeasured Zip Codes in the state of ohio. Submitted as partial fulfillment of the requirements for the Masters of The University of Toledo.
Phien-wej, N., P.H. Giao and P. Nutalaya. 1998. Field experiment of artificial recharge through a well with reference to land subsidence control. Eng Geol 50:187–201.
Psti.G,I.Bogardi,W.E,Kelly , R.J.Kalinski(1993).Co kriging of geoelectric and well data define aquifer protective layers , Ground Water , no 31 , pp:905-912.
R.Sakthivadivel , A.S.Chawla . Artifical recharge of river water : An experiment in Madhya Ganga canal project , India.
Saif ud Din , Ahmad Al Dousari , Abdul Nabi Al Ghadban . 2005 Sustainable fresh resources management in northern Kuwait – A Remote sensing view from Raudatain.
Von Hoyer, M., M. Junker, C. Centurion, D.I. Soza, F.A. Larroza, S.F. Larroza and J.L. Rolon. 2000. Sustained Water supply by artificial groundwater recharge in the chaco of Paraguay. Hydrogeology and Environment geology, pp.207-215.
Yalcin , 2002 . General Directorate of Land Registry and Cadesaster.
YueSun, A., A. Shaozhong Kang, F. Li and L. Zhang. 2009. Comparison of interpolation methods for depth to groundwater and its temporal and spatial variations in the Minqin oasis of northwest China. J. Environ. Model. and Software (24): 1163–1170.

Urban Water Management

Characterization and Strategies for Implementing Sustainable Urban Drainage Systems in Consolidated Cities with High Flood Risk. Case Study: Barranquilla - Colombia

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Keywords: Storm drainage; Barranquilla Streams; Sustainable Management; Peak flow

Introduction

The city of Barranquilla, in Colombia, nowadays lacks from a storm sewer system and a storwamter management master plan. The stormwater runoff flows on the streets' surface generating risk for the population and causing paralysis of the urban activities during the rain events every year. The construction of a conventional storm sewer system for the entire city would be economically unfeasible, therefore it is necessary to propose strategies for implementing alternatives of sustainable urban drainage systems including the conveyance system for managing urban watersheds, for reducing peak flow, for controlling pollution and for mitigating flood risk. A research project was conducted to diagnose the current conditions of the stormwater management in the city and to propose strategies for implementing Sustainable Urban Drainage Systems-SUDS as an alternative for urban stormwater management, including the implementation of a real-time stormwater monitoring system.

General diagnosis of stormwater drainage conditions in Barranquilla

Barranquilla, with an area of about 120 Km2, is divided by two main basins: the eastern basin, which covers the largest percentage of the city, discharges directly into the Magdalena River, and the western basin, which flows to the Mallorquín estuary and finally to the Caribbean Sea (Figure 1). The eastern basin has an extend and consolidated urban area, currently lacks from a conventional storm sewer system in more than 90% of the area, so during the rainy season runoff flowis on the streets with extremply dangerous velocities (up to 10 m/s) that puts in high risk the citizens and causes considerable damage on the infrastructure and the economy of the city. The western basin is partially urbanized but also lacks from a storm sewer in most of the area, and even though some channels are canalized, many of them may increase the flood risk in downstream areas. The average annual rainfall in Barranquilla is 850 mm, from which almost 50% falls between August and October. Typically the rain events are of high intensity and short duration. For example, a recorded event of 70 mm, had 120 mm/hr intensity during 40 minutes.

Figure 1. Elevations Urban sub-watersheds in the city of Barranquilla that have high flood risk (Left). SRTM-90 (USGS) and Eastern and Western basins (Right).

The runoff flow rate on the streets may varies between 12 and 150 m3/s for basins between 78 and 543 Ha. The average slope in the city is 2%, and the speed of flow could be up 10m/s, dominating the supercritical flow. These characteristics show the severity of storm drainage conditions that threatening the population and the infrastructure of the city. Figure 2 shows an image of a street of Barranquilla during a normal rain event.

Figure 2. Conditions of drainage on the roads during the winter season every year. Courtesy of: El Heraldo newspaper.

Strategies for SUDS implementation

As part of the results of the research project, different strategies have been proposed for consolidated urban areas and expansion areas of Barranquilla, considering the urban layout, hydrology, soil type, hydraulic conditions, land use, local regulations among other factors. These strategies focus on the restoration of the hydrological conditions in urban watershed, the progressive and strategically programmed construction of a stormwater conveyance sewer system and the implementation, and measures for pollution control. The proposed strategies are from structural to non-structural measures for the consolidated urban areas and developing areas, including retention, detention, infiltration, and conveyance systems, regulation and incentive strategies for new and old constructions for encouraging the use of SUDS.

Stormwater monitoring system for Barranquilla

One of the actions for managing stormwater runoff in Barranquilla is a stormwater monitoring system implemented in 2013 by the Universidad del Norte. The system has rain gauges distributed in all the city, level and speed sensors, hydrological and hydraulic models and a free access web platform for the citizens to be informed about raining conditions and areas with high flood risk (Figure 3). A description and design criteria of the monitoring system are presented in the paper.

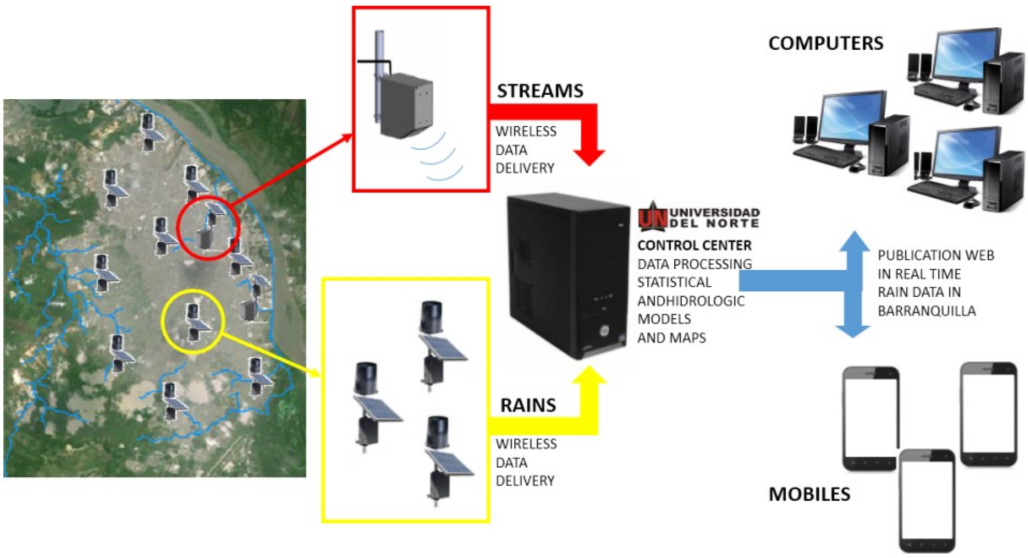

Figure 3. Stormwater monitoring system for the city of Barranquilla implemented by Uninorte.

Modelling Decentralised Systems for Urban Drainage and Flood Mitigation

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Keywords: SUDS, Urban Drainage, Decentralised Systems, Flood Mitigation, Climate Change Impact

Assessing the performance of decentralised urban drainage and flood mitigation systems requires novel hydrological modelling approaches that can handle a large number of spatially distributed measures and enables a water re-distribution functionality to simulate exceedance flow control.

Climate change impacts and urban growth increases the pressures on the already existing flood risk situation in urban areas (IPCC, 2012). Here, the control of exceedance surface water flows is of particular concern for flood management (Balmforth et al., 2006). In the context of uncertainty about future projections, flexible and sustainable adaptation strategies have to be defined. Systems need to be considered in a holistic manner, analysing the interrelations within the overall urban structure and combining the management of water and vegetated spaces (PUB, 2013). Here the techniques of low impact development, water sensitive urban design and sustainable urban drainage systems are first steps taken towards this approach of decentralised drainage and flood mitigation systems. An objective to mitigate these impacts is to drain the water in a more natural way using infiltration, retention and storage devices in urban areas (Butler & Davies, 2011). These measures are defined as SUstainable Drainage Systems (SUDS), which are small-scale source-control structures with a limited capacity. To enable the required control of exceedance flow in case of storm events that surpass the capacity of SUDS, a combination of local measures and larger-scale multipurpose spaces for water retention may provide an appropriate strategy to cope with the impacts of climate change and urban growth. It is the objective of this paper to describe the implementation of a simulation tool enabling the modelling of these drainage management strategies and to present first modelling results.

In addition to the GIS data required for a hydrological model set-up, i.e. on watershed boundaries, land use, soil types, groundwater and the river network, the users may now define detailed maps of small scale SUDS locations and larger-scale urban water retention areas. This calls for a modelling approach which can handle a large number of spatially distributed measures. For this purpose the numerical model KalypsoHydrology, a semi-distributed hydrological model for the simulation of the land-based water balances in river catchments and the river discharges (Pasche, 2003) was enhanced with a tool to work with overlays. Overlays are areas with additional information of soil profiles, drainage as well as water receiving functionality, groundwater recharge and vegetation to model SUDS elements and large scale retention areas. In this model hydrological response units (hydrotops) are created by the intersection of land use, soil type, watershed and overlay data.

Based on previous work the numerical core has been refined to enable the detailed simulation of the water balances and drainage concentration in SUDS elements (Hellmers, 2010). These measures are subdivided into logical layers according to the attributes of their material and functionality, e.g. soil, storage and drainage characteristics. The enhanced methodology allows designated areas to receive and distribute water, so that a conveyance of exceedance in a chain of small scale SUDS measures and large scale multipurpose retention spaces is enabled. During the computation these areas are transformed into additional small scale sub-catchments and an algorithm has been implemented to cross link these sub-catchments in the overall drainage network plan with drainage strands and drainage nodes.

The enhanced hydrological model, KalypsoHydrology, is part of the open source product Kalypso (http://kalypso.bjoernsen.de). It comprises hydrologic and hydrodynamic simulation models for the process of flood risk management planning. Derived from the calibrated basic model, scenario simulations can be created in the software tool with GIS data of future urban development projections and areas of overlays with the attributes of adaptation strategies like SUDS or larger retention areas. Hydrodynamical models like KalypsoWSPM or Kalypso1D/2D are applied in the process chain of

Kalypso to compute the water surface flows. In the post-processing the inundated areas and flow depth can be computed on the basis of digital terrain data with the module KalypsoFlood (see Figure 1).

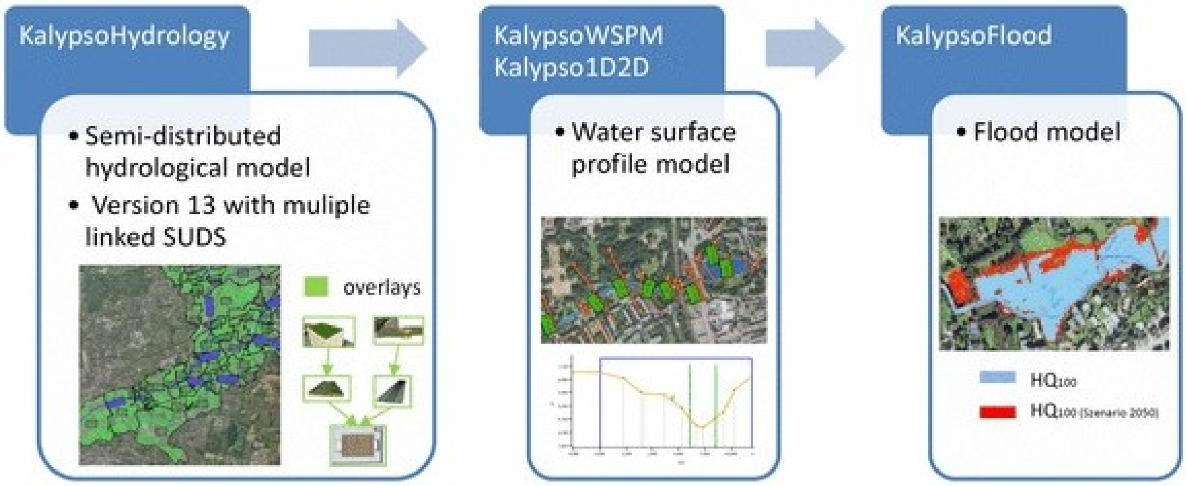

Figure 1. Kalypso modules for urban drainage and flood modelling.

The model set up has been applied in the course of the KLIMZUG-Nord project to quantify the impacts of land use and climate change projections for 2050 in a river catchment in Hamburg. Adaptation strategies with small scale SUDS measures and larger-scale urban retention areas are integrated in the scenarios. For a "suburban area", an "urban-suburban area" and an "urban area" the results of the flood peak discharge simulations are presented in the paper. The results show a positive mitigating performance efficiency that can be reached using SUDS and exceeding flow control in urban areas.
The semi-distributed SUDS model implemented in the enhanced KalypsoHydrology module, coupled with KalypsoWSPM or Kalypso1D/2D and KalypsoFlood modules, provide an appropriate framework to represent the drainage and flood management in urban catchments.

Acknowledgement
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References
Balmforth D., Digman C., Kellagher R. and Butler D. (2006). *Designing for Exceedance in Urban Drainage – Good Practice*. Construction Industry Research & Information Association (CIRIA), Report C635.
Butler D. and Davies J. (2011). *Urban Drainage*. 3rd Edition. Spon Press, New York, NY, USA.
Hellmers S. (2010). *Hydrological Impacts of Climate Change on Flood Probability in Small Urban Catchments and Possibilities of Flood Risk Mitigation*. Wasserbauschrift Band 13, Insitute of River and Coastal Engineering, TUHH, Hamburg.
IPCC (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.
Pasche E. (2003). *Wasserbau – fünf Jahre: Alles fließt*; River and Coastal Engineering at the Technical University Hamburg Harburg; Schüthedruck GmbH, Hamburg.
PUB (2013). *Managing Urban Runoff - Drainage Handbook*, first edition, PUB the national water agency, Singapore.

Water Transportation by Using Waterbuss in Banjir Kanal Timur (BKT) to Reduce Traffic Jam in Jakarta

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Keywords: BKT (Banjir Kanal Timur), Traffic jam, Alternate route, Water transportation, Waterbuss

Traffic jam is one of the biggest problems being faced by Jakarta. Transportation facilities and infrastructure that are not well integrated make traffic jam in Jakarta getting worse. There needs to be alternative transportation modes that are not required to build a new highway because the supply of land in Jakarta increasingly depleted. When viewed from the condition of the waters, Jakarta has 13 watersheds to the sea (BPLHD DKI Jakarta) that has not been utilized. These statistics illustrate the potential of the river as an alternative mass transportation lines.

These water transportation using the waterbuss as the main mode to transporting the passengers. These designs of this route consist of 7 waterbuss shelter. These shelter built at various strategic places a long roadside Jenderal Basuki Rahmat until Jenderal Rs Soekanto. Shelter serves to raise and lower the passenger who will use the water transportation. Alternate route of water transportation in the Banjir Kanal Timur is divided into 5 sections. This is because there are floodgates between shelter 4th and 5th. Due to these floodgates waterbuss cannot traverse the path between the shelter 4th and 5th.

These water transportation can be used along the Banjir Kanal Timur because the minimum water level averages the calculation of the Muskingum-Cunge method still meet the minimum standards set that is more than 2 m. Water transportation is able to reduce traffic jam on Section I: Jenderal Basuki Rahmat Road-Kolonel Sugiono Road by 37.5%. While water transportation on Section II: Kolonel Sugiono Road-Rs Soekanto Road can reduce traffic jam by 32.8%.

River, Estuarine and Coastal Dynamics

Numerical Simulation of Breaking Waves on a Plane Slope with a Parallel Level Set Solver

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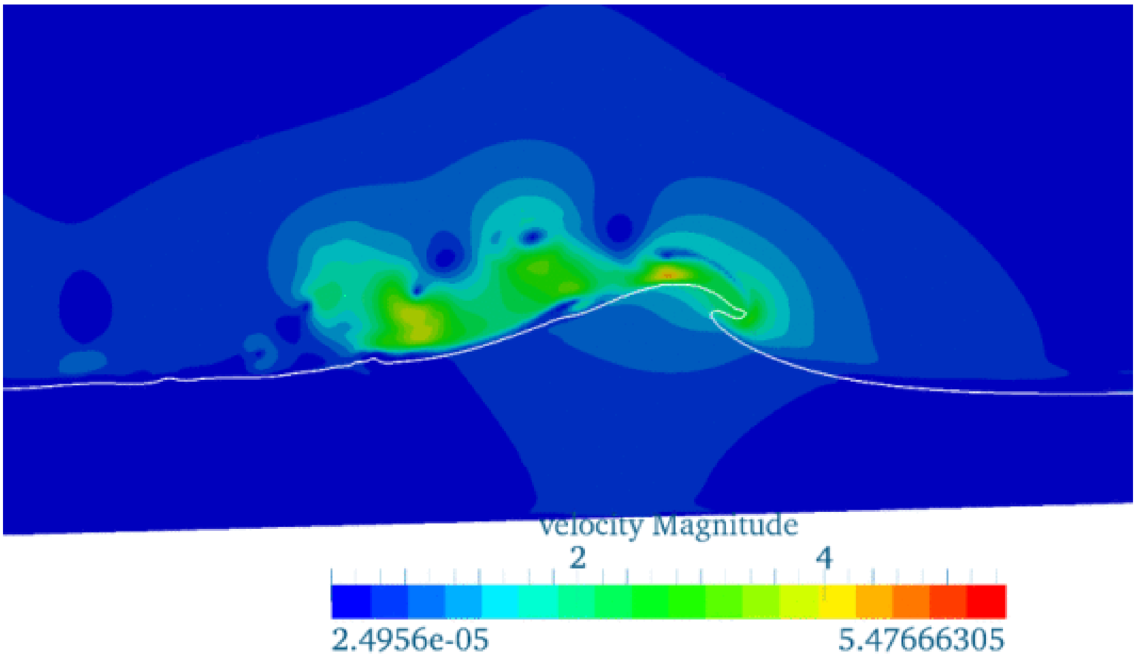
Keywords: Breaking waves, CFD modelling, Wave breaking, Free surface

In the present study, spilling breaking waves are simulated using a numerical model with interface capturing technique. The numerical model solves the Reynolds-Averaged-Navier-Stokes (RANS) equations on a uniform Cartesian grid and complex geometry is modeled with a ghost cell immersed boundary method. The flow problem is solved as two-phase flow of water and air with the free-surface represented as the interface between the two phases. Thus, the level set method (LSM)is used to capture the complex free-surface changes. The temporal and spatial turbulent kinetic energy in the breaking waves is described by k-ω model. The conservative 5th order Weighted Essentially Non-Oscillatory (WENO) scheme is employed for the convective discretization. A much stronger coupling between velocity and pressure is obtained by using a staggered grid which is essential for a two phase model. The present model is fully parallelized using the Message Processing Interface (MPI) library routines.

The paper presents the changes in the free surface profile, vertical and horizontal velocity variation and turbulence production in different regimes from onset to just after breaking. Numerical experiments are carried out with the 5th order cnoidal waves on a plane slope of 1:35 at a water depth of 0.4m. The present numerical model is validated and compared with the experimental data reported in Ting and Kirby (1994,1996). The results from the numerical model are in good agreement with the experimental data regarding instantaneous free surface elevation, horizontal velocity and wave group envelope. A snapshot of the velocity variation during wave breaking of spilling breaker from the present numerical model is shown in the figure below.



References

Ting, F.C., Kirby, J.T., 1994. Observation of undertow and turbulence in a laboratory surf zone. Coastal Engineering. 24 (1– 2), 51– 80.

Ting, F.C., Kirby, J.T., 1996. Dynamics of surf-zone turbulence in a spilling breaker. Coastal Engineering 27 (3– 4), 131–160.

A Methodology Framework for Calibration of 2D Hidro-Morphodynamic Models of Rivers with High Hydrological and Morphological Interaction

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Keywords: Hydrodynamics, Morphodynamics, River Dynamics, Calibration

Introduction

Proper implementation of 2D numerical models for hydrodynamic, sedimentologic and morphologic simulation of rivers depends on the procedure and quality of the results from the calibration and validation processes. A general practice for calibrating 2D hidro-morphodynamic models consists of adjusting the hydrodynamic, sedimentological and morphological components individually and sequentially. This practice works properly in rivers where the hydrograph variability from low to high flows does not considerably affect the bed level related to the water depth. However, in rivers with a high interaction of hydrodynamic and morphodynamic conditions within an annual hydrological cycle, the sequential calibration is not feasible. This paper describes a methodology framework proposed for calibrating 2D hydromorphological models with a comprehensive procedure including hydrodinamic, sedimentologic, and morphologic variables at once. The methodology framework was implemented with MIKE-21C for calibrating a 75 Km segment of the Meta River in Colombia, which relationship between bed level and water depth considerably changes within the annual cycle from low to high flows requiring a comprehensive and simultaneous calibration.

Methodology

The methodology starts generating a morphological and sedimentological seed by using theoretical and field measured data for the required variables. The hydrodynamic model is calibrated based on this seed. Once the hydrodynamic model is calibrated, the sedimentological and morphological (bed level changes) models are then calibrated simultaneously selecting scenarios from an experimental design, evaluating the response variables and checking that the hydrodynamic calibration keeps adequatly by using statistical and eyeball comparison between measured and simulated data. The methodology is systematic but also requires the analysis of the results in order to identify sensitive parameters and variability ranges. Bank erosion was not included in the calibration process.

The methodology framework was applied for calibrating a 75 Km of the Meta River in Colombia (Figure 1) which was selected based on morphological, geomorphological, hydrological, hydraulic, sedimentological and navigation criteria. The software package MIKE-21C was used, which allows studying the spatial and temporal variation of depth, bed level, velocity and shear stress during extended time intervals (DHI, 2011; Papanicolaou, Elhakeem, Krallis, & Edinger, 2008). The numerical model has the following characteristics:

- Bank lines, vegetated islands and sandbars were defined from field measurements and satellite imagery analysis between August 26th and September 25th of 2012.
- Bank lines and vegetated islands were assumed to be fixed for simulation time domain.
- Time domain of three years, for which the assumption of fixed bank lines and islands is valid for average flow hydrographs in the sector.
- Constant diameter, equivalent at mean bed sediment size (D_{50} = 0.35 mm).
- Computational grid of 1074 x 64 (jxk). Cells with average dimensions of 31 m

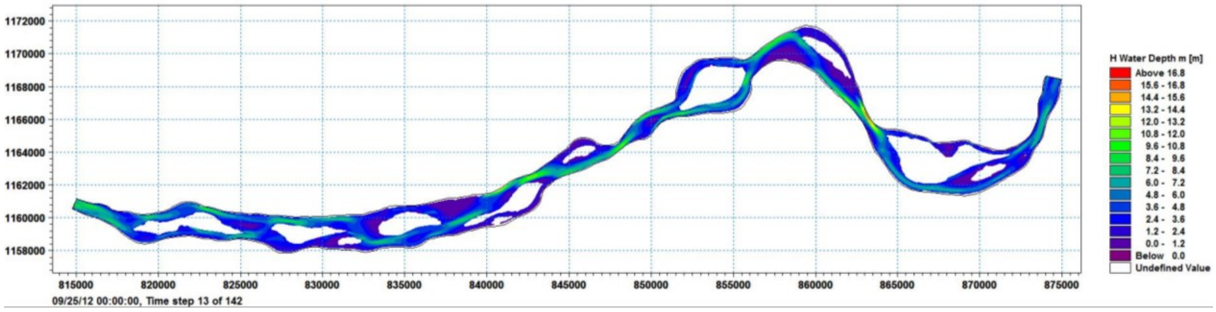

Figure 1. Result of the75 Km of the Meta River simulated by MIKE-21C model.

According to the model's mathematical approach and a sensitive analysis based on the simulation results, the following variables were relevant for the calibration: roughness, sediment transport equation, coefficients of suspended and bed sediment load, helical flow intensity, bed slope, and cross section slope. The following criteria were used to evaluate the goodness of fit of the calibration by comparing the simulated results with data collected from hydrographical field work: Water surface elevation and flow rate time series. For this study case, the best fit was found with a Chezy´s roughness coefficient $C = 55h^{0.17}$,where h is the water depth. Figure 2 shows the measured and simulated water elevation and the velocity vectors measured with ADCP and simulated by the model. Flow rate distribution through island branches, suspended sediment transport rate, the Thalweg and bed level changes, where also evaluated.

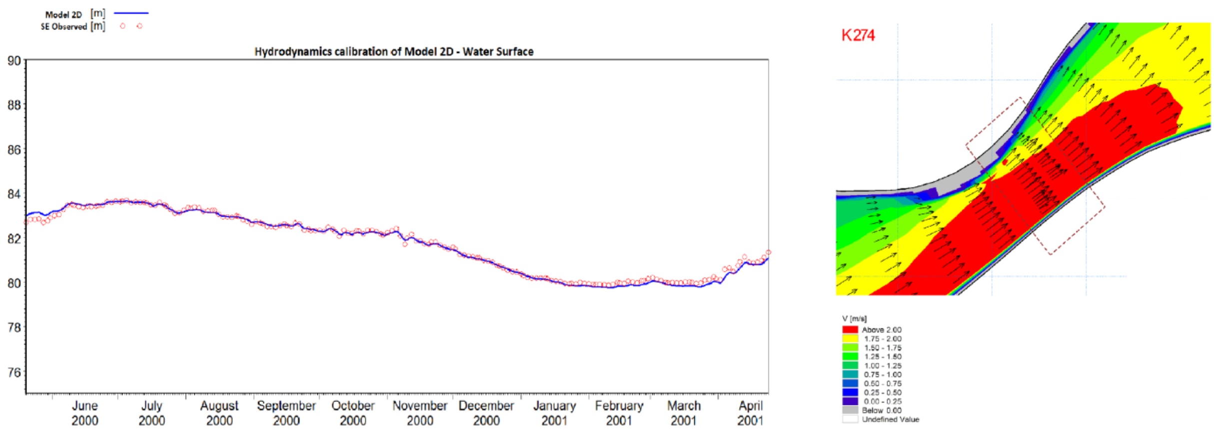

Figure 2. Simulated and measured water levels (Left). Simulated and measured velocity (Right).

Obtaining the coefficient of determination between bed level profiles through grid cells corresponding to the simulated and measured Thalwegs, for field measurement Campaigns I and II during different times of the year. For the study case, this value was close to 0.91, indicating a good fit. The purposed methodology allows developing a systematic and much more efficient procedure for calibrating and validating 2D hidro-morfodynamic numeric models with a sensitive interrelation between hydrodynamic, hydrological and morphological behaviors, such as the study case of the Meta River. The full article presents the purposed methodology framework, the results obtained and recommendations oriented towards calibrating and validating hidro-morphodynamic river models.

References

DHI (2011). mikebydhi.com. Reterieved October the 14th 2013.

Papanicolaou, A., Elhakeem, M., Krallis, G., & Edinger, J. (2008). Sediment Transport Modeling Review-Curent and Fure Developments. Journal Hydraulic, 1-14.

Joint Probability Approach in Design Flood Estimation: Recent Developments in Australia.

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Keywords: Monte Carlo Simulation, Hydrologic modelling, Design flow estimation

Over the past 15 years there has been progressive development of the joint probability approach (JPA) to design flood estimation in Australia. Original work commenced in 2001 with the publication of a seminal report through the Cooperative Research Centre for Catchment Hydrology (CRC-CH) by Rahman et al (2001). The approach outlined in that work is a Monte Carlo Simulation method and is commonly known in Australia as the CRC-CH methodology. TheCRC-CH methodology considers random variables like event duration, rainfall intensity,rainfall temporal distribution and antecedent rainfall conditions. More recently, an update of the Australian Rainfall and Runoff (AR&R) procedures in 2013(AR&R, 2013) saw the development of a stratified sampling approach which retains the critical duration concept deployed in the design event approach (DEA) detailed in the 1987 and 1998 AR&R updates (AR&R, 1987,1998). This approach is commonly known as the TPT (Total Probability Theorem) approach.

In January 2011 much of eastern Australia was devastated by floods. A subsequent Inquiry instigated by the State of Queensland, Australia, recommended a comprehensive hydrologic assessment as part of the Brisbane River Catchment Flood Study (BRCFS). This comprehensive hydrologic assessment required that design flood estimates be updated for the Brisbane River catchment using competing methodologies including methods based on the JPA. The ensuing work culminated in further advances in the development of the JPA. Specifically, the BRCFS saw (i) the incorporation of the Importance Sampling into the CRC-CH methodology (Diermanse et al, 2014), (ii) the use of space-time rainfall patterns generated by the multiplicative cascade model (Seed, 2014) (iii) the incorporation of Gaussian and Student-t copulas to account for correlated variables (Diermanse et al, 2014) and (iv) the trialing of an additional sampling approach known as the Complete Storm Sampling (CSS) methodology based on total catchment depth rather than event based IFD tables. However, for the CSS methodology, it is necessary to replicate published burst rainfall statistics derived from application of catchment wide spatial-temporal patterns which remains a challenge. The study will be completed in late 2014.

This paper outlines the three methodologies viz. the CRC-CH, TPT and the CSS. The paper concludes that the three methodologies have their strengths and weaknesses, but collectively provide a deeper insight in appropriate Monte Carlo simulation techniques for large catchments.

References

AR&R, 1987, 1998: Australian Rainfall and Runoff – A guide to flood estimation. Institution of Engineers, Australia.

AR&R, 2013: Monte Carlo simulation techniques, Australian rainfall and runoff discussion paper, May 2013. Authors: Rory Nathan and Erwin Weinmann.

Diermanse F, Carroll D, Beckers J, Ayre R.& Schuurmans J (2014) "A Monte Carlo Framework forthe Brisbane River Catchment", Hydrology & Water Resources Symposium, Perth, Australia, Feb 2014.

Rahman A, Weinmann E, Hoang T, Laurenson E & Nathan R (2001) "Monte Carlo Simulation of Flood Frequency Curves from Rainfall", Technical Report 4, CRC-CH.

Seed A, (2014) "Stochastic simulation of Space-Time Rainfall Patterns for the Brisbane River Catchment", Hydrology & Water Resources Symposium, Perth, Australia, Feb 2014.

Simulation and Prediction of Storm Surges and Waves Driven by Hurricanes for Assessment of Coastal Flooding and Inundation

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Keywords: Storm Surge Modeling, Wave Processes, Coastal Flooding, Hurricane Wind

When a hurricane makes its landfall, it releases its devastating force onto coast and inland, and causes hazardous flood and inundation due to storm surges and waves. Simulation and real-time prediction of wind and storm surge driven by hurricanes are vitally important to assess the impact of tropical cyclones on coastal communities. Risk of coastal hazards due to flooding and inundation must be evaluated before storm seasons for the purposes of flood management and planning; and propagation of storm surges and waves should be forecasted during a hurricane period so that decision of mitigations and evacuation can be made in time.

Fast and accurate assessment of flooding and inundation induced by hurricane is a challenging task due to the complexity of tropical cyclone wind structures and the large- and multi-scale processes of coastal and ocean waters driven by dynamic forcing of astronomical tides, wind waves, storm surges and river inflows. Usually, simulation of wave deformation and transformation in a large-scale regional area from deep ocean water to shallow water in surf zone is much more time-consuming than the effort to only simulate storm surges driven by cyclonic wind forcing. Most existing storm-surge models for hurricane simulations heavily rely on high performance computers which are expensive.

This presentation highlights NCCHE's research on development and application of CCHE2D-Coast, an integrated coastal/estuarine/riverine/ocean process modeling system (e.g. Ding et al. 2013), for simulating and predicting coastal flooding and inundation induced by storm surges, wave setup, tides, and river flood inflow during a hurricane period. A brief description on the framework of mathematical theories and numerical technologies will be given. Model validations by hindcasting surface water levels and waves of Hurricane Gustav (2008) in the Gulf of Mexico (Figure 1 and Figure 2) and Hurricane Sandy (2012) in the Atlantic Ocean (Figure 3) will be presented. A real-time prediction capability of CCHE2D-Coast will be demonstrated by forecasting flooding risk of Hurricane Isaac (2012) in the Mississippi Gulf Coast. This presentation will further give an engineering application of this modeling system for seeking solutions of coastal flood protection in the low-lying area in New Jersey by considering the combined condition of tropical cyclone and sea level rise due to climate change.

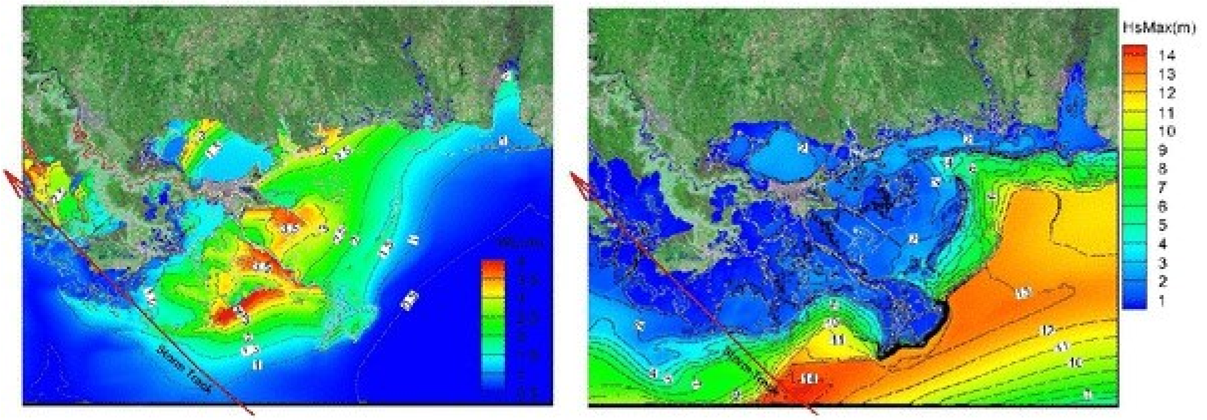

Figure 1. Maximum water surface elevations (left) and wave heights (right) induced by Hurricane Gustav (2008) in the northern Gulf of Mexico.

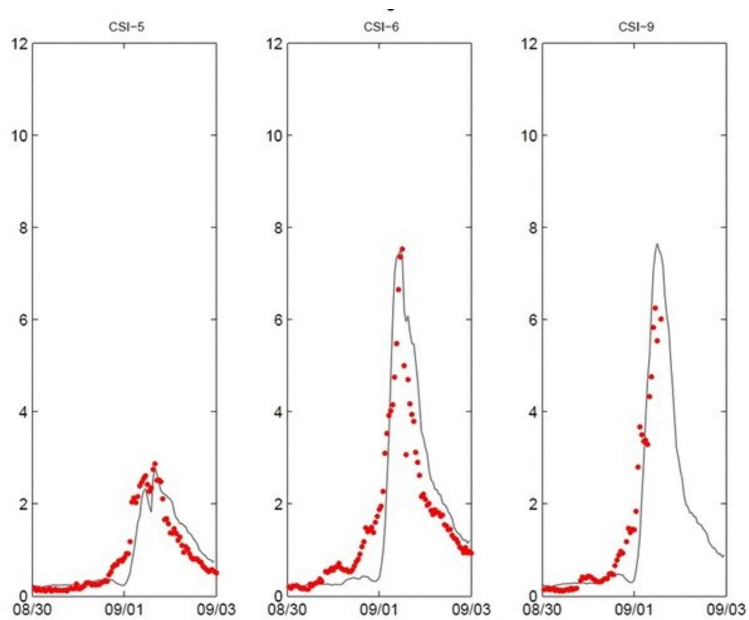

Figure 2. Comparisons of wave heights in Gustav (2008) in the Louisiana coast: CSI-5: South of Terrebonne Bay. CSI-6: Chevron Platform, ST-52B, Terrebonne Bay. CSI-9: Grand Isle Blocks.

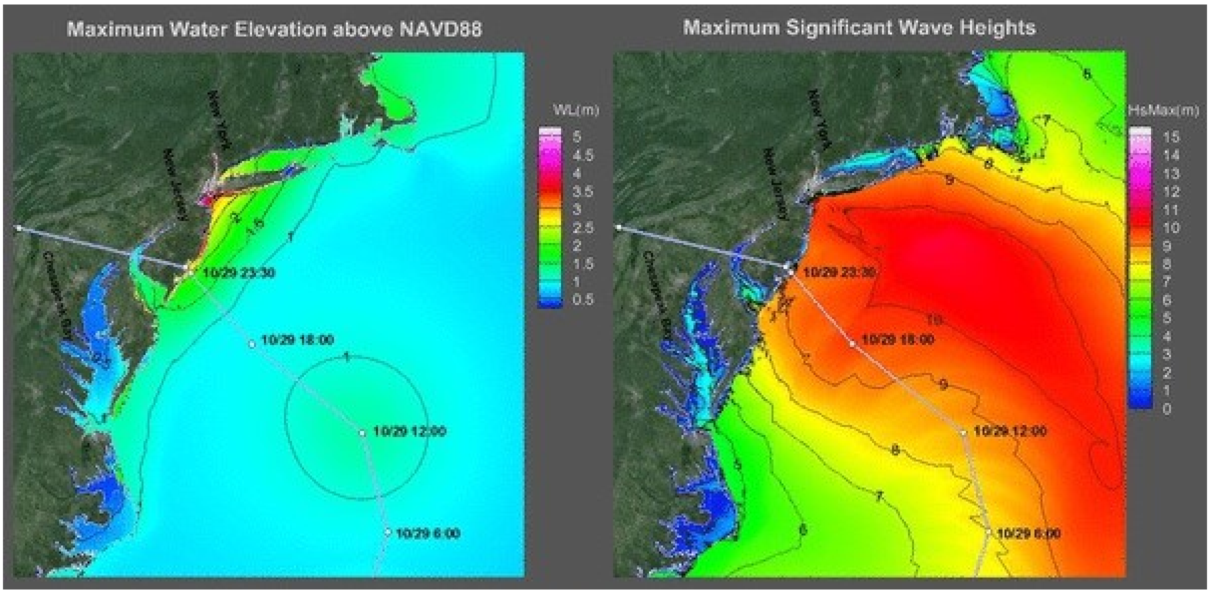

Figure 3. Maximum water levels (left) and wave heights (right) produced by Hurricane Sandy (2012) in the U.S. East Coast.

It is worth to note that all the modules of CCHE2D-Coast share one grid system for simulating hydrodynamic processes in sequence. Instead of using the so-called model steering operation adopted in many other storm-surge models, CCHE2D-Coast does not need to switch executable codes of the modules. Therefore, this model eliminates possible errors and loss of information due to interpolation and extrapolation of the results between different grid systems for different process models. The mesh is non-orthogonal, which allows general structural quadrilateral grids to model irregular coastlines in a flexible way. And it enables to use spatially-varying mesh resolution to focus on different regions of interest in coastal zones, estuaries, and inland watersheds and infrastructures. Computationally, advanced numerical schemes for solving wave and current make this integrated model efficient and capable of running simulations in a standard PC with a relatively short computational time.

Reference

Ding, Y., et al. (2013). Impact Assessment of Sea-Level Rise and Hazardous Storms on Coasts and Estuaries Using Integrated Processes Model, Ocean Engineering, 71(1), 74–95.

Countermeasures for Preserving Riverine Tidal Flats in a Ship-Bottom Shaped Channel of the Lower Ota River floodway

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Keywords: Ship-bottom shaped channel, Tidal flat, Bed variation, Flood flow, Alternate bar, Riprap, BVC method, Estuary

Recently, expanding flood control capacity by river bed excavations is considered as one of the adaptation techniques to increase in flood frequency and discharge by global warming. However, excavating river bed causes degradation of river bed. And, the channel degradation results in channel incisions and narrowing as shown Figure 1(a). Therefore, while many researchers and engineers have tried to improve such a river (e.g. Darby & Simon, 1999), previous studies have not provided the idea how they decided the stable cross sectional profiles in incised and narrowed rivers properly. Fukuoka (2012a) indicated dynamic relation equation (Fukuoka' equations) between a river's dimensionless width, dimensionless depth and dimensionless channel-forming discharge based on flood flows and channel properties in stable alluvial rivers. Moreover, he proposed design method for incised and narrowed rivers by coupling the Fukuoka's equations and numerical simulation of the flood flows and bed variations in the Satsunai River where the channel degradation and incision results from a series of spur dikes and growing vegetation on the flood plains (Fukuoka, 2012b). The study also indicated that the determined stable cross-sectional bed profiles were almost ship-bottom shaped channels (See Figure 1(b)) having the sort of continuous wetted perimeter seen in natural rivers. The ship-bottom shaped channels are almost stable for under the channel-forming discharge because the cross-sectional bed profiles are formed by bed variations and bank erosions by a series of floods. Therefore, we believe that the ship-bottom shaped channels are effective for improving incised and narrowed rivers toward stable rivers under design flood discharge. However, river bank protection method in the ship-bottom shaped channel remains as technical issues.

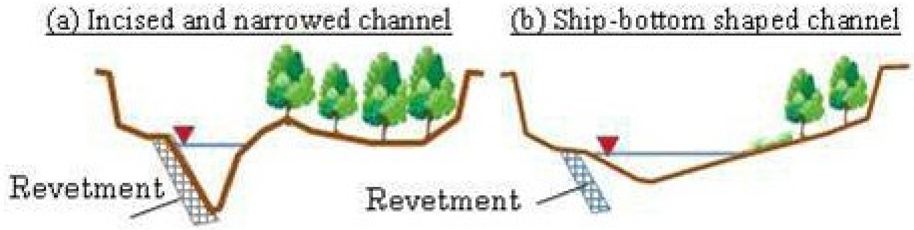

Figure 1 River improvement of incised river toward stable river

In the lower Ota River floodway, the cross-sectional profiles have gradually changed to stable ship-bottom shaped channels from compound channels by bed variations and erosions in a series of floods in past about 50 years. But, tidal flats along the river bank in the ship-bottom shaped channel are decreasing year by year due to gradual bed variations and erosions (see Figure 2). It is required to preserve the tidal flats along the river bank in the ship-bottom shaped channel of the floodway. This issue is closely associated with the design method of river bank protection in the ship-bottom shaped channels.

In this study, therefore, we evaluate effects of installing ripraps on the topographic changes in the tidal flats and determine appropriately locations and elevations of the ripraps for preserving the tidal flats in the ship-bottom shaped channels by the numerical simulation for flood flows and bed variations.

Moreover, we propose the design procedure for improving incised and narrowed channels toward stable ship-bottom shaped channels.
In order to determine the locations and elevations of the ripraps, we took two steps approach as follows. First, we simulated flood flows and bed variations during a series of floods in the next 30 years under the present river conditions. The unsteady quasi three-dimensional flood flow analysis (Uchida & Fukuoka. 2013) is applied in order to evaluate bed surface velocities and vertical velocity distributions properly. The bed variation analysis is used conventional method which consists of bed load formula and continuity equations for sediment and grain sizes. Figure 3 shows contour of calculated dimensionless shear stress in the peak discharge. From these results, we narrowed down installation locations and elevations of ripraps to several cases as shown Figure 4.

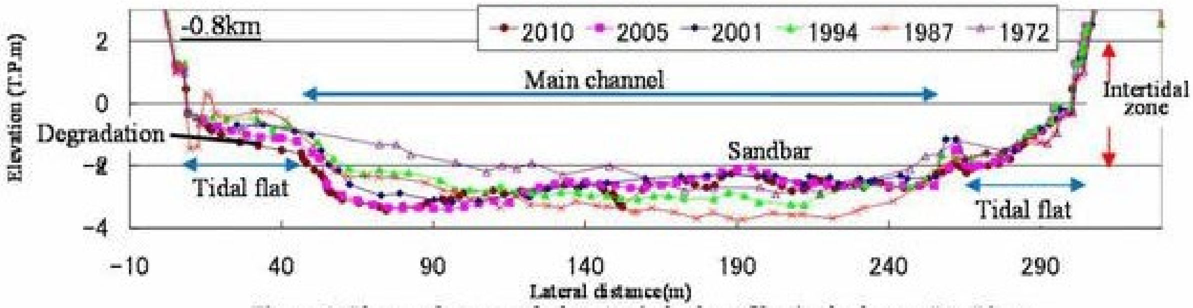

Figure 2 Observed temporal changes in bed profiles in the lower Ota River

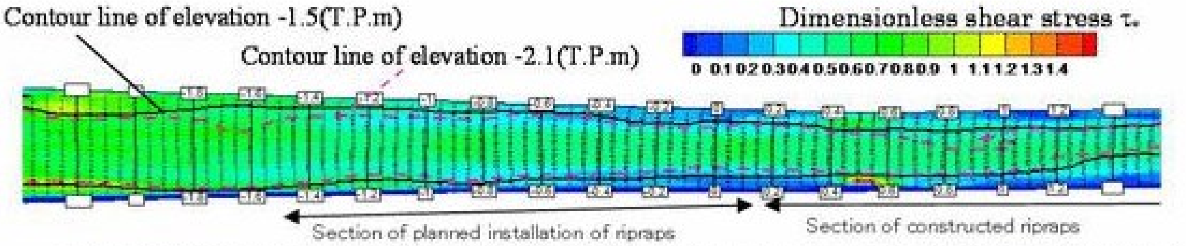

Figure 3 Calculated contour of dimensionless shear stress in present river conditions (In peak discharge)

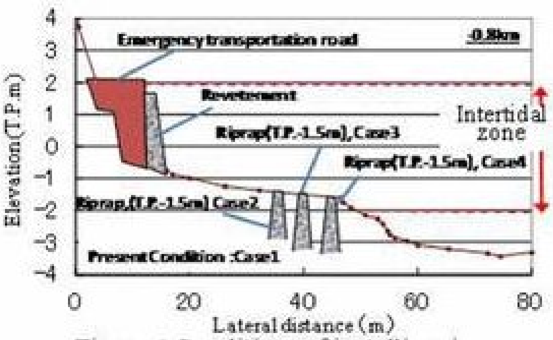

Figure 4 Conditions of installing ripraps

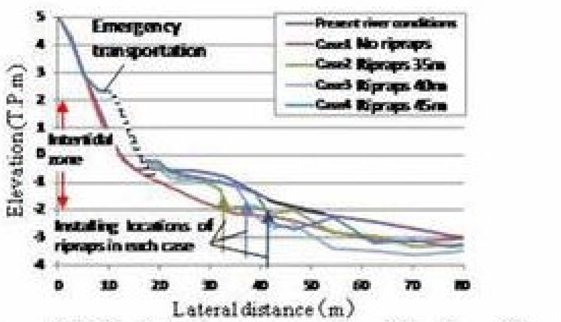

Figure 5 Calculated cross-sectional bed profiles

In each case (Case2, Case3, Case4), the ripraps are installed on the tidal flats at different locations for lateral directions so as to minimize spatial changes in dimensionless shear stresses around the tidal flats. And, elevations of the ripraps in each case are determined to almost -1.5(T.P.m). Second, we simulated the effects of riprap installations on flood flows and bed variations around the tidal flats in each case by using the calculation model. Figure 5 shows calculated cross-sectional bed profiles around the tidal flats after a series of the floods. From these results of numerical simulations, we selected Case3's design because the locations and elevations of Case3 are most effective for preserving the riverine tidal flats against the bed scouring and erosion in the ship-bottom shaped channel. Finally, from the above conclusions, we derived a design procedure for improving incised and narrowed channel rivers toward stable ship-bottom shaped channels. In the full paper, we discuss the design procedure in detail.

References

S. Darby & A. Simon: Incised River Channels: Processes, Forms, Engineering, and Management, 1999.

S.Fukuoka: Dimensionless Width and Depth and Sediment Transport Rate in Stable Rivers, 3rd International Symposium on Shallow Flows (ISSF), CD-ROM, 2012 (a).

S.Fukuoka: Study of Stable Cross-sectional Forms Harmonizing the Flood Control and River Environment in the Satsunai River, Annual Report of River Center of Hokkaido, 2012 (b).

T.Uchida & S.Fukuoka: Numerical Calculation for Bed Variation in Compound-Meandering Channel Using Depth Integrated Model without Assumption of Shallow Water Flow, THESIS 2013, USB memory, 2013.

Three Dimensional Modeling of Caspian Sea Currents Using FVCOM Model

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Keywords: Water circulation, Wind stress, Heat flux, Lacustrine water

The Caspian Sea is the biggest lake in the world containing 43% of the global volume of lacustrine waters. Compared to other lakes in the world, Caspian Sea is still unknown in many ways. There are a lot of oil extraction projects taking place in different regions of the Caspian Sea. On the other hand several unique and endangered pelagians live in this Sea which may be damaged if any oil pollution diffused in the Caspian Sea.

Water circulation has the main impact on oil pollution diffusion in the Seas, therefore in this paper we have used FVCOM model to simulate and study the water circulation in the Caspian Sea as the first step of oil spill study in the Caspian Sea. Water circulation has been modeled as a result of different environmental parameters including wind stress, heat flux, and precipitation/evaporation and river inflow.

Model inputs consist of bathymetry provided from GEBCO and coastline boundary provided from NOAA website in addition of 10 m U and V wind velocity, 2 m air temperature, relative humidity, atmospheric pressure, precipitation, evaporation, downward long wave radiation and downward shortwave radiation provided from ECMWF website.

The lake has been discretized with an unstructured mesh shown in Fig. 1, as it is clear in this picture; the mesh size reduces in Southern part of the Caspian Sea because of the priority of the Southern part in our study. The simulation is conducted based on 1982 atmospheric data since it has the minimum Sea level change between the first and last day of the year (Ibrayev et al., 2010). Fig. 2 shows the monthly mean surface current velocity in January.

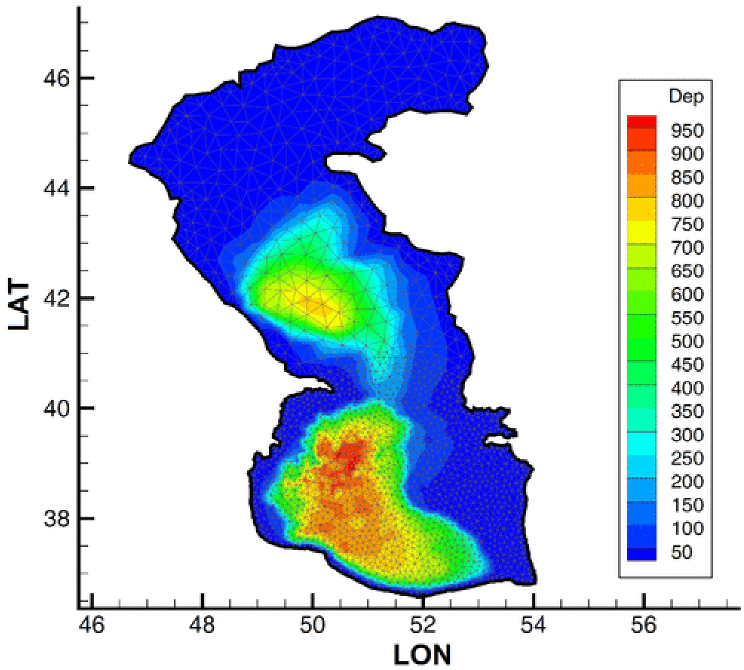

Figure 1.

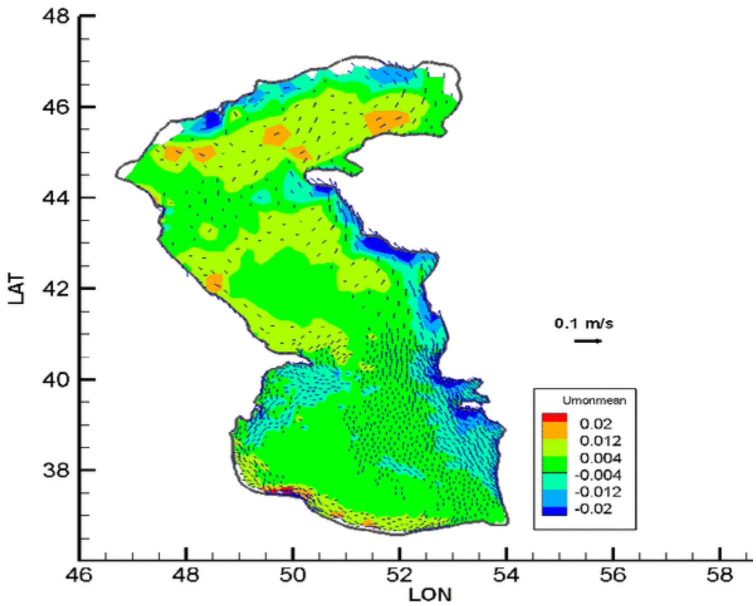

Figure 2.

Reference

Ibrayev, R. A., Özsoy, E., Schrum, C., and Sur, H. I.: Seasonal variability of the Caspian Sea three-dimensional circulation, sea level and air-sea interaction, Ocean Sci., 6, 311–329, 2010.

Tide/Surge Levels Interactions Inside of the Seine Bay: Application to Johanna and Xynthia Storms

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Keywords: Tide, Surge levels, Interactions, Seine Estuary, Numerical modelling, Johanna, Xynthia

The context

The Seine estuary risk control office (ORMES), the agglomeration of Le Havre (CODAH), the Grand Port Maritime du Havre, the Public Interest Grouping Seine-Aval, METEO-FRANCE (among other partners) and CEREMA have joined together to form a Technical Commission for the Study and the Evaluation of Maritime Submersions in the Seine Estuary (CteeSMES). Within this commission, which aim is to improve the collective knowledge on physical processes related to maritime surge levels. Inside of this project, four main subjects are dealt with: the evaluation of water levels and wave heights at the coastline; the determination of land locations of water entrance; the knowledge of hydrodynamic submersions by the sea, the portual basins and the mouth of the Seine and the determination of storage areas; the hazard exposure of social and economic stakes.

In particular, one of the main objective of the global project is the building of a numerical model for surge levels and associated inundations inside of the Seine Estuary. That's why the CEREMA has built a numerical model of the Seine Estuary based on TELEMAC2D in order to study the evolution of surge levels from the ocean to the harbour area of Le Havre and, also, to evaluate the interactions between tide and surge levels in the Seine Bay and in portual basins of Le Havre.

Presentation of the numerical model for surge levels of the Seine Estuary

The study site is the Seine estuary. In this area, a numerical model based on TELEMAC2D ([1]) has been built in 2010 and is described in [2]. This initial numerical model has been modified through the update of its bathymetry and its extension to take into account two portual basins of Le Havre harbour, called "bassin du commerce" and "bassin du Roy". The bathymetry of the model was partially provided by Le Havre and Rouen Harbours for the north-east part of the model. EMODNET ([10]) provided the bathymetry of the model for the southest part of the numerical model.

Simulation data

Maritime boundary conditions were provided by a global signal calculated by a numerical surge levels' model developed inside of Saint-Venant Hydraulic laboratory for the Atlantic coast and the Channel. Winds and pressure fields were CFSR data.

Calibration of the numerical model for surge levels in the Seine Estuary

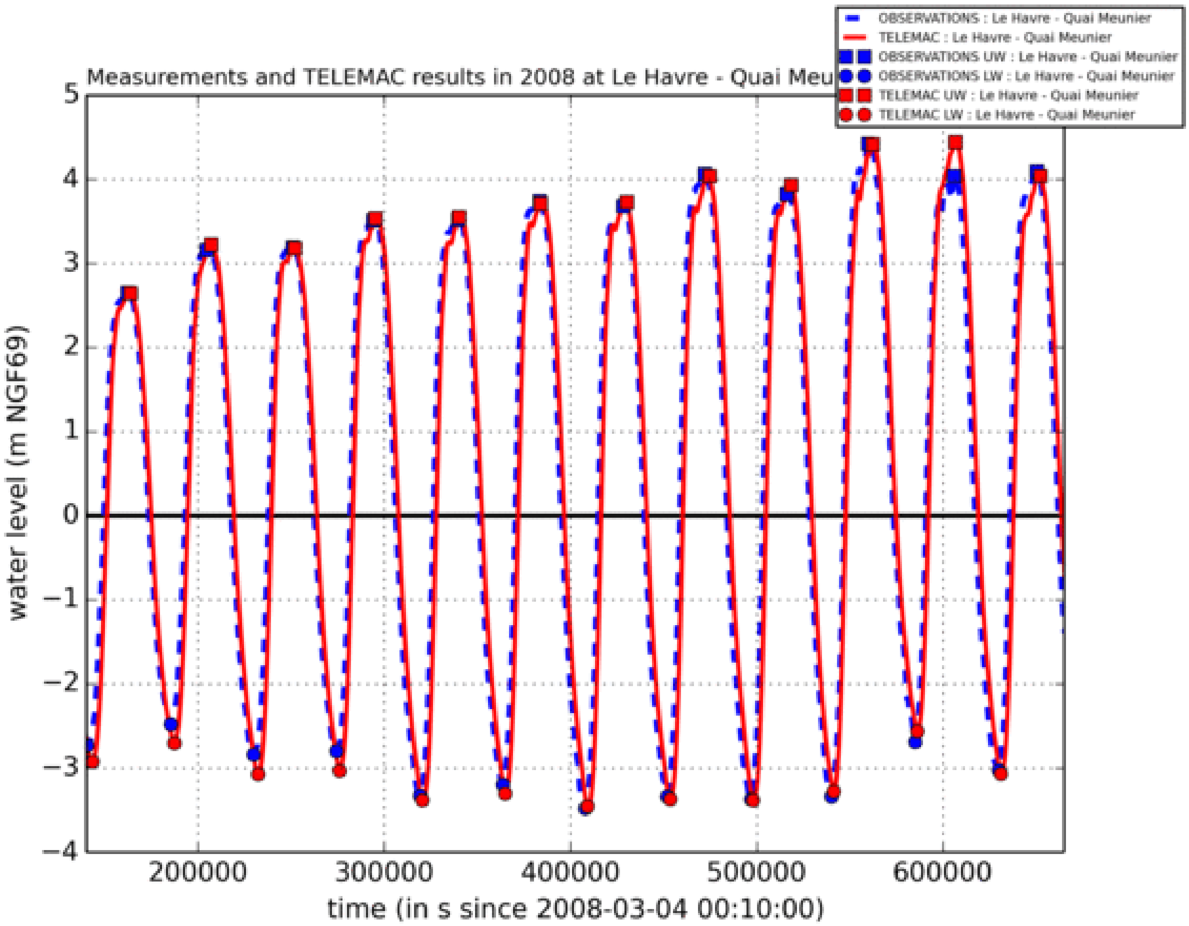
To calibrate the global signal (tide + surge levels), measurements available on seven outputs of the Seine Estuary and provided by ports of Le Havre and Rouen were used to optimize the coefficient for wind influence and for bottom friction.

The numerical model was calibrated on JOHANNA and XYNTHIA storm events, which respectively occurred in March 2008 and in February 2010.

Table 1 shows calibration results for Xynthia storm. It can be seen that the calibration is very good in Le Havre harbour, in particular near René Coty basin and "Quai Meunier".

Table 1: Calibration results for XYNTHIA (difference between numerical and observations error for the location).

minimum	maximum	average	standard deviation	error during storm peak	
Tancarville	0.0	0.0	0.0	0.0	0.0
Fatouviille	0.33	-0.10	0.13	0.11	0.31
Honfleur	0.34	-0.12	0.01	0.12	-0.03
Balise A	0.26	-0.15	-0.03	0.11	0.09
René Coty basin	0.30	-0.11	0.01	0.11	0.12
Quai Meunier	0.40	-0.05	0.05	0.11	0.00
Port 2000	0.47	0.04	0.15	0.10	0.1
ANTIFER	0.53	0.10	0.21	0.10	0.20



Interactions between surge levels and tide

Once the numerical model of the Seine Bay had been calibrated both for tide and surge levels, it is possible to draw the evolution of surge levels from the ocean to Le Havre (quai Meunier) and then to compare the signal obtained at each point of the Seine Bay with that obtained without taking into consideration tide for each event. That will permit to evaluate the contribution of interactions between tide and surge levels inside of the Seine Bay for Xynthia and Johanna events, but also for other events in the slice [1979-2010].

References

[1] Hervouet J.M. (2006) - Hydrodynamics of free surface flows. Ed. Wiley. 390 p.
[2] B. Boyer, convention GPMH-CETMEF, projet de création d'une châtière, rapport de courantologie, décembre 2012, 47 pages.
[3] LEVY F., construction d'un modèle de surcotes sur la façade atlantique, rapport provisoire, avril 2013.
[4] http://www.shom.fr/les-services-en-ligne/predictions-de-maree/predictions-en-ligne/
[5] Augris C., Clabaut P, Costa S., Gourmelon F, Latteux B., 2004. Évolution morpho-sédimentaire du domaine littoral et marin de la Seine Maritime. Ifremer, Conseil Général de la Seine Maritime, EDF. Ed. Ifremer. Bilans & Prospectives, 159 p.
[6] Cariolet et al.,Aspects météo-marins de la tempête du 10 mars 2008 en Atlantique et en Manche, Norois, n 215, 2010/2, p. 11-31.
[7] Le Provost C., F. Rabilloud, F. Lyard, J.M. Molines, 1996: Evaluation des solutions de marées le long des plateaux continentaux, internal report, group MEOM, LEGI, Grenoble.
[8] http://www.imcce.fr/phemu03/Promenade/pages5/525.html
[9] http://bouteloup.pierre.free.fr/astro/maree/aree.html
[10] http://www.emodnet-hydrography.eu/

Effect of Hydrodynamics on Sediment Transport near a Coastal Inlet

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Keywords: Hydrodynamics, Sediment transport, Numerical model, Coastal inlet.

Introduction

The Merrimack Estuary, a tidal estuary, is located in northeastern Massachusetts. The estuarine embayment, including the Plum Island Sound, is characterized by tidal marsh, tidal creeks, small islands and ponds. The bay receives freshwater inflows from Merrimack River at the west and is connected to the Atlantic Ocean through the Newburyport Inlet at the east. Ebb/flood tidal currents through the inlet erode sediment from Plum Island and transport sand into the navigation channel. Salisbury Beach and Plum Island in the northern and southern sides of the inlet are facing the open ocean (Figure 1). Winter storms (nor'easter) and waves pounding the coast frequently result in severe beach erosion and sand migration in the area.

Method

The Coastal Modeling System (CMS) is a coupled flow, wave, and sediment transport model, which consists of CMS-Flow and CMS-Wave. Physical processes calculated by CMS-Flow are circulation, sediment transport, and morphology change (Sanchez et al. 2011). CMS-Wave is a two-dimensional wave spectral transformation model that contains approximations for wave diffraction, reflection, wave transmission, wave run-up, and wave-current interaction (Lin et al. 2011).

The CMS was applied in this study to investigate the roles that hydrodynamic forcings play in erosion and shoaling in the inlet, and sediment movement along the shoreline. The modeling domain was a rectangular area covering the western shelf of the Gulf of Maine, Plum Island Sound, and the mouths of the Merrimack River and two other rivers. A telescoping grid system was created with a finer resolution of 4 m around the estuarine entrance and beaches, and a coarser resolution of 200 m on the shelf. Tide, waves, wind, and river flows were specified as the CMS forcing.

Model calibration and validation

A field program was designed to conduct current and water level measurements in the vicinity of the estuarine entrance and on the eastern side of Plum Island. A historical dataset of water levels was also available from the Plum Island Ecosystems Long Term Ecological Research (PIE-LTER) spanning 2001-2010 (Vallino and Hopkinson, 1998). The historical data were used to calibrate the CMS and the model validation was performed against the field data collected in September 2012.

Results

The measurements show that the spring tidal amplitude is close to 3 m in the area, and the average wave height is around 1 m or less during summer and the peak wave height can reach to 6-8 m during a winter storm. The river discharges into the Sound are high during the peak flow season. The measured stream flows at the Merrimack River can be more than 2500 m3/s during extreme wet years. The preliminary CMS results show that the calculated water level and current are in agreement with the measurements. The CMS simulates the tidal propagation and the flow pattern in the system, and the general accretion and erosion trends as well as the shoaling near the Newburyport Inlet are captured. The changes in sediment transport and morphology are controlled mainly by current and wave interaction around the estuarine entrance and adjacent beaches.

Acknowledgements

The authors wish to thank for the support by the US Army Corps of Engineers New England District and New York District. The field data were collected by the Woods Hole Group. Permission was granted by the Chief, US Army Corps of Engineers to publish this information.

References

Lin, L., Demirbilek, Z., Thomas, R., and Rosati III, J., 2011. Verification and Validation of the Coastal Modeling System, Report 2: CMS-Wave. Coastal and Hydraulics Laboratory Technical Report ERDC/CHL-TR-11-10. Vicksburg, MS: US Army Engineer Research and Development Center.

Sanchez, A., Wu, W., Beck, T. W., Li, H., Rosati III, J., Thomas, R., Rosati, J. D., Demirbilek, Z., Brown, M., and Reed, C. W., 2011. Verification and validation of the Coastal Modeling System, Report 3: Hydrodynamics. Coastal and Hydraulics Laboratory Technical Report ERDC/CHL-TR-11-10. Vicksburg, MS: U. S. Army Engineer Research and Development Center.

Vallino, J. J., and Hopkinson Jr., C. S., 1998. Estimation of dispersion and characteristic mixing times in Plum Island Sound Estuary, Estuar. Coast. Shelf Sci., 46(3), 333–350.

Coastal Storm Surge Flooding Impact under Different Climate Scenarios in Pearl River Delta

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Keywords:

The Pearl River Delta, located in south-eastern China, is one of the most economic regions in China. After 20 years development, the region created 10% of Chinese gross domestic products and gathered 3% of the national population on the territory just accounting for 0.4% of the total territory. Due to the low lying topography of the Pearl River Delta, flooding risk caused by storm surge becomes the major risk along the coastal area in Pearl River Delta. This research aims are to analyze and assess inundation risks by storm surges, using hydraulic modeling approaches Anuga Model(developed by Australia National University and Geoscience Australia) coupling with ROMS model (The Regional Ocean Modeling System)and SAGA GIS(developed by Dept. for Physical Geography, Göttingen and University of Hamburg) based topological analyses to identify areas, which face highest risks under present and future climate conditions. Then comparing the DELFT 3D model, the uncertainty and sensitivity of the modeling are analysized under consideration of different climate scenarios.

Stability Studies on Tandem Breakwater with Concrete Cube Armour

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Keywords: Conventional breakwater, Concrete cube armour, Armour stability, Reef, Energy dissipation, Tandem breakwater

The breakwater construction in deeper waters requires heavier armour units due to larger wave loads. Such large stones are uneconomical to quarry or transport and / or may not be available nearby. Another problem is uncertainty in the design conditions resulting in breakwater damage due to increased wave loads. The structural stability and economy in construction of breakwater are the need of hour.

Cox and Clark (1992) through limited model studies designed a submerged reef to protect the inner shorter breakwater and called it a tandem breakwater. A breakwater of armour weight of 3 Tons was designed and a submerged reef with stone armour of weight up to 1 Ton at a seaward distance of 40 m which was economical by 1million dollars compared to conventional breakwater design which otherwise required an armour of 8 Tons. It was concluded that such a tandem breakwater could be an optimal structure. Cornett et al. (1993) through small scale model tests showed that, a low crested reef breakwater with height (h) greater than or equal to 0.6 times the depth of water (d) and crest width (B) of more than 0.1 m located seaward of main breakwater, can reduce wave loading and erosion of rock armour. They validated the tandem breakwater concept and concluded that, there was an optimum spacing (X) between the structures depending upon wave conditions and geometry of breakwaters. Shirlal et al. (2006) conducted physical model studies on stability of a uniformly sloped conventional rubble mound breakwater defenced by a seaward submerged reef. Tests were carried out for different reef spacings and for different relative heights and relative widths of the reef. They observed that a reef of width (B/d) of 0.6 to 0.75 constructed at a seaward distance (X/d) of 6.25 to 8.33 breaks all the incoming waves and dissipates energy and protects the breakwater optimally.

Under these circumstances, an optimum solution could be a tandem breakwater consisting of a seaward submerged reef and a breakwater. The present paper involves a detailed experimental study of influence of seaward location and crest width of an optimum protective submerged reef on the stability of main conventional breakwater made of concrete cube armour.

Initially, a 0.70 m high of 1:30 scale model of conventional (single) breakwater of 1V:2H slope and trapezoidal cross section is constructed on the flume bed with concrete cube as primary armour of weight 79.51 gms. This is designed for a non-breaking wave of height 0.1 m. This model is tested for armour stability with monochromatic waves of heights 0.1 m to 0.16 m and periods 1.5 sec to 2.5 sec in water depths of 0.3 m, 0.35 m and 0.4 m. Later, a 1:30 scale model of a breakwater, of trapezoidal cross section with a uniform slope of 1V:2H is constructed, at 32 m from the wave generator flap, on the flat bed of wave flume with primary armour of concrete cubes of reduced weight of 40 gms (i.e. Dn50 of 0.0255 m). The crest width of breakwater is kept as 0.1 m and the height at 0.6 m. A stable trapezoidal submerged reef having a slope of 1V:2H with a height (h) of 0.25 m and varying crest widths (B) of 0.3 m and 0.4 m (i.e. B/d of 0.75 to 1.33) is constructed, using a pile of concrete cubes of an optimum weight of 25 gms (i.e. dn50 of 0.0218 m), on the seaward side of the main breakwater at different distances (X) of 2.5 m and 4.0 m (i.e. X/d of 6.25 to 8.33 and 10.0 to 13.33). The schematic diagram of tandem breakwater test model with concrete cube armour is shown in Fig. 1. These models are tested for breakwater armour stability under above mentioned conditions. During the experiments, data such as incident and transmitted wave heights and movement of armour cubes of main breakwater are recorded. It is found that submerged reef of crest width 0.4 m located at a seaward distance of 2.5 m completely safeguards the main breakwater.

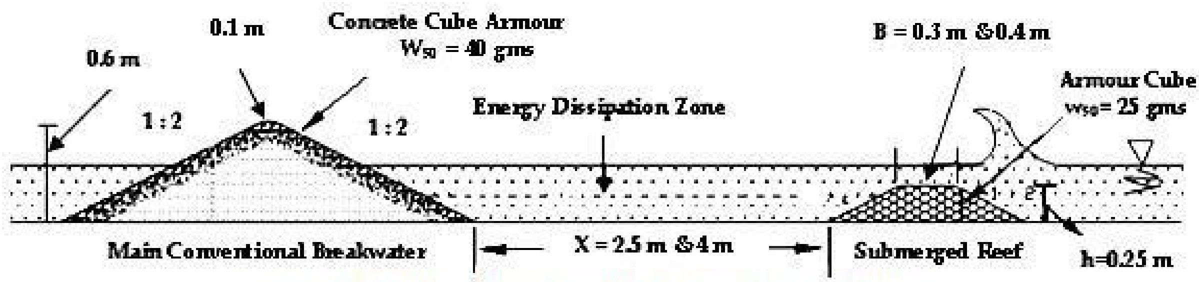

Fig. 1. Details of test model of tandem breakwater

Finally, the optimum tandem breakwater configuration consisting of 1V:2H sloped trapezoidal conventional breakwater of 0.6 m with concrete armour cube of 40 gms and a 0.25 m high submerged trapezoidal reef of 1V:2H slope, made of concrete cubes of 25 gms, with crest width of 0.4 m placed at a seaward distance of 2.5 m is evolved.

A Coupled DEM-CFD Simulation of Rip-Rap Revetments in Tidal Areas

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Keywords: Revetment, Rip-Rap, Discrete Element Method, Computational Fluid Dynamics, Model Tests

Revetments are used as erosion protection for slopes on waterways and costal shores. They have to resist hydraulic loads such as ship and wind induced waves and currents as well as tidal currents, tidal varying water levels and storm surges. Because of numerous advantages such as a high flexibility and robustness against settlements, rip-rap revetments are used most frequently for slopes on waterways.
In some areas the current basis of rip-rap design is inadequate for dealing with the complexity and variety of boundary conditions, especially in tidal zones. A numerical model is developed which is capable of simulating the resistance of rip-rap to hydraulic loads. The rip-rap-water-interaction is modelled holistically by the use of two numerical methods.
The numerical modelling of rip-rap revetments is undertaken by using the Distinct Element Method (DEM). With the DEM, the numerical rip-rap stones can be modelled as autonomous objects, so that the movement of stones with all degrees of freedom can be represented realistically. Typical irregular shapes of stones are produced by overlapping spherical particles. In this way the reproduction of the rip-rap-stones with a realistic size and mass distribution regarding the corresponding armourstone category is possible.
By coupling the mechanical DEM calculation with a computational fluid dynamics (CFD) code, the acting forces on the rip-rap due to waves and currents can be simulated realistically (Figure 1). It is aimed to subject the numerical rip-rap to the characteristical ship-induced waves and currents. Besides the ship induced water movements the influences of tidal varying water levels and wind waves are simulated. The hydraulic impacts are modelled with the help of time dependent boundary conditions. The reaction of the rip-rap stones due to the acting hydraulic forces is recorded in the DEM code.

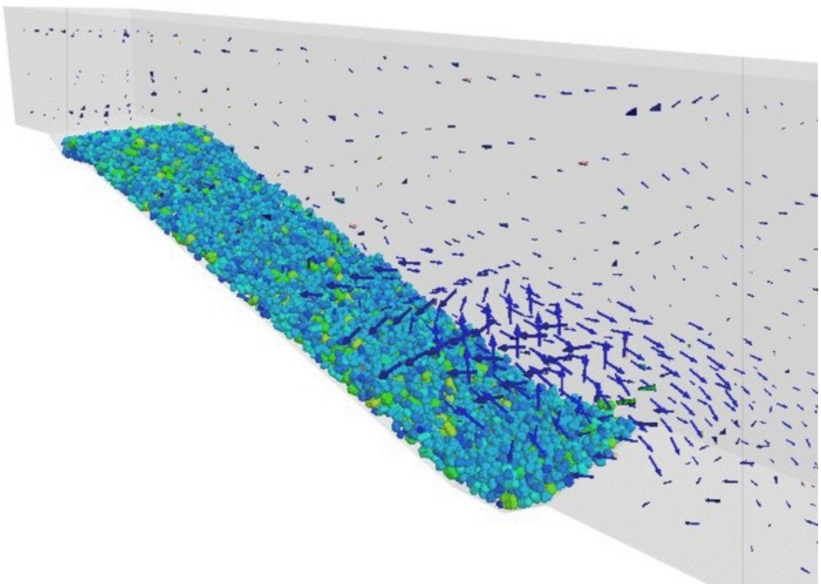

Figure 1. Coupled computation of numerical rip-rap with wave impact.

The results of the numerical simulation are validated by physical model tests in a laboratory flume in the scale 1:1 and by additional field measurements in the Elbe estuary. Rip-rap stones are instrumented with pressure sensors and acceleration sensors in addition to the measurement of the hydraulic forces.

Influence of Artificial Sandbanks in the Mouth of the Elbe Estuary on Estuarine and Coastal Hydrodynamics and Mitigation of Tidal Energy for a Better Flood Defense

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Keywords: Elbe estuary, sandbanks, Flood protection, Risk mitigation, THESEUS, TIDE, Numerical model, Damping of tidal energy

Coastal areas are among the most densely populated areas of the world. They play an important role in terms of industry, agriculture, trade, tourism and settlement to mention some key sectors. Today these areas already suffer from various problems like erosion, flood risk and long-term habitat deterioration. Since the concentration of people in coastal areas is expected to grow fast in the next decades and economies continue to develop, the asset base of risk will increase. Furthermore global climate change will raise the likelihood of extreme events, as well as accelerate habitat decline. The combination of increasing economic and social values and the impacts of climate change will lead to a growing pressure on coastal systems. The Elbe estuary plays an important role for Northern Germany and functions for example as an important federal waterway. The whole Elbe River has undergone several anthropogenic changes since the 16th century like diking and river regulations. These modifications led in combination with natural changes in hydrodynamics to an unfavorable hydro-morphological evolution, namely to an increase of the tidal energy and the tidal pumping further upstream.

Within the framework of different EU research projects (THESEUS, TIDE) investigations of the efficiency of artificial sandbanks in the mouth of the Elbe estuary for mitigation of tidal energy and a better storm surge protection were investigated. The efficiency of the artificial sandbanks was analyzed by means of two- and three-dimensional hydro- and morphodynamic models. The models calculate the water level and current velocities as well as the transport of dissolved constituents. To allow the investigation of the effects of the artificial sand banks on water level and currents in the inner estuary a high spatial grid resolution was used. Furthermore the hydrodynamic models run under different climate change scenarios and storm surge conditions.

The paper will present the overall results of the investigations and will give an outlook how those measures can contribute to innovative risk mitigation. Moreover the paper gives an insight to options and tools for coastal defense planning strategies.

References

Sothmann J., Schuster, D., Kappenberg, J. & Ohle, N. (2011): Efficiency of artificial sandbanks in the mouth of the Elbe Estuary for damping the incoming tidal energy. In Holger Schüttrumpf (Ed.), Proceedings of the 5th International Short Conference on Applied Coastal Research, Aachen.

Schulte-Rentrop, A. & Rudolph, E. (2012): A sensitivity study of storm surges under the conditions of climate change in the Elbe estuary. In: Walter Leal Filho (Ed.), Climate Change and Disaster Risk Management, pp. 295-309. DOI: 10.1007/978-3-642-31110-9_18, Springer-Verlag Berlin Heidelberg.

Use of the Subgrid Technique in Operational Models

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Keywords: Subgrid modeling, Wetting and drying, Semi-implicit schemes, Operational forecast models

The subgrid technique offers the possibility to take into account the bathymetric information at subgrid scale allowing model bathymetry to be accurate up to measurement accuracy while performing computations on relatively coarse grids permitting large time steps. For that purpose, an algorithm that correctly represents the precise mass balance in regions where wetting and drying occur was derived in [1] and [2]. Computational grid-cells are permitted to be wet, partially wet or dry and no drying threshold is needed.
Based on the subgrid technique, an operational forecast model for water level, salinity and temperature of the Elbe Estuary in Germany was implemented. The subgrid technique shows less restriction on grid generation: e.g. easy fit of lateral boundaries; potential one-dimensional approximation of tributary rivers; use of homogeneous, flow aligned unstructured grid (quadrilaterals, triangles if needed). User-defined grid subdivision at subgrid level allows an excellent representation of the volume. Consequently, simulation of wetting and drying of tidal flats can be performed more accurately.
Bottom friction requires a particular treatment. Based on the conveyance approach, an appropriate empirical correction was worked out. The aforementioned features make the subgrid technique very efficient, robust and accurate.
Comparison of simulation results for the Elbe Estuary obtained with a model based on the subgrid technique and a classical model showed good agreement for both long term simulations of tidal dynamics and short term operational forecasts. The computational speed-up reached through the use of subgrid was about a factor of 20. A typical daily forecast can be carried out in less than 10 minutes on standard PC-like hardware.
On the subgrid level, we are using an average resolution of 16 m which allows incorporating significant details of the large intertidal mudflat areas. The Subgrid technique improves accuracy if used with the same (high) resolution classical computational grid. On the other hand, comparable results are obtained if the subgrid technique is used even on a much coarser computational grid. Therefore, subgrid models are particularly suitable for simulations where real computation time is an important issue. More generally, the subgrid technique is a promising framework to perform accurate temporal and spatial large scale simulations of coastal and estuarine flows and transport processes like flooding and drying of large areas at low computational cost. Other potential applications of the subgrid technique are sensitivity studies.

References

1. Casulli V. A high-resolution wetting and drying algorithm for free-surface hydrodynamics. International Journal for Numerical Methods in Fluids 2009, 60, 391:408.
2. Casulli V. and Stelling GS. Semi-implicit subgrid modelling of three-dimensional free-surface flows. International Journal for Numerical Methods in Fluids 2010, 67, 441:449
3. Sehili A., Lang G. and Lippert C. High Resolution Subgrid Models: Background, Grid generation and Implementation. Ocean Dynamics 2014, accepted.

Efficacy of Beach Vegetation in Controlling Wave Runup and Rundown – An Experimental Investigation

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Keywords: Beach vegetation, Nylon rod model, Regular and staggered model configurations, Wave run up, Wave rundown

Coastal vegetation is a potential ecofriendly and economically viable counter measure for beach erosion by reducing wave run up and rundown. Besides this, it also has additional advantages such as enhancing the aesthetics, beach conservation, and adding to biodiversity. Moreover, coastal vegetation helps to develop sand dunes in front of the forest by trapping sand carried by the wind, which plays a significant role in beach building and taming extreme wave attack.

In the last decade there has been a growing interest in the studies which attempt to understand the impact of vegetation on flow field in the marine ecosystems (Hiraishi and Harada, 2003, Matsutomi et al. 2006, Asano et al. 2008, Cavallaro et al. 2010). This surge of interest is a new approach to a concept which tries to solve coastal and hydraulic engineering problems taking ecological balance into account. One of the primary motivations of vegetation studies is to understand related transport processes in natural environments, such as the transport of pollutants, heat, sediment, etc. Tree morphology is an important aspect when considering the wave attenuation ability of coastal forests, because attenuation results from the hydrodynamic resistance of tree components such as trunks, branches and leaves. Water waves propagating through submerged and emergent vegetation lose energy by performing work on the vegetation stems, which directly results in smaller wave heights. Wave attenuation by vegetation is a function of vegetation characteristics such as geometry, density, stiffness, and spatial coverage as well as wave conditions such as incident wave height, period, and direction. Vegetation-wave interactions are highly dynamic in that the vegetation field is exposed to variable wave forcing that changes with time as stems bend, flatten to the bed, or are washed out. As evidenced by these many dependencies and the extensive variety of coastal plants, the variability of wave damping by vegetation is large (Mendez and Losada, 2004). The reduction of run-up and inundation depth will reduce the area of destruction behind a vegetation belt in the vertical direction.

Casuarina Equisetifolia or 'Beach Sea Oak' is native to the tropical and subtropical coastlines of Australia, Southeast Asia, Malaysia, Melanesia, and Polynesia and New Caledonia and is one of the world's fastest growing (1m to 3 m per year) trees. It is a nitrogen-fixing, medium to large evergreen tree 6 m to 30 m or more in height. The tree has a thin crown of green, drooping branch lets. The narrow crown of the tree becomes irregular and spread with age. Casuarina Equisetifolia is predominantly a coastal species and has the rare property of growing upright and symmetrical on windswept coasts. The densities of the tree are 1600-10,000 trees/ha can be planted with 1m to 2.5 m between trees. Diameter of Casuarina Equisetifolia is about 0.5 m. These trees protect shorelines against erosion by making attenuating steep waves. It is concurred that beach plants are an integral part of ecofriendly shore protection techniques, there is scarcity of information to ensure its successful design and realization.

The investigations were undertaken in the wave flume of Marine Structures Laboratory, Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, India. The experiments were carried out in a 50 m long wave flume with a paddle type wave maker. The incident wave characteristics (H) were recorded by three wave probes. In the present investigation, an attempt has been made to study the effect of regular/straight line and staggering emerging vegetation upon wave run up and rundown for a constant water depth (d). The test model of Casuarina Equisetifolia meadow was prepared by fixing 0.20 m long nylon rods of 0.08 m diameter at a spacing of 0.05 m c/c on a 0.04 m thick concrete slab of size 1 m × 0.73 m in regular/straight line and staggered position. Then models were placed in the wave flume on the beach of slope 1V:12H at about 38m away from wave flap as shown in Fig. 1. The experiments were conducted for waves heights (H) of 0.08 m to 0.16 m and periods (T) of 1.4 sec to 2.5 sec generated in a constant water depth (d) of 0.4 m.

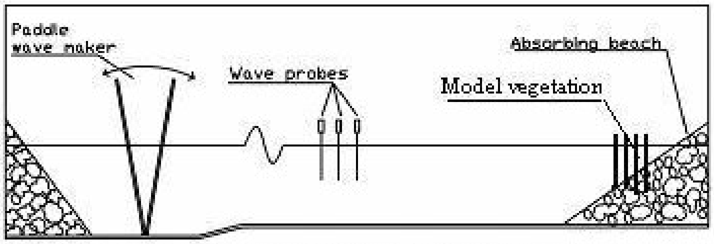

Fig. 1 Schematic diagram of experimental set up and beach vegetation model

In the laboratory, the test models were subjected to varying wave steepness parameter (H/gT2) between 0.0015 and 0.007 and wave run-up (Ru), and rundown (Rd) on the beach slope were recorded for the regular and staggered beach vegetation. The results for plain beach without vegetation, and beach with vegetation were compared and the following conclusions were drawn:

Relative beach run up (Ru/H) varied from 0.61 to 0.36 over the plain beach slope. While it varied between 0.59 and 0.31 for the regular/straight line configuration and from 0.6 to 0.29 for the staggered configuration of vegetation.

For a plain beach, the relative rundown Rd/H varied between 0.61 and 0.19. While, it dropped from 0.53 to 0.19 and from 0.45 to 0.15 for the regular/straight line and for the staggered beach vegetation respectively.

The beach vegetation is effective in controlling wave run up and rundown and hence it may be considered as a measure for beach erosion depending upon the site conditions.

References

Asano, Toshiyuki, (2008). Utilization of coastal forests as tsunami brrier facilities. Proc. NITK -KU Joint Seminar; Recent Advance in Engineering and Technology. Department of Ocean Civil Engineering, Kagoshima University Nov 2008, 15-22.

Cavallaro L., Re C.L., Paratore, G., Viviano, A., and Foti, E. (2010). Response of Posidonia oceanic to wave motion in shallow-waters: Preliminary experimental results. Proc. 32nd International Conference on Coastal Engineering. Coastal Engineering Research Council. 1-10.(Chennai, India), 1279–1285.

Hiraishi, T. and Harada, K. (2003). Greenbelt tsunami prevention in South-Pacific region, Report of Port and Airport Res. lnst, Vol.42, No.2, l-23.

Matsutomi, H. (2006) . Governing equations for inundated flow in vegetated area and similarity laws for trunk, Proc. 30th International Conference on Coastal Engineering. Vol.2, l638-1650.

Mendez, F.J., Losada, I.J., 2004. An empirical model to estimate the propagation of random breaking and nonbreaking waves over vegetation fields. Coastal Eng. 51, 103–118.

Rusnė-Šilutė Road Impact on Nemunas River Dynamics near Rusnė

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Keywords: Nemunas, Rusne, Flood

Nemunas river is the largest stream of Lithuania (annual mean discharge 616 m^3/s) flowing into Curonian lagoon located at the southeast part of the Baltic Proper. Nemunas has a well developed delta with three main branches Skirvyte, Atmata, Pakalne separating at the village of Rusne. Extensive flooding of the floodplain reaching up to 6-10 km width is characteristic for lower reaches of Nemunas. High flood level is mainly caused by snow melting in spring and the peak discharge and water level near Rusne may reach, respectively 5894 m^3/s 2.93 m for 1% flood events. Even the annual flood events can completely interrupt transport connection with Rusne island because the only road to the island (Rusnė-Šilutė road) is being regularly overtopped. The influence of the Rusnė-Šilutė road on the hydrological regime of the spring flood in Nemunas river is considered in this work. The results of the modelling can be used for the road design.

To assess the impact of the road on the hydrological regime a two-dimensional model of the river was built. The model covers an area of 170 km^2 and includes part of Nemunas river and its catchment territory from the mouth of Gege river to the mouth of Šyša river. The in-house shallow water software SWEVOLVER was used for hydrodynamical modeling. SWEVOLVER performs calculations on a triangular mesh. Lines of the roads, dams, canals and rivers were included in the mesh. LIDAR data was used as topographic data source. Bathymetric data were obtained by interpolation of profiles of the rivers along the main streams. The surface resistance was prescribed via roughness classes which were based on the land use data (CORINE). The typical spatial resolution of the finite-element mesh varied from meter to several hundreds of meters, and number of mesh points exceeded 380000.

The statistical characteristics of the flood events (water level and discharge for 100, 10 and 2 years return periods) were calculated using time series of hydrological observations at Rusne and Smalininkai stations. These characteristics allowed constructing the boundary conditions (scenario) for the model. Model calibration was based on the discharge and water level measurements made in 1979 at floodplain and in the Nemunas branches. The characteristics of spring flood 1979 are close to the flood of 10% occurence.

Road impact was examined by 18 case studies which includes calculations for the 3 flood scenarios for each road design variant. Road design variants included the current state of the road, the viaduct over the lowest section of the road, long viaduct and the variations of the road surface levels.

We concluded that the road design which prevents its overtopping should be chosen carefully, and modeling allowed for balancing between (1) maintaining the passage of the water over the floodplain, (2) avoiding risk to existing constructions (mainly – bridges), and (3) avoiding significant raise of the critical water levels in the nearby inhabited locations.

Implications of Freshwater Discharge on Estuarine Sediment Dynamics

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Keywords: Estuary, Sediment dynamics, Turbidity, Suspended particulate matter, Freshwater discharge

To maintain the required water depths for commercial navigation vessels in estuarine waterways several million cubic meters of sediments have to be dredged per year. Persistent low fresh-water discharge causes maximum sedimentation rates due to an intensifies net-upstream transport of fine sediments (tidal pumping) and increasing concentrations of suspended particulate matter (SPM). This particularly holds true for our case study the tidal Elbe. Here, large amounts of freshly accumulated fine sediments are being dredged in the upper part of the estuary and relocated further downstream, preferably in ebb-dominated areas. Thus, long periods of a persistent low fresh-water discharge means a worst case situation for the sediment and dredged material management. Hydrodynamic and sediment transport conditions lead to a conflict of interests between safeguarding a sufficient output rate of fine material (otherwise intensification of sediment cycles) and safeguarding the ecological status of the sea by minimizing the output rates of pollutants.

Clear tasks for the further improvement of sediment and dredged material management - among others - are (1) to gain better insight into the governing processes linking sediment dynamics within the estuary and fresh-water discharge and (2) to characterise the hydrological regime of the fresh-water discharge based on “morphodynamic relevant” indices. The set of known hydrological indices and parameters, e.g. daily discharge, mean discharge or the average low flow discharge on a monthly or yearly basis poorly represent the relevant time scales of the governing processes mentioned above (e.g. residence time of water masses and its transported sediments).

Thus, in this presentation we introduce such a “morphodynamic relevant” index, which is derived from time series analysis. The index classifies different events of persistent low fresh-water discharge based on the following information: threshold value of maximum discharge to determine beginning and end of individual events; duration of an individual event; frequency of similar events based on threshold value and duration. An analysis of the daily fresh-water discharge at the station Neu Darchau for the years 1902 – 2012 was done to determine the occurrence intervals for a particular type of event (threshold value and duration). For the analysis of single events it will be demonstrated that this index shows a good correspondence to sedimentation patterns, SPM data and continuous turbidity records (as a linear proxy for SPM concentration) taken at measuring stations in the upper estuary of the Elbe. However, this correspondence could only be observed for events that are persisting for at least several weeks as a rough order of magnitude.

The long-term development of SPM concentrations, e.g. the concentration averaged over the period of a half or full hydrological year, does not necessarily depend on one single event only. The longer the time period considered by the analysis the more the average SPM concentration is determined by the sequence of events, which are independent of each other. In order to take this into account we perform a hierarchical cluster analysis to group the discharge of single hydrological years into characteristic discharge modes, which again can be classified using the index introduced in the first step. Again, we use the discharge at station Neu Darchau for the years 1902 – 2012. Several clusters with distinct patterns and representing a higher number of hydrological years could be identified. During spring the mean fresh-water discharge reaches the maximum within the annual cycle, which supports the dredging and sediment management in safeguarding the required output rate. Vice versa, lowest fresh-water discharge in the Elbe usually occur during late summer. Therefore, those situations (or clusters) are of particular interest that are characterised by very low threshold values and long durations during

summer. In an extreme situation a first event already starts in spring and can continue well far in the summer.
In the recent past comparable hydrological conditions took place in the years 2003 till 2005 and 2012, followed by a strong increase in dredging amounts comparable to average conditions. From the manager's perspective the following questions are relevant: What is the occurrence interval of hydrological conditions like in 2012? Do we have to deal with such a situation every ten years or how often? Are there any early indicators available to get prepared for such a worst case situation? How can we improve sediment and dredged material management? The results of our analysis is providing additional information to find better answers to the antecedent questions.

An Analysis of MLR and NLP for Use in River Flood Routing and Comparision with the Muskingham Method

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Keywords: Flood wave routing, Muskingum, Nonlinear programming, Multiple linear regression

The development of precise and simple methods for flood simulation has greatly reduced financial damages and life losses in many flood-prone regions of the world. Most of the flood simulation techniques and procedures implemented up-to-date are based on the Saint-Venant's one-dimensional equation governing unsteady flows. In the present study, two new approaches for tackling the problem of optimal calibration of a flood model have been introduced. The first method is based on nonlinear programming (NLP), which permits to determine the optimum values of the routing coefficients in the diffusion wave or Muskingum method by minimizing a misfit function under the constraint of satisfying the continuity equation. The second method is based on Multiple Linear Regression (MLR) of in- and output variables in the Muskingum equations, which allows the direct computation of the routing coefficients. To calibrate and verify the two new routing models as well as of the traditional Muskingum method three (one for calibration and two for verification) observed flood hydrographs in a limited reach of Mehranrood River in northwest Iran are used. The results obtained by these two new methods are compared with those of the classical Muskingum method. It is found that the NLP- and the MLR- routed hydrographs come as close, if not better, to the observed output hydrographs as those of the Muskingum method. This is also corroborated by similar high values for the coefficient of determination R2 of the adjustment of the simulated to observed hydrographs for the three routing methods. However, limitations of all three kinematic-wave type routing methods become clear during the verification routing simulation for one flood even with a sharply rising input hydrograph, in the case of which, the application of full dynamic wave routing gives much better results. In spite of these restrictions - typical for kinematic wave routing methods - the two new parameter optimization methods proposed here for the automatic calibration of the routing coefficients in the widely used Muskingum method are powerful and reliable procedures for flood routing in rivers, not to the least due to the fact that they are convenient to use.

1. Introduction

Nowadays, the occurrence of floods all over the world has resulted in tremendous economic damages and life losses. Thus, the correct prediction of the rise and fall of a flood, i.e. flood wave routing, is of significant importance. Although the use of numerical simulation methods makes the prediction of this complex hydraulic phenomenon feasible, many fallacies in doing this properly still exist.The fundamental differential equation to describe one-dimensional unsteady river flow is the Saint-Venant equation (Chow et al., 1989), which is basically a special form of the Navier-Stokes applied to an inclined section of an open channel, where internal viscosity-induced frictional forces within the fluid are neglected against shear stresses induced by bed-friction or wind forces. This equation is to be solved in conjunction with the continuity equation for a control volume of water within the channel. Because of the nonlinearity of the convective acceleration term in the Saint-Venant equation, in its most complete form it can only be solved numerically at some non-negligible costs. For this reason, alternative approaches for flood wave routing, known under the names of diffusion and kinematic wave method - which are easily derived from the full Saint-Venant equations (also called the full dynamic wave method) by dropping the acceleration term (diffusion wave method) or both the acceleration- and the pressure term- (kinematic wave method) - have been proposed and which nowadays are widely used in practice. Diffusive wave theory was firstly presented by Hayami (1951). By simplification of the momentum equation and introduction a linear diffusion coefficient, Hayami (1951) derived an advection-diffusion equation that he solved analytically. An analysis of the kinematic wave routing theory was made later by Lighthill and Whitham (1955) who showed that the main part of a flood wave is approximated by a kinematic wave traveling downstream, whereas the part arising from the full solution of the Saint-Venant Eq., i.e. the dynamic wave, makes up only a small portion of the flood body, but travels in both upstream and downstream direction relative to the crest of the kinematic wave. Thus it is clear that kinematic wave theory cannot model backwater-effects. There have been a lot of investigations since then to what extent the various simplifications in the Saint-Venant Eqs. are valid for routing in a particular channel (e.g. Ponce et al.,1978; Weinmann and Laurenson, 1979; Ferrick, 1985). These authors found, among other things, that the kinematic wave approximation is valid for moderately steep channels. The literature review above clearly shows that research on Muskingum flood routing is alive and well and by no means exhausted. That is, the determination of the optimal routing coefficients in the Muskingum model in a real application is not yet satisfactorily solved and is, thus, still open to debate. This is the issue of the present paper, where two new parameter estimation techniques, namely, nonlinear programming (NLP) and multiple linear regression (MLR), will be applied to the routing of three floods which have already been analyzed by Oladghafari et al. (2009) by means of a classical Muskingum model. The routing coefficients obtained by these two parameter optimization techniques will eventually be compared with those used by Oladghafari et al. (2009) in his traditional Muskingum routing model.

2. Study Methods

In this study, the Muskingham, NLP and MLR methods have been used for flood routing along the reach of the Mehranrood River in the Azarbayejan-e-Sharghi province in northwestern Iran (Averiel, 2003).

3. Summary and Conclusions

Statistical comparison of the observed and calculated peak discharges (taken from the corresponding output hydrographs) as well as the percental errors for the NLP- , MLR- , and Muskingum flood routing methods, from which one can infer all three methods work more or less equally well, with some marginal advantages for the two automatic calibration methods NLP and MLR.

Based on Statistical analysis results we conclude that the two new parameter optimization methods proposed here for the automatic calibration of the routing coefficients in the widely used Muskingum flood routing method, namely, the nonlinear NLP-technique and the linear MLR-method are powerful and reliable procedures for flood routing in rivers. Although their precision is not necessarily better than that of the traditional Muskingum method – which is of no surprise, as these two methods are also based on the Muskingum formulation - they may be more conveniently used than Muskingum, where suitable routing coefficients (usually the storage parameter K and the weighting factor X) are often obtained only after some lengthy trial and error process.

References

Avriel, M. (2003). Nonlinear Programming: Analysis and Methods, Dover Publishing, Mineola, NY.

Chow, V.T., D.R. Maidment and L.W. Mays (1988). Applied Hydrology, McGraw-Hill, New York, NY.

Ferrick, M.G., (1985). Analysis of River Wave Types, CRREL Report 85-12, U.S.Army Cold Regions Research and Engineering Laboratory, Hanover, NH.

Gill, M.A. (1978). Flood routing by the Muskingum method. Journal of . Hydrology, 36, 353–363.

Gill. M.A. (1984). Time Lag Solution of the Muskingum Flood Routing Equation, Nordic Hydrology., 15, 3, 145–154.

Hayami,S. (1951). On the propagation of flood wave. Disaster Prevention Institute, Kyoto University, Japan ,16p.

Hooke, R. and T.A. Jeeves (1961). Direct search solution of numerical and statistical problems, Journal of the Association for Computing Machinery (ACM) 8, 2, 212–229.

Lighthill, M.J. and G. B. Whitham, (1955). On kinematic wave flood movement in a Long River., Proceedings of the Royal Society of London, Series A, 229, 228-316.

Luenberger, D.G.. (1984), Linear and Nonlinear Programming, Addison Wesley, Reading, MA

Oladghaffari, A., A. Fakheri-Fard, A. H. Nazemi and M. A. Ghorbani., (2009). Hydraulic Flood Routing Using Dynamic Wave Method and Comparison with Linear and Nonlinear Hydrologic Muskingum Routing Methods (Case Study: Lighvan-Chai), Water and Soil Science Journal, 20, 3, 47-60. In Farsi

Perumal, M. and K. G., Ranga Raju. (1998). Variable parameter stage hydrograph routing method: 1. Theory, ASCE Journal of Hydrology Engineering, 3, 2,115-121.
Perumal, M., B. Sahoo, T. Moramarco, and S. Barbetta (2009). Multilinear Muskingum Method for Stage-Hydrograph Routing in Compound Channels., J. Hydrol. Eng., 14(7), 663–670
Perumal, M., T. Moramarco, S. Barbetta, F. Melone and B. Sahoo. (2011). Real-time flood stage forecasting by parameter Muskingum stage hydrograph routing method, Hydrology Research, 42,(2–3), 150–161.
Tayfur, G. and T. Moramarco. (2007).Forecasting flood hydrographs at Tiber River Basin in Italy by artificial neural networks, International Congress on River Basin Management, Antalya, Turkey, Volume II, p.485-497.
Ponce, V.M. (1979). Simplified Muskingum method difference scheme. ASCE J.. Hydraulics Div., 105, 1, 925-929.
Weinmann, P.E. and E.M. Laurenson (1979). .Approximate Flood Routing Methods: A Review, ASCE J. Hydraulics Div., 105 (HY12), 1521.

Comparison of Physical Model Predictions and Prototype Measurements of Fluvial Morphodynamics in the Yangtze River Downstream of the Three Gorges Project

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Keywords: Fluvial morphodynamics, Yangtze River, The Three Gorges Project, Physical model predictions, Hydrological regime

The Three Gorges Project (TGP) begins to operate since Jun. 2003. So far in the Yangtze River downstream of the project, the hydrological regime and the features of river channel erosion/deposition are all changing significantly. In this study, the recent variation of flow and sediment transport, and of the erosion/deposition in the Yangtze River channel downstream of the TGP are briefly analyzed first. Then the prediction results of physical model tests on the river channel morphodynamics downstream of the TGP are presented. Comparison between the model predictions and the prototype measurements are made.

Prototype data analysis indicates that, operation of the TGP increases the flow rate for dry season and reduces the peak of big floods for the river downstream of the TGP; and the annual runoff at most control hydrological stations is about 5%~10% less after the TGP operation, according to the long series statistics; while the sediment load decreased drastically by 70%~88%. Downstream of the TGP, the suspended load is coarsened distinctly, especially that at the Jianli hydrological station, where d50 is coarsened from 0.009mm before the TGP operation to 0.105mm of 2010. In general, for the downstream river, the water level at the same medium or low flow rate has a tendency to decline after the TGP operation, while at high flow rate, as far as the prototype data of recent several years is concerned, the water level shows a little upward trend. According to calculation based on prototype topographic data, from Oct. 2002 to Oct. 2010, the amount of erosion at the bankfull channel for the river reach of Yichang~Chenglingji (408km long) downstream of the TGP is 0.625 billion m^3.

Recently, using physical model tests, the Changjiang (Yangtze) River Scientific Research Institute (CRSRI) predicted the morphodynamics of the river channel downstream of the TGP for the period of 2008~2022. The physical model has a horizontal scale of 1:400 and a vertical one of 1:100. The modeling range is the river reach of Yangjianao~Luoshan, about 300km long. Predictions of the physical model tests show that, when the TGP operates to 2022, the erosion occurs mainly in the low flow channel for the Yangjianao~Luoshan river reach. The sub-reaches of Yuanshi, Haoxue, Shatanzi and Zhongzhouzi have relatively larger erosion rates comparing with others within the modeling reach. In general the river channel is incised down with the operation of the TGP; the distance of river bank with the thalweg nestling against is lengthened downstream; and at transitional river sections the thalweg swings significantly and moves downstream. When the TGP operates to 2022, the overall river regime of the modeling river reach has no large change comparing with that of Oct. 2008, however, at certain local sub-reaches, significant variation occurs, especially the sub-reaches of Qigongling, Tiaoguan and Shashi, among which, the Qigonling river bend and the Tiaoguan river bend experience notable chute cutoff.

Comparison of the physical model test predictions and the prototype measurements shows that, the model predictions are in rather good agreement with the prototype measurements in terms of evolution of typical shoals, change of typical cross-sections and variation tendency of the river regime, etc. More details will be presented in the full length paper.

Sediment Transport and Morphodynamics

Regionalization and Contribution to the Study of Reservoirs Sedimentation: Lakes of Cape Bon and the Tunisia Central

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Keywords: Silting, Hilly Lake, Principal Components Analysis, Hierarchic Classification, Linear regression, Typology

In Tunisia, during the last two decades, the hilly Lakes occupy an important place in national strategies for water and soils Conservation (WSC). In addition to their role as protection of the environment, the hilly lakes appear as local reserves of water available for agriculture. Nevertheless these hydraulic infrastructures are rather sensitive to sedimentation due to solid contributions. In Tunisia, water erosion affects nearly 3 million hectares of agricultural land, and constitutes a threat to the sustainability of these hilly reserves.
26 hilly lakes are distributed in the Tunisia central and the Ridge until the Cap Bon. To conserve these reserves, we have research to find a simple and practical methodology which allows assessing the relative contribution of water erosion in sediment fluxes at the outlet of the small watersheds and to seek preferential links between the various explanatory attributes of sedimentation. To achieve this aims, extract a typology of the sedimentation variability of 26 hilly Lakes, is required.
The main objective of this paper is to form different classes of hilly Lakes, by using statistical method, and to define a representative lake of each class.
Based on the correlation table, the correlations between different variables are interpreted. Then three methods of analysis are used: the ACP; a descriptive analysis method to synthesize the most relevant information of the data, the hierarchical Classification to quantify the effect of the data in prioritizing different watersheds and the linear regression type 'Step wise' or 'Step by step' to finally get a relationship that expresses the parameters affecting the erosive process. By crossing the different results we try to identify a typology of hilly Lakes and to explain the reasons for such assemblies.
The results deduct three classes. The first group is the less vulnerable to the silting risk and is located on the southern and eastern borders West of the ridge and on the coastal plains. The lakes of this group are characterized by a low rate of silting, a large drainage area, a low relief, hydrographic network relatively hierarchical and an effect of precipitation and little intense runoff. A second group includes the most degraded environments cover almost the entire of the semi-arid zone of Central Tunisia. This group have very abrasive potential watershed, explained by high flow coefficients related mainly to higher erosive rainfall intensities associated with a moderate or accentuate topography, structure of soil over marl and a drainage non occupied and unimproved surface.
A third group extends share and other sides north and south of the Ridge, has the catchment characterized by a moderate to high sedimentation rate. The sedimentation rate is governed by a more or less marl soil structure and an intense hydrodynamic compounded by the steep slopes of these basins.
This study permitted to extract the preferential links between the various explanatory attributes of siltation, and to develop a typology of the reservoir siltation variability.
Although the generated results have clarified the study of conditional factors of silting, it is remarkable that this phenomenon remains as complex to the point that it cannot be apprehended by the integration of multiple attributes at the same time. This suggests not only the complexity of monitoring of clogging of the hilly Lakes deductions, but also its non-linear character. In order to overcome such a problem, the use of other non-parametric techniques, such as the application of artificial intelligence, is recommended.

3D Numerical Modelling of Contraction Scour under Steady Current using the Level Set Method

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Keywords: Sediment Transport, CFD, Scour, Level Set Method, Reynolds-Averaged Navier-Stokes (RANS), Bed Load Transport, Suspended Load Transport, Morphology

Contraction scour is a type of general scour that occurs due to a reduction in the channel cross-section. This is observed where the flow is constricted due to the placement of structures like bridges abutments and other onshore/offshore structures. The flow accelerates in constrictions, which increases the bed shear stress and increases the turbulence associated with it. Development of contraction scour could lead to the failure of the structure if too much sediment is eroded. Accurate predictions of scour processes are necessary to assist the design engineers in monitoring and correcting the aforementioned problems before the structures fail or become unsafe. A three-dimensional computational fluid dynamics model is used to calculate the scour and the deposition pattern in a contraction. The CFD model solves Reynolds-Averaged Navier-Stokes (RANS) equations in all three dimensions. The location of the free surface is modeled with the level set method, which calculates the complex motion of the free surface in a very realistic manner. The flow problem is solved as a two-phase flow of water and air, with the free surface represented by the interface between the two phases. The eddy viscosity in the RANS equation is determined by the use of the two-equation k-omega model. Using the conservative finite-difference framework on a structured-staggered grid, the convective terms of the RANS equations are discretized with the fifth-order WENO (weighted essentially non-oscillatory) scheme. This ensures a smooth and oscillation free solution under large gradients and shocks while maintaining a high order of accuracy. The pressure gradient term in the RANS equation is modelled using SIMPLE method. The iterative solution of the Poisson equation is done using a preconditioned BiCGStab algorithm. For time treatment an implicit time scheme is employed. The numerical model is parallelized using the domain decomposition coupled with the MPI library. An immersed boundary method is used for treatment of complex geometries, which is based on ghost cell extrapolation on a cartesian grid. The level set method is also used for representation of the sediment-water interface. The sediment transport rates in the bed cells are calculated with Engelund and Fredsøe's bed load formula. Van Rijn's formula for the suspended load is used to account for the suspended load transport. Exner's equation is used for calculating the bed morphology using the sediment continuity defect. This along with the use of level set method is essentially an eulerian approach and re-gridding at the water-sediment interface is not necessary. The numerical results for the contraction scour prediction are compared with physical experiments. The numerical model predicts the general evolution (geometry, location and maximum depth) of scour, deposition height and its location accurately with very minor differences compared to the physical experiments.

References

BAW. Morphologische versuche an einer rinne mit ein- schnuÌĹrung mittel- bis feinkiessohle. Company report: Baw-nr: A39530110064-01, 2009.
F. Engelund and J. Fredsøe. A sediment transport model for straight alluvial channels. Nord. Hydrol., 7(5):293–306, 1976.
L. C. van Rijn. Sediment transport, part ii: Suspended load transport. Journal of Hydraulic Engineering, 110(11):1613–1641, 1984b.
D. C. Wilcox. Turbulence Modeling for CFD. DCW Industries Inc., La Canada, California., 1994.

Flow and Riverbed Erosion-Deposition Simulation around Submerged Water Intake

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Keywords: Water intake engineering, Riverbed erosion-deposition, 3D numerical model, 2D numerical model

The research on flow movement and the riverbed erosion-deposition around the water intake is essential for the safe operation of water intake engineering. And it is necessary to demonstrate the reasonableness of the position of the water intake from the terms of flow pattern, the river regime and reduce the impact of water intaking on the fairways and flood control etc.. As an example, water intakes of one power plant locate at downstream of Yangtze River were selected in this paper. And a 3D numerical model is used to simulate local flows and plane 2D flow and sediment model is used to simulate riverbed erosion-deposition, suspended sediment concentration around submerged water intakes, respectively. And recent riverbed evolutions around the water intakes were predicted and so on. The boundary conditions of 3D flow model provided by the calculation results of 2D model. The water-sediment condition of typical series and high flow year, moderate flow year and low flow year typical year were selected. And the reservoir operation impact of the Three Gorges Project and the upstream reservoir to the water-sediment process downstream were take into account. Then, the better location and appropriate elevation of water intake were recommended based on the calculations result of models through analyzing the change of riverbed erosion-deposition, bed elevation and suspended sediment concentration around water intakes. The results show that the change of riverbed erosion and deposition around the water intake is not only affected by the conditions of incoming water and sediment, but also by the position of the local topography at the same river reach. Therefore, it is essential to select the appropriate location and elevation to the water intake engineering.

Velocity and Turbulence Measurements for Assessing the Stability of Riverbeds: A Comparison between UVP and ADVP

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Keywords: Velocity profiles, Turbulent kinetic energy, Open channel flow, Inception of motion, Stability parameters, Mobility parameters, Transport rate, UVP

Water flowing in natural streams and rivers can be a powerful resource to produce renewable energy. In the same time, this power has also the ability to change or even damage riverbeds, by scouring the banks, transporting sediments, and depositing them. Successfully maintaining the overall stability of active riverbeds is therefore a challenge of particularly high importance for water managers. This requires a deep understanding of the complex interactions between turbulent flow forces and forces stabilizing the riverbed. Particularly, in the case of a hydraulic rough flow regime, where sediments can be of the same order of magnitude as water depth, the flow features become complex to measure and analyze. Moreover, the entrainment of stones in rivers exhibits an intermittent behavior, in which near-bed turbulence plays a major part. In this research, using detailed flow and turbulence measurements, we address two typical shortcomings of the standard approaches used for assessing the stability of riverbeds.

For evaluating the stability of stones under a fluid flow, the most widely used conceptual framework relies on the stability threshold concept (Buffington and Montgomery 1997). It assumes that the inception of sediment motion occurs once the stability parameter, the ratio between the flow forces acting on the stones and the stabilizing forces, exceeds a threshold value. The Shields stability parameter, which is by far the most widely used, is based on the bed shear stress, which does not properly take into account the turbulence fluctuations in the flow, excepting the case of a uniform flow, while turbulent fluctuations are of primary importance in the mechanisms determining the stability of stones (Dwivedi et al. 2012, Hoffmans 2012). Particles could not be lifted up from the bed without the presence of turbulent fluctuations adjacent to the bed. Stones often get moved as a result of bursting flow motions. In general, this process is not reflected in the mean flow parameters, such as the mean bed shear stress, while it needs to be taken into account. It can only be accessed by means of parameters characterizing explicitly the turbulence in the water column. Therefore, a new approach was initiated recently and it quantifies the flow forces by means of a new set of parameters which combine explicitly the velocity and turbulence distributions over a certain water depth above the riverbed (Hofland 2005, Hoan et al. 2011). Although very promising results were already obtained, there is a need for more experimental verifications, supported by high quality turbulence measurements.

Another shortcoming of the standard Shields approach is the stability threshold concept. A univocal definition of the exact moment when stones start to move is impossible, due to the stochastic nature of particles entrainment. As a result, high errors can appear for instance in the sizing of riverbed protections (Buffington and Montgomery 1997), leading potentially to unsafe design or to a costly oversizing. Therefore, the threshold concept can be replaced by the stone transport concept, which relates the stability parameter to a quantitative and clearly defined measure of stone motion or bed damage (Figure 1). Sediments transport formulae can be applied in cases characterized by relatively large quantities of transported bed material, but they are limited to uniform flows. Here, the focus is on riverbed protections, which means a low-mobility transport, mainly under non-uniform flows.

In this paper, as an onset for using the newly developed bed stability parameters, we report new experimental results, which were obtained in a horizontal flume 6 m long and 15 cm wide, using uniform sediments of 8 mm, respectively 15 mm, representing an armor layer for riverbed protection, following two configurations. First, the entire bottom of the flume was paved with stones of uniform diameter (8 or 15 mm), leading to quasi-uniform flow conditions. Second, the flume bottom was smooth upstream of the zone of measurement while the downstream part was covered with gravels, leading to a sudden smooth-to-rough transition. The flow instantaneous velocity was measured with two complementary devices, an ultrasonic velocimeter probe (UVP) and an acoustic Doppler velocimeter profiler (ADVP), and the turbulence intensity was calculated for both configurations. The results are compared and discussed in detail. A general consistency between the two types of measurements is obtained. Some discrepancies are also highlighted close to the bed and tentative explanations are given.

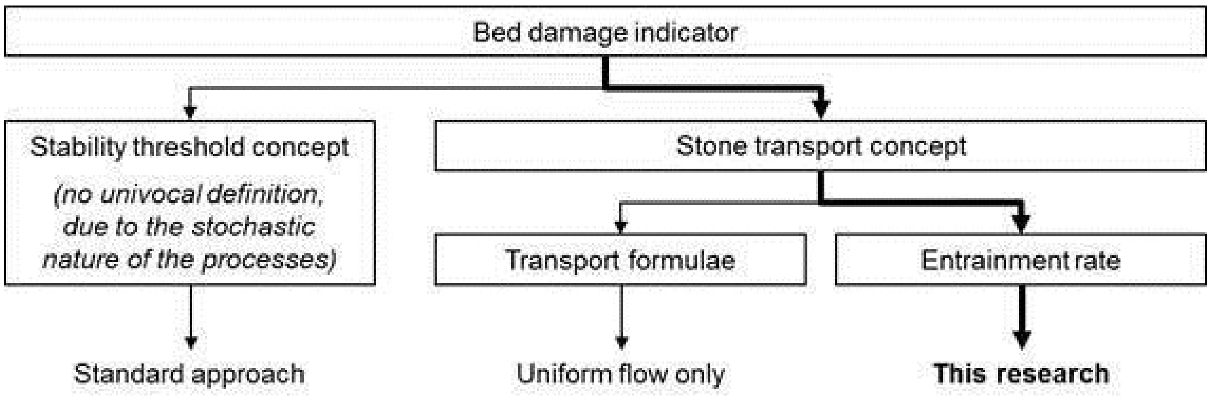

Figure 1. Conceptual framework for assessing stone motion.

References

Buffington, J. M. and D. R. Montgomery (1997). "A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers." Water Resources Research 33(8): 1993-2029.

Dwivedi, A., B. Melville, A. J. Raudkivi, A. Y. Shamseldin and Y.-M. Chiew (2012). "Role of Turbulence and Particle Exposure on Entrainment of Large Spherical Particles in Flows with Low Relative Submergence." Journal of Hydraulic Engineering 138(12): 1022-1030.

Hoan, N. T., M. Stive, R. Booij, B. Hofland and H. J. Verhagen (2011). "Stone Stability in Nonuniform Flow." Journal of Hydraulic Engineering 137(9): 884-893.

Hoffmans, G. J. C. M. (2012). "The Influence of Turbulence on Soil Erosion. ", Delft, The Netherlands, Eburon Uitgeverij B.V.

Hofland, B. (2005). "Rock and roll: turbulence-induced damage to granular bed protections", Delft Univ. of Technology.

Shoreline Changes Due to Construction of Alexandria Submerged Breakwater, Egypt

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Keywords: Submerged Breakwater, Coastal Management, Shoreline Changes, Alexandria Coastline, Coastal Erosion

During the last few years, Alexandria coastline has faced many flooding problems. In winters of 2003 to 2006, many surge storms struck the Alexandrian coastline; water and sand overtopped the seawall and destroyed many parts of it. In the coming years, these kinds of storms are likely to increase due to the phenomenon of SLR. The impacts of Sea Level Rise will be felt through both an increase in mean sea level and through an increase in the frequency of extreme sea-level events such as storm surges (Church et al., 2008).
The option of raising the level of the defences is not feasible due to both reductions in amenity and cost ineffectiveness, as existing infrastructure would have to be sacrificed to accommodate larger defences. This leads to the proposed deployment of a submerged offshore rubble mound breakwater and / or submerged offshore artificial reefs, to induce wave breaking and energy dissipation, in order to limit the wave heights reaching the beach (El-Sharnouby and Soliman, 2010; El-Sharnouby et al., 2007; Soliman and Reeve, 2009). More recently, submerged offshore artificial reefs applications have varied widely, including: aquaculture production; coastal protection (Seaman and Jensen, 2000); and habitat protection (Baine, 2001). Artificial reef materials should last a minimum of 30 years to provide cost-effective ecological service, and to be non-toxic to the marine environment (Grove et al., 1991).
This paper presents the shoreline changes due to the construction of a submerged breakwater. A case study of a submerged breakwater, which was constructed at Alexandria coastal area, Egypt, to stabilize the eroded beach of Miamy - Asafra - Mandara -Montaza areas in years 2006 to 2008, is presented. The breakwater system consists of one main parallel part and two overlapping parts approximately 150 to 300 meters offshore. The total length of the breakwaters is 2520 meters with water depth ranging from 2.5 to 8.5 meters at the location of the structure. A bathymetry surveying has been conducted in years 2006, 2008, 2009 and 2010. These data are presented and analyzed to introduce the shoreline response due to the construction of the submerged breakwater using the Digital Shoreline Analysis System (DSAS) which is a software application added to the Geographical Informational System (GIS) software " ArcView ". The analysis of the collected data shows shoreline accretion along most areas of Miamy beach, western part of Asafra beach, eastern part of Mandara beach and Montaza beach with range from 0.4 to 8.7 meter per year. In contrast, areas of shoreline erosion exist at eastern part of Asafra beach and western part of Mandara beach with range from -0.8 to -20.8 meter per year. A beach width varied from 25 to 50 meters compared to 0.0 to 25 meters before the submerged breakwater installation has been established in most areas of the protected beach.

References

Baine, M. (2001). Artificial reefs: a review of their design application management and performance. Ocean & Coastal Management 44, No. (3-4), 241-259.
Church, J. A., White, N. J., Aarup, T., Wilson, W. S., Woodworth, P. L., Domingues, C. M., Hunter, J. R. and Lambeck, K. (2008). Understanding global sea levels: past, present and future. Sustainability Science 3, No. 1, 9-22.
El-Sharnouby, B., Nagy, H. and Abdrabbo, F. Stability of shoreline for Miami –Montaza area. Technical note, Faculty of Engineering, Alexandria University, Egypt, 2007
El-Sharnouby, B. and Soliman, A. Shoreline response for long wide and deep submerged breakwater of Alexandria city, Egypt. Proceeding of 26th International Conference on Seaports and Maritime

Transport. Alexandria, Egypt, Port Training Institute, Arab Academy for Science, Technology & Maritime Transport, 2010.
Grove, R. S., Sonu, C. J. and Nakamura, M. Design and engineering of manufactured habitats for fisheries enhancement: Artificial habitats for marine and freshwater, (Fisheries. W. J. Seaman and L. M. E. Sprague (ed.)). San Diego, California, Academic Press, Inc., 1991, pp. 109 – 149.
Seaman, W. J. and Jensen, A. C. Purposes and Practices of Artificial Reef Evaluation. Artificial reef evaluation: with application to natural marine habitats. (W. J. E. Seaman). Boca Raton, Florida, USA, CRC Marine Science Series, CRC Press LLC, 2000, pp. 1 – 20.
Soliman, A. and Reeve, D. Applying the artificial submerged reefs techniques to reduce the flooding problems along the Alexandria Coastline. Proceeding of the Institution of Civil Engineers Conference: Coasts, Marine Structures and Breakwaters. Edinburgh, Scotland, UK, 2009, pp. 1-12.

The Motion of Grains of a Bed-Load Layer under a Turbulent Liquid Flow

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Keywords: Sediment transport, bed load, water stream, turbulent boundary layer

Sediment transport by a fluid flow is frequently found in both nature and industry. Under moderate shear stresses, a moving granular layer takes place in which the grains stay in contact with the fixed part of the granular bed. This kind of transport, known as bed load, is present in the displacement of riverbeds, in the transport of sand by wind, and in the transport of sand in petroleum pipelines. Although of importance for many scientific domains, the trajectories of individual grains in the moving bed is not well understood. The knowledge of the typical trajectory of grains is necessary for the correct prediction of the bed-load transport rate. This paper presents an experimental investigation on the motion of grains of a granular bed sheared by a liquid flow. In our experiments, fully-developed turbulent water flows were imposed over a granular bed of known granulometry. The tested conditions were close to incipient bed load, and therefore the thickness of the bed-load layer was of the order of the grains diameter. For different flow rates, the water flow over the moving bed was measured by Particle Image Velocimetry and the displacements of grains were filmed with a high-speed camera. The trajectories of individual grains were determined by post-processing the images, and the typical lengths and velocities were computed. Finally, the motion of grains was correlated to the water flow conditions, and the bed-load transport rate was estimated and compared with semi-empirical transport rate equations.

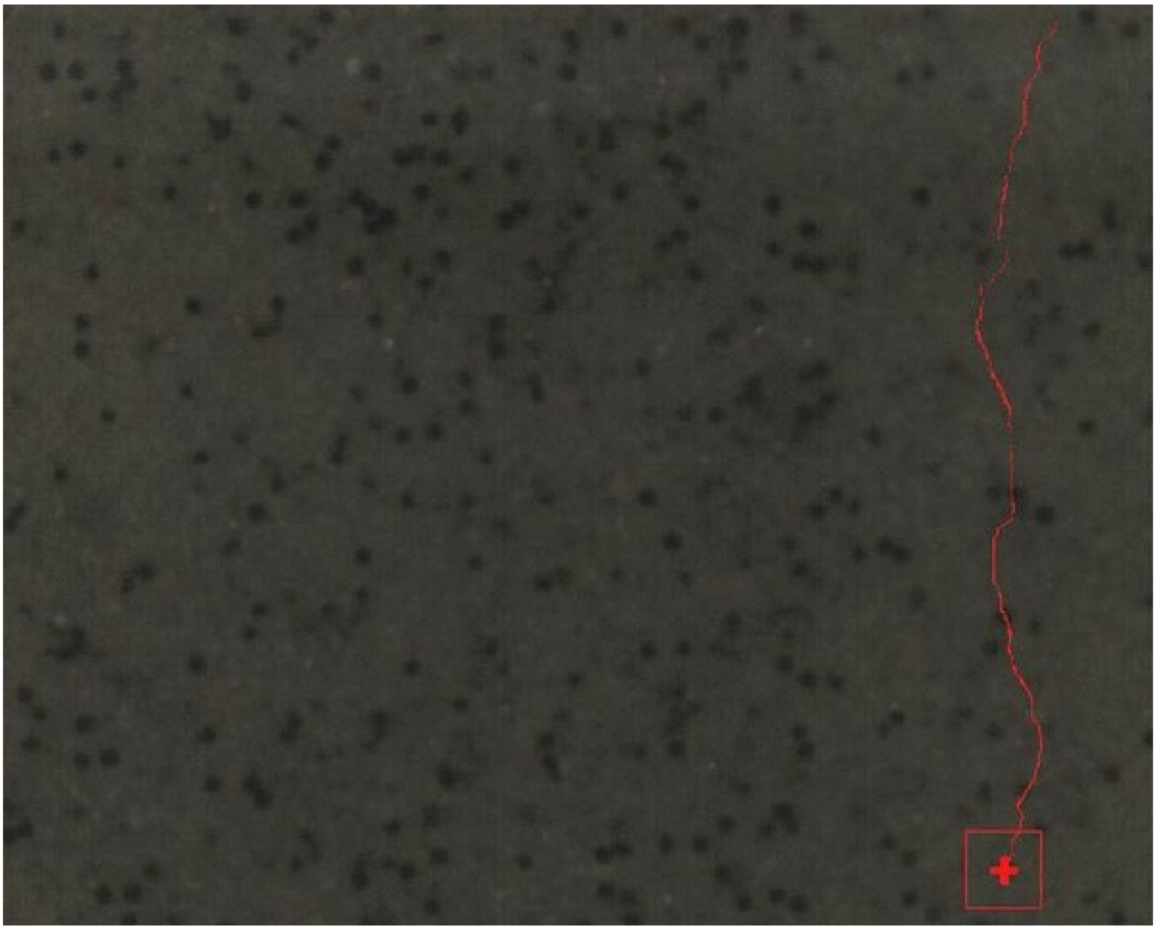

Figure 1. Tracking of an individual grain.

A Stratigraphic Soil Model for Coastal Morphodynamics

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Keywords: Coastal morphodynamics, Stratigraphy, Sediment transport

Morphodynamics in coastal areas is to a large part driven by the energy of the tide. This leads to a periodic alternation of erosion and deposition. To model the sediment transport in these areas correctly, it is important to store the temporal variation of deposited sediments, so that during erosion phases lastly deposited sediments are being eroded firstly. Since the magnitude of these transport processes can vary spatially and temporarily, creating a user-defined vertical discretization that displays the stratigraphy sufficiently is very hard. In most existing models an unphysical mixing of different sediments in the upper layer occurs, which leads to a loss of information. E.g. two distinct deposition events with different sediment characteristics occur and the information is stored in just one user-defined layer where it is perfectly mixed. The information about the chronological sequence of deposition is not available.

This soil model presented here is able to create a vertical discretization that is based solely on the sediment inventory and the differences in its vertical distribution. The goal is to represent the vertical variation of sediments over time and space as unaltered as possible. The model is capable of deciding when the changes of the distribution of new sediments are distinctive enough that they should be deposited in a new layer so no unwarranted mixing occurs.

The user has to provide a set of classifications which describe the sediment and its locally varying distribution. First, there are soil classes. These consist of upper and lower boundaries for the grain size, so each sediment fraction can be assigned to a soil class. Typical soil classes are sand, silt und clay. For each soil class, all the individual masses of the associated fractions are summed up. Second, there are soil textures. They describe the mass distribution of the soil classes and are defined by a validity range for each soil class. E.g. the soil texture sandy Silt consists of 50 – 80 % silt, 12 – 50 % sand and 0 – 8 % clay.

The sediment distribution of each layer as well as that of the depositional flux can be described with this classification. As long as the composition of the depositional flux leads to the same soil texture as the one of the top layer, the sediment is deposited in that layer. But if the soil texture of the depositional flux differs from that of the top layer, a new layer in which the sediment is deposited is created. In that way, the chronological sequence of the sediment distribution is stored with very little loss of information.

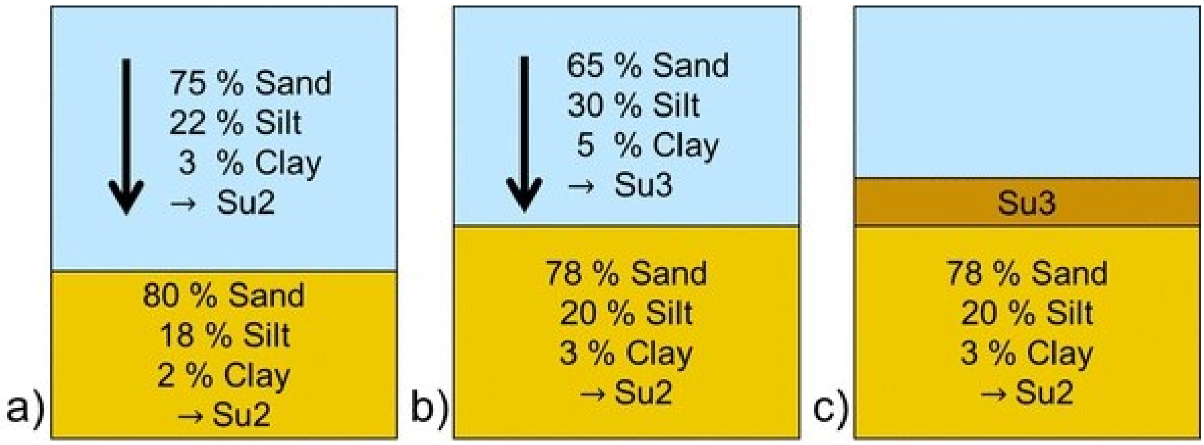

Figure1. Formation of a new layer: a) Deposition of sediments that differs only slightly from the sediment in the top layer (Su2 = soil texture poor silty sand); b) Deposition occurred in existing layer; Sediment distribution of the depositional flux differs enough from the sediment in the top layer (Su3 = medium silty sand); c) Deposition occurred in new layer.

For data storage purposes a maximum amount of possible layers has to be specified. If this number is reached, two layers have to be merged. This is not done by simply merging the two oldest layers, but by looking for two adjacent layers with a similar sediment distribution, so the stratigraphy remains as long as possible in its original state.

A significant difference towards existing morphodynamic models is the absence of a transport or exchange layer. The main function of an exchange layer is to describe the sediment available for transport processes and to provide the basis for the calculation of important variables that describe the interaction between water column and soil, mostly bed roughness and resulting shear stresses. It serves as a thin layer which keeps track of short-period sediment transport processes. It is also limiting the sediment available for erosion per time step. There are approaches to determine the thickness from sediment parameters like the d50 as well as hydrologic parameters like current velocity or shear stress. The idea behind these approaches is to calculate how deep the energy of the water current reaches into the soil.

In the model presented here such a thin transport layer is not implemented because the changes in the sediment distribution are accurately described in the layer structure.

The presented concept was coupled with a 2D-xz hydrodynamic model. First results are shown to demonstrate the functionality of the algorithms. Simulations of a settling column will be shown and how the changing sediment composition of the depositional flux caused by different settling velocities leads to the development of a stratified soil. Another example with tidal conditions is used to study the behaviour of the model under more complex conditions.

2DH Morphodynamic Time-Dependent Hindcast Modelling of a Groyne System in Ghana

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Keywords: XBeach, Groyne, Numerical modelling, Hindcast, Morphodynamics, Swell waves

Coastal erosion is a major threat to the whole of the West-African coast. Along the northwest coast of Africa average rates of coastal retreat are between one and two meters per year (UNESCO, 2012). In 2009, the Ghanaian government decided to protect the coast in Ada, where the average rate of coastal retreat is locally, close to the Volta river mouth, more than 6 m/year. In total, a stretch of about 16 km is to be defended with a combination of a groyne system and a beach nourishment. The project is split into two phases: first the groynes in the most critical stretch near the Volta river mouth are built (finished in the summer of 2013), then the remaining groynes and the beach nourishment are executed in the second phase (currently ongoing).

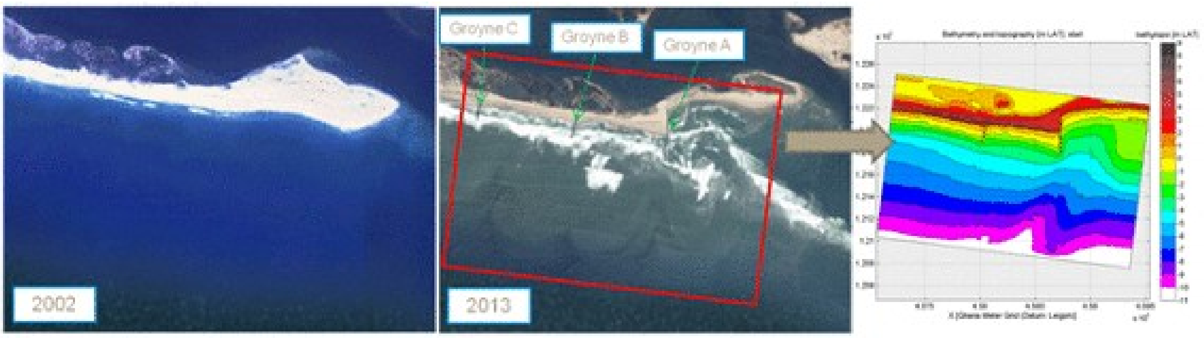

Figure 1. Left: Volta river mouth (©Google Earth, 2002). Middle: hindcast model area (red rectangle) on background of ©Google Earth (2013). Right: interpolated measured bathymetry in March 2013.

During and after the construction works of the groynes of phase 1, severe erosion was observed east of the very first and most eastern groyne (cf. Figure 1, groyne A). This was expected because of the net wave-induced longshore current directed to the east along the Ada coast. However, the observed erosion occurred faster than predicted during the design of phase 1 (IMDC, 2011). This warranted further investigation into what the main causes of this local severe erosion are. A 2DH morphological numerical model XBeach was used for this purpose. XBeach is a depth-averaged two-dimensional time-dependent model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and backbarrier during storms (Roelvink et al., 2009). The model domain encompasses a longshore distance of 2.5 km around the first two groynes (cf. Figure 1, groynes A & B) closest to the Volta river mouth and extends 1 km offshore, up until a bed level of -11 m LAT.

The default parameter settings in XBeach are primarily intended for the North Sea wave conditions off the Dutch coast (Roelvink et al., 2009). The wave climate off Ghana differs significantly from the wave climate in the North Sea, since the wave climate off the West-African coast is swell dominated (IMDC, 2013). Calibration of the XBeach model was therefore necessary and it was performed with a 1DH cross-shore profile model of a beach cross-section in the project area. The calibration was mainly based on the wave asymmetry/skewness parameters (Pender and K., 2013), the wave breaking and dune avalanching trigger parameters (Splinter and P., 2012) until a more or less stable and comparable to the measured beach profile was obtained under the wave action over a year (Verheyen et al., 2014).

With these calibrated parameters, the morphological evolution around groynes A and B was hindcasted with the 2DH XBeach model during the period of almost one year (i.e. 01/04/2012 – 01/03/2013) starting from a measured bathymetry and topography in March 2012. Over the course of the hindcast modelling, the groynes were introduced in the model as a non-erodible hard layer on the

dates of their construction. The model was forced by 2D wave spectra generated by the wave hindcast model (IMDC, 2013) and water levels based on the astronomical tide during this period.
Validation of the hindcast model end result with bathymetric and topographic measurements in March 2013 (cf. Figure 2), shows that the model is capable of reproducing the important morphological changes in mostly a qualitative way and less quantitatively, but very satisfactory nonetheless. The model seems to somewhat overestimate the erosion west of the groynes, as a result of an underestimation of onshore sediment transport during mild wave conditions. This is a known limitation of XBeach (van Thiel de Vries, 2009), since it was initially developed for storm conditions over relatively short periods (i.e. hours or days, but not months, years).

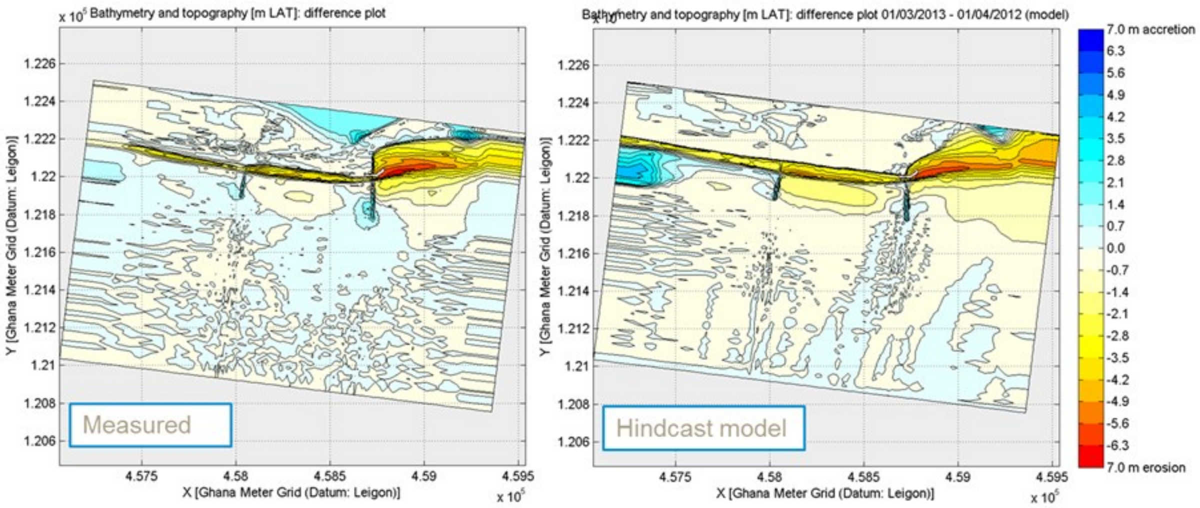

Figure 2. Bathymetry difference plots (i.e. difference between 01/03/2013 and 01/04/2012).

Analysis of the significant wave height, longshore currents, sediment transport and water levels shows that important causes of the severe beach erosion east of the first groyne were found to be:

- A 2D bathymetric feature (i.e. a trough or bottom depression, cf. right in Figure 1): it greatly influences the swell waves (wave refraction, divergence/convergence) and causes a longshore sediment transport gradient leading to a local erosion hotspot.
- 2D topographical features (i.e. differences in beach crest height west and east from the first groyne): this allows overwash to occur east more than west, causing the beach to retreat more in the east.

A hindcast without introducing groynes into the model was also performed simultaneously. This confirmed that the groynes themselves also contributed to the severe erosion in the east. However it also showed that the beach west of groyne A has clearly benefitted from the construction of the groynes, since the beach erosion to the west of the groynes was less with groynes than without.

References

IMDC (2011). “Ada Coastal Protection Works: Urgent Measures - Design Report”, RA11024, v2.0.
IMDC (2013). “Ada Coastal Protection Works Phase II: Wave Modelling”, RA13159, v1.0.
Pender, D., Karunarathna, H. (2013). "A statistical-process based approach for modelling beach profile variability", Coastal Engineering 81.
Roelvink D., Reniers A., van Dongeren A., van Thiel de Vries J., McCall R., Lescinski J. (2009). “Modelling storm impacts on beaches, dunes and barrier islands”, Coastal Engineering, Vol. 56, p.1133-1152.
Splinter K.D., Palmsten M.L. (2012). “Modelling dune response to an East Coast Low”, Marine Geology 329–331, p. 46–57.
UNESCO (2012). http://www.unesco.org/new/en/media-services/single-view/news/coastal_erosion_major_threat_to_west_africa

van Thiel de Vries, J. (2009). "Dune erosion during storm surges", PhD Thesis, TU Delft.
Verheyen, B., Gruwez, V., Zimmermann, N., Wauters, P., Bolle, A. (2014). "Medium term time-dependent morphodynamic modelling of beach profile evolution in Ada, Ghana", 11th ICHE, Hamburg, 28 September – 2 October 2014 (submitted for approval).

Analysis of Sediment Transport in the Middle Reach of the Yangtze River after Operation of the Three Gorges Project

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Keywords: Three Gorges Project; Middle reach of the Yangtze River; Recovery of sediment concentration; Sediment concentration; Long distance erosion; Sediment transport; Hydrological station; Channel downstream of the TGP

The middle reach of the Yangtze River, from Yichang to Hukou, is about 954km long, among which, the 347km river reach from Zhicheng to Chenglingji is called the well-known Jingjiang River (see Figure 1). To the south of the Jingjiang River, three outlets (i.e. Songzi, Taiping and Ouchi), divert flow and sediment from the Yangtze River to the Dongting Lake. The Dongting Lake gathers further flow and sediment from its four main tributaries of Xiang River, Zi River, Yuan River and Li River, and then discharges the flow and sediment back into the Yangtze River at Chenglingji. The Three Gorges Project (TGP) began to operate in June 2003 with a storage level of 135m, then 156m in Sept. 2006, and 175m in Oct. 2010. Operation of the TGP has changed the hydrological regime of the channel downstream. The flow sediment concentration in the middle reach of the Yangtze River will be seriously unsaturated for a long period, and the recovery of the sediment concentration in the flow will cause long distance erosion in the river channel. In this study, with about 60 years of prototype data, the variation of the following aspects of the river after the operation of the TGP are analyzed, these include: the flow and sediment characteristics, the ratios of flow and sediment diversions via the three outlets, the annual sediment transport and the different fractions of suspended load at main hydrological stations in the middle reach of the Yangtze River, etc. The analysis results show that, the annual runoff in the middle reach of the Yangtze River has no obvious change trend since the operation of the TGP, but the flow sediment concentration reduces significantly; the ratios of flow and sediment diversions via the three outlets only change slightly; it seems that the flow and sediment allocation of the Yangtze River- Dongting Lake system has only relatively small effects on the recovery of flow sediment concentration in the river. The annual sediment transport at all the hydrological stations in the middle reach of the Yangtze River is much less than that before the TGP operation; the part of sediment with $d < 0.125$mm recovers slowly along the river, and the degree of recovery is far less than that before the operation (see Figure 2(a)). The main reason (for this insufficient recovery) is that there is little presence of sediment with this size in the channel of the middle reach of the Yangtze River; this is also the fundamental essence of the long distance erosion occurring in the river channel downstream of the TGP. For the part of sediment with $d > 0.125$mm, the recovery rate is relatively fast in the river reach from Yichang to Jianli, and the concentration for this part of sediment recovers almost to the saturation state at Jianli station, as is shown in Figure 2(b). The main reason for this fast recovery is that the river channel downstream of the Shashi Station is mainly sandy river bed and there is rich presence of sediment with this size in the bed; this also explains why the erosion occurs mainly in the Jingjiang River so far. Along with the continually construction of cascade reservoirs upstream of the TGP, it is expected according to the current river channel erosion that, if only the part of sediment with $d > 0.125$mm is considered, the averaged annual erosion amount will be generally no more than 3.0×107 ton in the middle reach of the Yangtze river in the future.

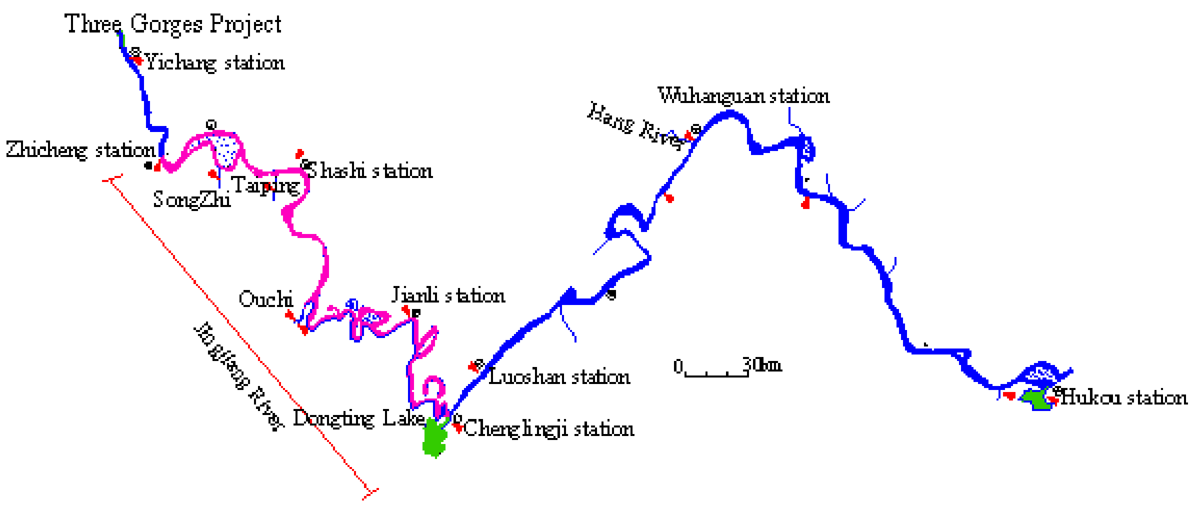

Figure 1. Sketch mapof the middle Yangtze River.

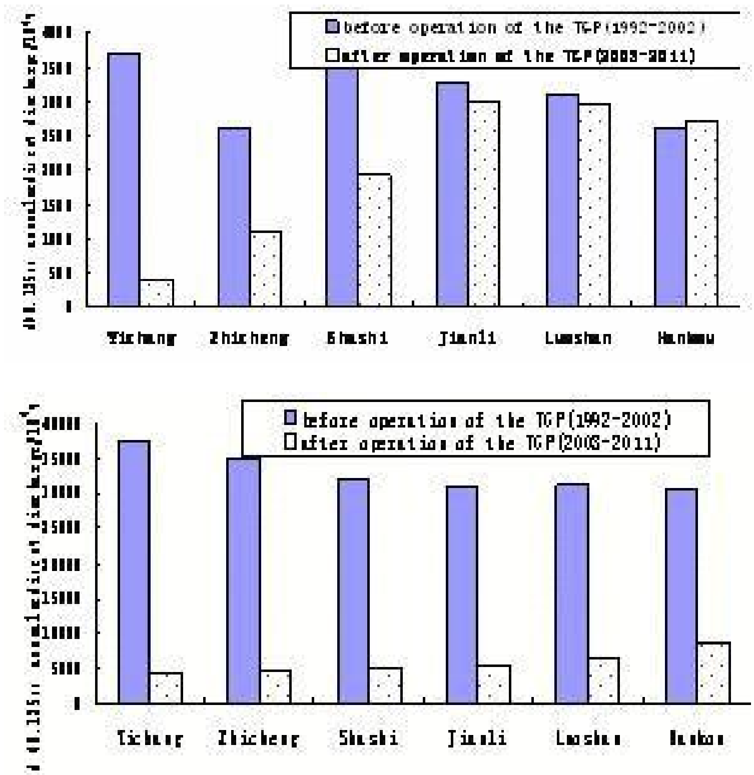

Figure 2. Comparison of the different fractions of suspended load in the middle reach of the Yyangtze before and after operation of the TGP.

Calculation of Sediment Transport Capacity of Flowing Water in Rivers with Machine Learning

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Keywords: Artificial neural networks (ANNs), Adaptive-network-based fuzzy inference system (ANFIS), Bed load, Bed-material load, Machine learning, Sediment transport, Support vector regression (SVR), Symbolic regression (SR)

Fluvial sediment transport literature is characterized by an abundance of studies comparing sediment transport formulae, which calculate either the bed-material load (mainly for sand-bed rivers) or the bed load (mainly for gravel-bed rivers). However, these studies exhibit different results and conclusions exposing the insufficiency of the sediment transport formulae utilized for engineering projects.The present paper shows the potential of machine learning in quantifying fluvial sediment transport by summarizing the work done by the authors in the recent past and discusses the conclusions drawn from these studies.

For the quantification of bed-material load, numerous sediment transport functions have been introduced in the past years based on different concepts. There are four basic approaches used in the derivation of sediment transport formulae (Yang, 1977): 1) The deterministic approach, which obeys the laws of physics and usually is based on an independent variable like slope, shear stress, stream power, unit stream power etc. 2) The regression approach, which has emerged from the thought that sediment transport is such a complex phenomenon that cannot be described by a single dominant variable. 3) The pioneering probabilistic approach of Einstein, which highlighted the complexity and the stochastic nature of the sediment transport in a rather laborious way for common usage in engineering, and 4) The regime approach, which was developed as a result of long-term measurements in equilibrium conditions.

Bed load transport formulae are founded upon the premise that a specific relation exists between hydraulic variables, sedimentological parameters, and the rate at which bed load is being transported. Gomez and Church (1989) distinguish four principal approaches to have emerged to the design of bed load transport formulae, based upon bed shear stress, stream discharge, stochastic functions for sediment movement, or stream power. Most bed load formulae owe their derivation to a comparatively restricted database, while their utility has been established on the basis of relatively few field data.

The emerging results from all these concepts usually differ drastically from each other and from the measured data. Consequently, none of the published sediment transport equations has gained universal acceptance in confidently predicting sediment transport rates, especially in natural rivers. An alternative approach may be the usage of machine learning, which is especially attractive for modeling processes, in which knowledge of the physics of the problem is inadequate. While the selection of the proper independent variables, which serve as inputs, is a prerequisite for the correct estimation of sediment transport in alluvial rivers, the regression scheme that is utilized, is of significance as well. Witten et al. (2011) argued that the universal learner is an idealistic fantasy since experience has shown that no single machine learning technique is appropriate to all data mining problems due to the fact that certain classes of model syntax may be inappropriate as a representation of a physical system. Hence, in this paper, several machine learning techniques are employed in order to test various input combinations, which comprise dimensionless variables based on fundamental concepts of sediment transport and fluid mechanics, and they are compared for their efficacy in predicting sediment transport rates that occur in rivers. The utilized machine learning techniques are the adaptive-network-

based fuzzy inference systems (ANFIS), artificial neural networks (ANNs), symbolic regression (SR) based on genetic programming (GP), and support vector regression (SVR).
The data used in this study originate from the well-known Brownlie dataset for the bed-material load calculation in sand-bed rivers and from selected coarse-bed streams and rivers in Idaho for the bed load calculation.
The generated models are robust and the results are encouraging, given the complexity of the problem and the inevitable noise inclusion from the field measurements and superior to those of some of the well-known sediment transport formulae. The conclusions of this study support that the regression scheme is of importance, since all the input combinations tested (based mainly on shear stress, or stream power, or unit stream power) generated similarly good results, with respect to the machine learning technique employed. ANNs and ANFIS performed best, followed by SVR and SR.

References
Gomez B, Church M (1989). An assessment of bed load sediment transport formulae for gravel bed rivers. Water Resources Research 25(6), 1161–1186.
Witten IH, Frank E, Hall MA (2011). Data Mining: Practical Machine Learning Tools and Techniques, 3rd edn. Morgan Kaufmann, Burlington, MA.
Yang CT (1977). The movement of sediment in rivers. Surveys in Geophysics 3 (1), 39–68.

Scouring and Armoring in Alluvial Rrivers

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Keywords: Armoring, Active layer, Sand wave, Bed composition

Despite the ubiquity of bed armoring phenomenon in alluvial rivers, there is still large discrepancy between its simulation and the observation. The main objective of the paper is to develop a more appropriate method to simulate the scouring and armoring process. Since bed material on the surface exchange with the sediment in water column in the active layer which can be attributed to the sand wave movement and turbulence burst process through experiments and observations, a kinetic equation on the basis of mass conservation mechanism is established to describe the temporal and spatial variety of bed material composition, which helps reveal the relationship between the variety of bed material composition and both of the flow intensity and scouring intensity, as well as reflect the supplementation process of bed materials from the active layer to the surface. With the equation founded and transformed, the parameters are calibrated through the flume experiments and a numerical differential method is used to solve the kinetic equation. Some experiments are also conducted as computational applications with the above method, and the results show that simulated values are consistent with the experimental data, which proves the equation makes a valid description of bed material composition in the process and is available for bed scouring and armoring simulation.

Modeling of Climate Change Effects on Coastal Erosion

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Keywords: Coastal erosion, Climate change, Coastal flooding, Nearshore numerical models, Extreme value theory

In the present work a Boussinesq type hydrodynamics and morphodynamics model is developed and applied to simulate cross-shore coastal erosion during a storm surge event under extreme wave conditions.

Non linear wave transformation in the surf and swash zone is computed by a non-linear breaking wave model based on the higher order Boussinesq equations for breaking and non-breaking waves (Karambas, 2012).

The new Camenen and Larson (2007) transport rate formula (involving unsteady aspects of the sand transport phenomenon) is adopted for estimating the sheet flow sediment transport rates, as well as the bed load and suspended load over ripples. Suspended sediment transport rate is incorporated by solving the depth-integrated transport equation for suspended sediment (Karambas, 2006). The model is validated against large scale experimental data for cross-shore profile evolution (Dette et al., 1998).

The model is applied to Eresos beach (Lesbos island, Greece) where significant coastal erosion took place due to climate change effects: large waves from S and SE, change of annual frequency and duration of winds and sea level rise due to storm surge. The effect of the sea wall on coastal erosion, is also simulated by the model. The model is tested against measured profiles after a storm event.

The model is also applied to determine extreme beach erosion and coastal erosion hazard due to storms in Eresos beach. Extreme values of wave height and period as well as sea level rise are estimated using extreme value theory techniques. Marginal Generalized Extreme Value (GEV) distributions are first fitted to wave height and storm surge annual maxima. The dependence structure between wave height and storm surge extremes is modeled using a distribution from the family of Multivariate Extreme Value distributions (MVE), namely the simple bivariate logistic distribution function (Tawn, 1988). The MVE family is selected based on the dependence of wave height and storm surge extremes on similar atmospheric forcing mechanisms, which renders them consistent with asymptotic dependence (Galiatsatou & Prinos, 2005). The extreme wave period is supposed to be conditionally related to the wave height extremes (Callaghan et al. 2008). In the present study, a GEV distribution function with location and scale modeled as empirical regression functions of the wave height, is utilized.

References

Callaghan, D.P., Nielsen, P., Short, A. and Ranasinghe, R., 2008, "Statistical simulation of wave climate and extreme beach erosion", Coastal Engineering 55, 375-390.

Camenen, B., Larson, M., 2007. A unified sediment transport formulation for coastal inlet application. Technical Report, ERDC/CH: CR-07-1, US Army Corps of Engineers, Engineering Research and Development Center, Vicksburg, MS, USA, pp. 247.

Dette H.H., Peters K. and Newe J., 1998. Large wave flume experiment '96/97.MAST III - SAFE Project, Report No. 825.

Galiatsatou, P. and Prinos, P., 2005, "Analysis of dependence in a bivariate process of extreme waves and surges", Proc. 1st International Conference on Coastal Zone Management and Engineering in the Middle East, Dubai 2005, 221-225.

Karambas, Th.V., 2006. Prediction of sediment transport in the swash zone by using a nonlinear wave model. Continental Shelf Research 26, 599-609.

Karambas Th. V., 2012.Design of detached breakwaters for coastal protection: development and application of an advanced numerical model' Proceedings of the 33rd International Conference on Coastal Engineering 2012,1(33), sediment.115. doi:10.9753/icce.v33.sediment.115

Tawn, J.A., 1988, Bivariate extreme value theory: model and estimation, Biometrika 75(4), 397-415.

Suspended Sediment Dynamics in the Mixing Zone - a Case Study from the Weser Estuary

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Keywords: River flow, Turbulence statistics, Wake zone, Scour, ADV, Cohesive sediment, Sediment transport

1. Introduction

Transport of suspended sediments in the mixing zone of strongly tidal influenced estuaries such as the Weser estuary at the German North Sea coast show a complex behavior. Large amounts of sediments are repeatedly resuspended, transported and partly deposited during the tidal cycle. This sediment transport controlled by tidal forcing often results in a net upstream transport, potentially causing increased siltation in harbors and navigational channels (e.g. van Rijn, 2005). Different mechanisms have been proposed to explain this residual transport. Classical concepts emphasize the role of estuarine circulation (e.g. Festa and Hansen, 1978), or the tidal current asymmetry, where higher flood velocities induce higher upstream transport (e.g. Dyer, 1989). In a numerical process study Burchard and Baumert (1998) found these effects to be important for the formation of the estuarine turbidity maximum zone. Moreover, salt induced changes in vertical mixing efficiency, there called the "tidal mixing asymmetry" originally proposed by Jay and Musiak (1994), contribute to the net upstream transport of sediments. Here we elaborate on previous efforts investigating the transport mechanisms for the Weser estuary (Lang et al., 1989, Lang, 1990), based on in-situ measurements and a numerical modelling process study.

2. Methods

The three-dimensional numerical model is based on the UnTRIM method (Casulli and Zanolli, 2005), using an unstructured grid in the horizontal to provide a good representation of the complex topography. Transport of suspended particulate matter (SPM) is modeled by coupling UnTRIM with the SediMorph module to take into account sediment deposition and erosion of three different sediment size classes.

Measurements were conducted in terms of three 13-hour cross-sectional ADCP measurements at different locations in the estuary (Aqua Vision BV, 2011). Acoustic backscatter was calibrated with respect to suspended sediment concentration by means of water samples, collected at the respective locations.

3. Results and Discussion

Cross-sectional measurements in the estuarine turbidity maximum of the Weser (56.5 km downstream from the tidal weir) show that for the given hydrological situation the flood current is vertically more homogenous as the ebb current, which is strongly concentrated at the surface (Fig. 1, left panel). In combination, this distribution of current velocities result in stronger sediment transport in flood direction compared to weaker sediment transport in ebb direction (Fig. 1, right panel).

The hydrodynamic reason for these different velocity profiles can be obtained from numerical modelling results. Though the water column in the Weser estuary is generally well mixed, salinity induced periodic stratification and straining occurs in the region of freshwater influence .

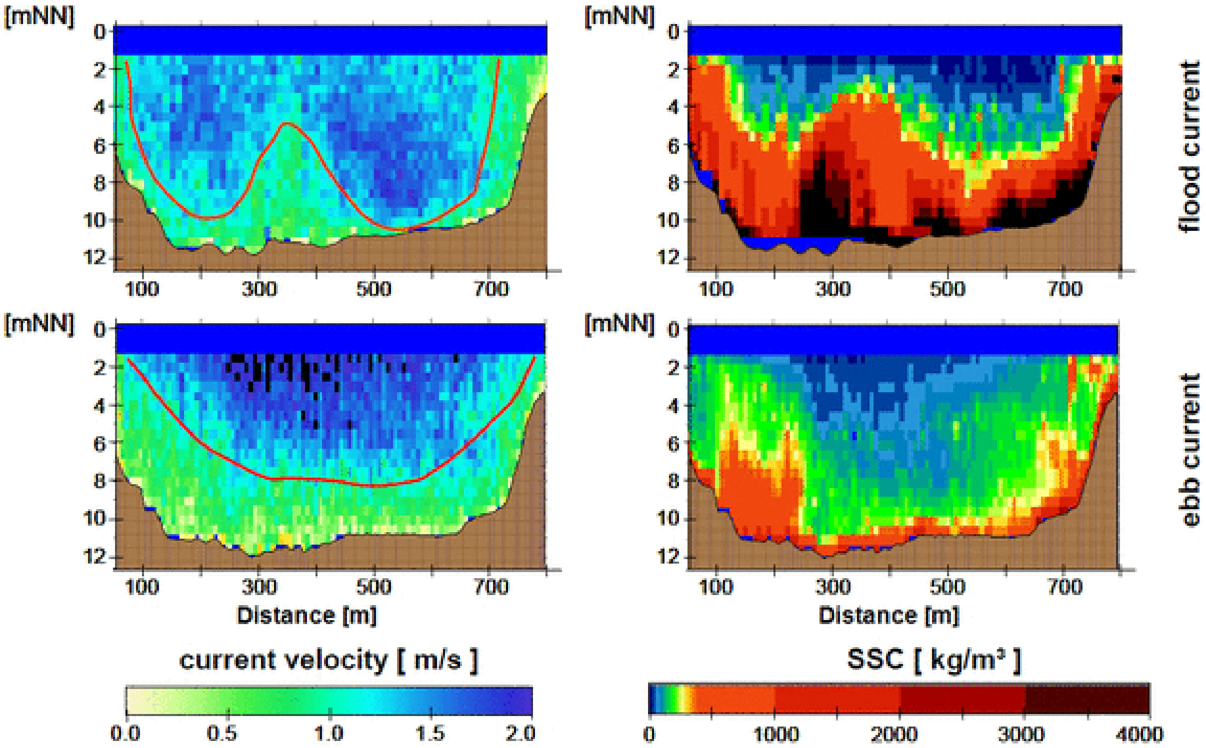

Figure 1. Current velocity (left) and sediment concentration (right) for flood current (upper) and ebb current (lower) from ADCP measurements at a cross section in the Weser-estuary (km 56.5) in June 2011.

Model results show that this temporary stratification reduces mixing and thus the upward directed turbulent transport after settling during slack water, which is in accordance with the observed distribution of current velocities and suspended sediment concentration.

References

Aqua Vision BV. Suspended sediment measurements in the Weser, June 2011: Aqua Vision BV; 2011.

Burchard H, Baumert H. The Formation of Estuarine Turbidity Maxima Due to Density Effects in the Salt Wedge. A Hydrodynamic Process Study. Journal of Physical Oceanography 1998;28:309–21.

Casulli V, Zanolli P. High resolution methods for multidimensional advection–diffusion problems in free-surface hydrodynamics. Ocean Modelling 2005;10(1-2):137–51.

Dyer KR. Sediment processes in estuaries: Future research requirements. J. Geophys. Res. 1989;94(C10):14327.

Festa JF, Hansen DV. Turbidity maxima in partially mixed estuaries: A two-dimensional numerical model. Estuarine and Coastal Marine Science 1978;7(4):347–59.

Jay DA, Musiak JD. Particle trapping in estuarine tidal flows. J. Geophys. Res. 1994;99(C10):20445.

Lang G. Zur Schwebstoffdynamik von Trübungszonen in Ästuarien; PhD thesis. University of Hannover. 1990.

Lang G, Schubert R, Markofsky M, Fanger H, Grabemann I, Krasemann HL et al. Data interpretation and numerical modeling of the Mud and Suspended Sediment Experiment 1985. J. Geophys. Res. 1989;94(C10):14381.

van Rijn LC. Principles of sedimentation and erosion engineering in rivers, estuaries and coastal seas. The Netherlands: Aqua Publications; 2005.

Effects of Sediment Supply on Low-Flow Channel Formation

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Keywords: Alternate bar, Low-flow channel, Emergent bar, Degradation, Sediment supply, Riffle and pool sequence, Numerical simulation

Low-flow channels with pool and riffle sequences provide habitat for fish and vegetation during inter-flood periods. In regard to appropriate sediment management for river environments, it is important to investigate the effects of water discharge and sediment supply (both of which may be controlled by a dam as a water release and a sediment flushing from reservoirs) on the morphology of low-flow channels between floods. Such investigation can also provide information for investigating what controls on water discharge and sediment supply are better for the maintenance of riparian habitat. Many works on the river morphology change have mainly treated effects of the water discharge. However, effect of the sediment supply on the morphology change has not been always discussed.
In this study, we investigated a low-flow channel formation process in alternate bars under the conditions with and without sediment supply using flume experiments, and discussed the effect of the sediment supply on that process. A two-dimensional numerical model was also developed to further investigate the effects of sediment supply on river restoration. The simulation results were verified against the experimental results. By investigating river bed variation in detail, it was possible to clarify the formation processes of emerged bars bounding a low-flow channel. Effects of the sediment supply on the longitudinal profiles of low-flow channels and on the moving characteristics of an individual pool were also investigated.
The results obtained in this study are summarized as follows:

- Low-flow channels develop as a consequence of the emergent bar formation which was caused by the concentration of flow to the pools of alternate bars. In case that the river bed level did not change because of the sediment supply, the emergent bars were considerably unstable and repeated appearance and disappearance. Then, the low-flow channels were shallow and fluctuated actively. On the other hand, in case that the river bed degradation progressed because of the cutoff sediment supply, the emergent bars were stable. Then, the deep and stable low-flow channels were formed.
- A riffle with a large head and a pool with a gentle gradient in gravel bed rivers were also found in low-flow channels which were shallow and fluctuated. Such riffle and pool sequence became stable in case that low-flow channel was deep and stable by means of the river bed degradation.
- An individual pool moved to the downstream when the riverbed level did not change, whereas it stopped when the low-flow channel became stable.
- The meandering wavelength of low-flow channel with river bed degradation was longer than that without it.
- The formation process of low-flow channels observed in the experiments was found to be reproduced by the numerical simulation in both types of sediment supply. However, the meandering wavelength of low-flow channel could not always be reproduced by the simulation.

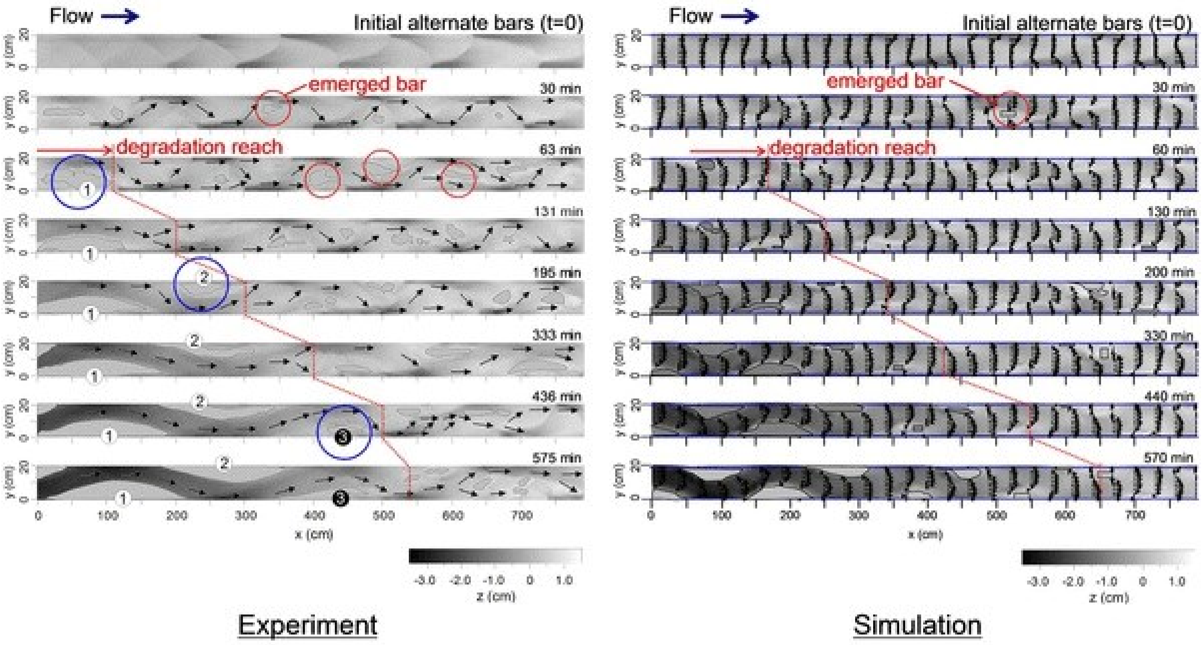

Figure 1. Low-flow channel formation under controlled sediment supply, as well as variation in bed topography.

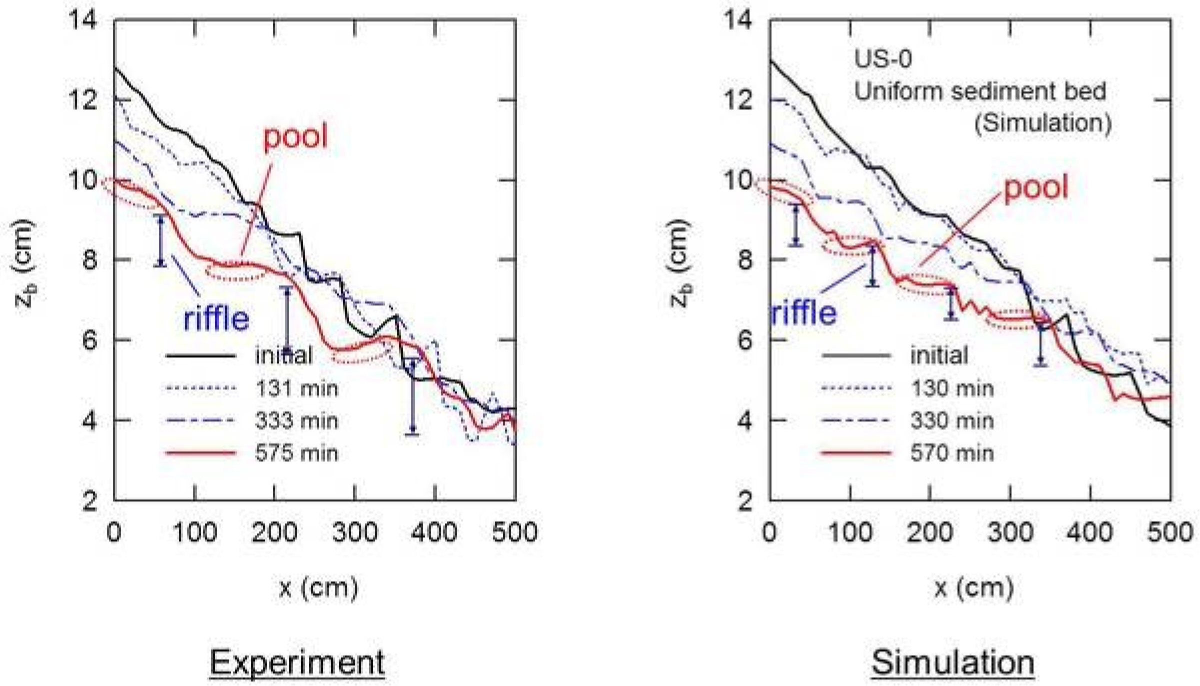

Figure 2. Longitudinal bed profile in low-flow channel formation process.

Morphological Changes of Reach Two of the Nile River

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Keywords: Morphology, Over topping, Erosion and sedimentation

The primary purpose of barrages is to raise the river water level and so provide additional head to the irrigation canals supplying the cultivated areas in Upper Egypt.
The Ministry of Water Recourses and Irrigation (MWRI) is constructing new barrages to replace the existing structures and so ensure the continued supply of water to the large irrigation areas downstream, and the new barrages incorporate a hydropower annex utilize the natural resource of the Nile River for hydropower generation, finally improve the navigation in the Nile River by constructed new locks.
For any new barrage there are probable negative impacts such as:

- Inundation of Agricultural land on river islands and areas adjacent to the river by overtopping.
- Impacts on river morphology by erosion and sedimentation.

This research will focus on studying the hydraulic impacts such as erosion, sedimentation and overtopping. For studying these impacts study area on the Nile River is determined between Esna barrage and Naga Hammadi barrage 192 km, at the period from 1982 to 2005. Two main sets of data were used in the analysis, included the contour maps for the Nile River bed between Esna and Naga Hanmmadi barrages for the year 1982 and 2005. Cross sections were deducted from these maps at space of 4 kilometers. These cross sections were used to compare the 1982 and 2005 cross sections in order to calculate erosion and sedimentation quantities of 26 cross sections which are selected along the study reach. On the other hand, cross sections of year 1982 were input to the numerical model GSTARS in order to predict the flow stage corresponding to different discharges along the reach and sediment routing was performed. Finally, 2005 cross sections were used to develop water surface profile and to map the overtopping areas by future discharge of 4051m3/s using topographic maps. 16 sectors were affected by overtopping and it could be noted that the total areas are 792.32 feddans were mapped the major areas are in river islands as 528.5 feddans are mapped.

First Results of Modelling Benthos Influence on Sediment Entrainment Using a Generic Approach within the MOSSCO Framework

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Keywords: Biological effects, Sediment transport, Abra alba, Microphytobenthos, MOSSCO

Flow and sediment transport can be significantly affected by the presence of benthic organisms. Benthos can have a stabilizing or destabilizing effect on the sediment erodibility, depending on their feeding, sheltering and locomotion behavior. The erodibility of sediment can be notably modified by the mucus produced by benthic organisms, for example, extracellular polymeric substances (EPS) secreted by microphytobenthos (Paterson 1997) or by means of bioturbation by epifauna and infauna. As a direct effect of benthic animals and macrophytes their protrusion in the boundary layer changes the bed roughness and thus bed shear stress. Wave and currents may be strongly damped due to a locally dense occupation of biota (Le Hir et al. 2007). Production of the fecal pallets and pseudo-feces by macrofauna results in aggregation of particles, changing the settling velocity. Graf und Rosenberg (1997) have shown that physical properties of marine sediments, such as porosity and permeability can also be modified by benthic infauna.

In the last decade, several process-based models have been developed, in which biological effects on the sediment transport have been parameterized as forcing variables (e.g. Wood et al. 2002, Knaapen et al. 2003, Paarlberg et al. 2005) or biological processes have been modeled using differential equations (François et al. 1997, 2002, Orvain et al. 2003, Orvain 2005, Montserrat Trotsenburg 2011, Orvain et al. 2012). However, according to Le Hir et al. (2007) mathematical models for a direct coupling of physical and biological processes, which include two-way feedbacks between biology and physics, do not exist yet.

To model these effects, a conceptual model has been developed which classifies biological impacts on sediment transport into stabilizing and destabilizing effects. These effects are further classified based on their area of influence (domain), i.e. near bed flow and sediment transport (bed roughness, suspended sediment aggregation, bed shear stress), bed surface (sediment erodibility, critical bed shear stress, bed sediment aggregation) and underlying sediment (redistribution of particles). For example, bioturbation by Macoma balthica has a destabilizing effect on sediment erodibility, which causes to increase erodibility and decrease critical bed shear stress. In contrast EPS secreted by microphytobenthos has a stabilizing effect resulting in increase of critical bed shear stress and decrease of erodibility.

The conceptual model offers the flexibility to include several species and their effects on sediment transport, once having been parameterized. To account for such flexibility, a software infrastructure was developed with a generic interface for macrofauna, microphytobenthos and macrophytes. Each newly defined species has to be a subclass of these three benthic fauna, which may have several methods for describing their individual effects on sediment transport. The biological effect of different species on the same sediment transport parameter, i.e. critical bed shear stress, is superimposed within the generic interfaces. The so-calculated benthos effects have been included in a sediment transport and hydrodynamic model via the modular coupling framework of MOSSCO (MOdular coupling System for Shelves and Coasts). This innovative modular framework integrates diverse models across physical domains from benthic to atmospheric components.

As a first step, stabilizing and destabilizing effect of typical species for the North Sea, macrofauna (Macoma balthica) and microphytobenthos, on critical bed shear stress and sediment erodibility have been considered. The effects of these species have been parameterized based on available data.First results of a sensitivity analysis on a 1D setup representing conditions at Helgoland in the German

Bight using this framework are presented successfully illustrating the contrasting effects of sediment stabilization and destabilization.

References

François, F.; Gerino, M.; Stora, G.; Durbec, J. P.; Poggiale, J. C. (2002): Functional approach to sediment reworking by gallery-forming macrobenthic organisms: modeling and application with the polychaete Nereis diversicolor. In: Mar. Ecol. Prog. Ser. 229, S. 127–136. DOI: 10.3354/meps229127.

François, Frédérique; Poggiale, Jean-Christophe; Durbec, Jean-Pierre; Stora, Georges (1997): A New Approach for the Modelling of Sediment Reworking Induced by a Macrobenthic Community. In: Acta Biotheoretica 45 (3/4), S. 295–319. DOI: 10.1023/A:1000636109604.

Graf, Gerhard; Rosenberg, Rutger (1997): Bioresuspension and biodeposition: a review. In: Journal of Marine Systems 11 (3-4), S. 269–278. DOI: 10.1016/S0924-7963(96)00126-1.

Knaapen, M.A.F. Holzhauser, H.; Hulscher, S.J.M.H. (2003b): On the modelling bilogical effects on morphology in estuaries and seas. In: Third IAHR Symposium on River, Coastal and Estuarine Morphodynamics, RCEM 2003, 13.

Le Hir, P.; Monbet, Y.; Orvain, F. (2007): Sediment erodability in sediment transport modelling: Can we account for biota effects? In: Continental Shelf Research 27 (8), S. 1116–1142. DOI: 10.1016/j.csr.2005.11.016.

Montserrat Trotsenburg, Francesc (2011a): Estuarine ecosystem engineering. Biogeomorphology in the estuarine intertidal. [S.l.]: [s.n.].

Orvain, Francis; Le Hir, Pierre; Sauriau, Pierre-Guy (2003b): A model of fluff layer erosion and subsequent bed erosion in the presence of the bioturbator, Hydrobia ulvae. In: J Mar Res 61 (6), S. 821–849. DOI: 10.1357/002224003322981165.

Orvain, F. (2005): A model of sediment transport under the influence of surface bioturbation: generalisation to the facultative suspension-feeder Scrobicularia plana. In: Mar. Ecol. Prog. Ser. 286, S. 43–56. DOI: 10.3354/meps286043.

Orvain, Francis; Le Hir, Pierre; Sauriau, Pierre-Guy; Lefebvre, Sébastien (2012a): Modelling the effects of macrofauna on sediment transport and bed elevation: Application over a cross-shore mudflat profile and model validation. In: Estuarine, Coastal and Shelf Science 108, S. 64–75. DOI: 10.1016/j.ecss.2011.12.036.

Paarlberg, A. J.; Knaapen, M.A.F.; Vries, M. B. de; Hulscher, S.J.M.H.; Wang, Z. B. (2005): Biological influences on morphology and bed composition of an intertidal flat. In: Estuarine, Coastal and Shelf Science 64 (4), S. 577–590. DOI: 10.1016/j.ecss.2005.04.008.

Paterson, D. M. and Black, K. S. (1999): Water flow, sediment dynamics and benthic biology. In: Advances in Ecological Research 29, S. 155–193.

Wood, Rose; Widdows, John (2002): A model of sediment transport over an intertidal transect, comparing the influences of biological and physical factors. In: Limnol. Oceangr. 47 (3), S. 848–855. DOI: 10.4319/lo.2002.47.3.0848.

Analysis on Historical Changes in River Morphology Influenced by Barrage Construction and Tributary Confluence

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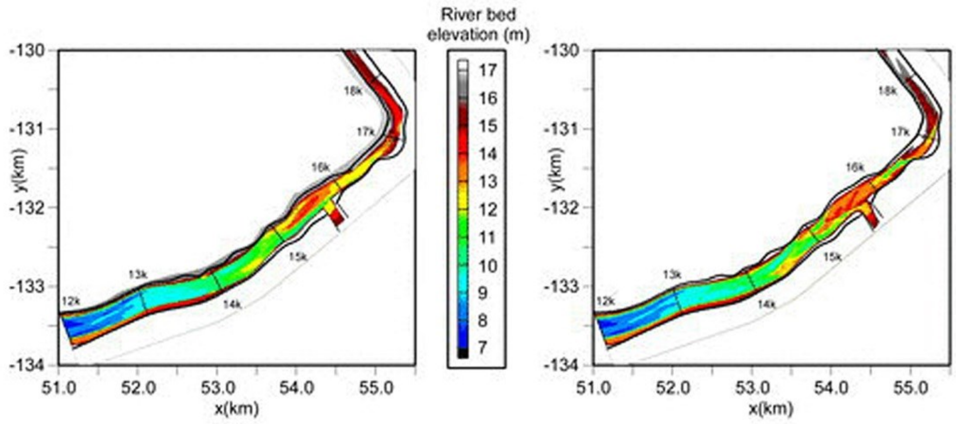
Keywords: River geomorphology, Sedimentation, 2D flow analysis, Ecological regime shift

Restoration, channelization and discharge control for flood management and water use frequently brings irreversible regime shifts in flow, sediment and ecological systems, which sometimes give negative impacts on the aquatic nature. Especially, the river management and restoration works that change the river morphodynamics cause unexpectedly significant changes in hydrodynamics, channel morphology, water quality, fluvial process and ecological structures of fauna and flora. In many cases after some river works, the quality of the river declined in the aspects of flow conveyance capacity, water use, landscape, ecological services, etc. The field site focused in this study is a reach of 12-18 km from the river mouth of Kako River. Kako River is a first-class river stretching through the southern region in Hyogo Prefecture whose total length and catchment area are 96km and 1,730km2, respectively. The Ministry of Infrastructure, Transportation and Tourism, MLIT, is in charge of river management, which provides us datasets of geomorphology, hydrology and restoration works that are necessary for the present analysis. The topic in this study is morphological changes in the last two and half decades especially after construction of the Kakogawa Barrage at a length of 12 km in 1987. The major impacts that may cause the regime shift in morpho- and hydrodynamics are formation of the reservoir by the barrage and confluence of a major tributary from the left bank. The engineering and ecological issues in this reach are formation of an island in front of the tributary mouth, main channel migration from the left to right bank around the confluence, vegetation overgrowth on emergent sandbars, erosion of the main channel and deposition on the floodplain, loss of spawning habitat for sweetfish or plecoglossus altivelis, water depth decrease in the area of regatta course and other issues. In order to examine the mechanism of the historical changes in river morphology as well as to discuss engineering countermeasures for reducing the negative impact on river environment, a numerical analysis on hydrodynamic and sedimentation processes was carried out by using an open source software, the "iRIC (international River Interface Cooperative) Software", developed under a bilateral cooperation between the USGS and the Foundation of Hokkaido River Disaster Prevention Research Center, Japan. The solver employed is the "Nays2D" that is capable of analyzing unsteady two-dimensional river flows and various scales of sedimentation processes. The analytical domain is a 6 km long reach including a major tributary joining from the left-bank side. The downstream boundary is placed at the Kakogawa Barrage and the upstream boundary is assumed at a cross section just at the upstream side of a meandering reach. Discharges were given at the upstream boundary and at the inlet of tributary. The water level at the barrage was given as a downstream boundary condition. In order to give a well-developed velocity and sedimentation flux at the upstream boundary, a virtual approaching reach connected to the upstream end was assumed. The historical records of water levels and discharges at the two gauging stations, grain size curves of sediment materials, Manning's roughness coefficients and cross-section profiles were provided by the MLIT. A general coordinate system and computational grids were automatically generated by using a module equipped in the iRIC. A preliminary computation was performed with varying numerical conditions in order to determine computational grid scale, dimensions of the virtual approaching reach and start-up duration of computation. Influence of sediment grain size distribution on the numerical solution was also examined by comparing the cases of mixed-size and uniform-size bed materials. The upstream boundary condition of bed load flux was given by computing sediment flux in the virtual approaching reach assuming an equilibrium state of bed load. The fact that the wash load is negligibly small in this reach was taken into consideration. The preliminary analysis suggested that the uniform-size sediment provided a good approximation in describing fluvial process in this reach. The analysis started in 1992

when the first cross-section survey after the barrage construction was carried out and finished in 2013. In all, a 21-year-long analysis was carried out.
An example of the numerical results is shown in the figure, which represents an analytical solution of the river bed profile in 2004 compared with that observed in the survey. Characteristic geomorphological features such as formation of an island at the tributary confluence of 15-16 km and an emerged sandbar development at the left bank side around 14.5 km are well reproduced by the present analysis. The latter reach corresponds to the regatta course where the water recently became shallower than the regatta draft. In order to find a hydrodynamic mechanism that is responsible for the geomorphological change, a short duration of fluvial process was also analyzed by investigating flow and sediment processes during several predominant flood events. Additionally, the influence of the two major impacts, i.e. reservoir formation and tributary confluence, was quantitatively investigated by performing a response analysis under two scenarios, that is, without the reservoir and without tributary. The present situation serves as a reference case in the response analysis.
The analysis can be applied for finding some countermeasures to minimize the undesirable geomorphological changes and to recreate a desirable river landscape. By using the analytical model, assessment of river works, for example, flow and sediment regulation by installing dikes, spurs and groynes, artificial modification of river morphology, etc., can be achieved. The best solution for a sustainable river management would be proposed in this manner.



(a) River bed profile observed in the cross-section survey in 2004.

(b) River bed profile in 2004 computed by the numerical model.

Seasonal Transfer and Net Accumulation of Suspended Sediment in the Yellow Sea and East China Sea

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Keywords: Seasonal transfer, Net accumulation, Suspended sediment, in the Yellow Sea and East China Sea

The Yellow Sea and East China Sea (YSECS) are wide shelf seas with seasonally variable hydrodynamic features, and relatively high suspended sediment concentration (SSC). The suspended sediments are mainly terrigenous with a large amount of nutrients and pollutants. These substances transfer and deposit, which impact greatly on the ecology and environment in the region.

The seasonal transfer and net accumulation of suspended sediment in the YSECS are studied using remote sensing time series data from SeaWiFS, historical field data on SSC, and numerically simulated circulation from ROMS (Regional Ocean Modeling System), which were processed for multi-year monthly mean dataset to demonstrate their climatological patterns. Generally, the circulation dominates the advection and long-term fate of suspended sediment in shelf seas, whereas the wave action and tidal currents govern re-suspension and vertical diffusion. This study would highlight the long-term transport of suspended sediment in the YSECS. Firstly, the suspended sediment flux (SSF) driven by the circulation in the YSECS was achieved using the method established by Pang et al. (2011). The comparison with Pang et al. (2011)'s result shows that the SSF has been probably upgraded by enhancing the accuracy of simulated circulation with the substitution ROMS for the POM (Princeton Ocean Model). Based on the SSF, monthly mean net deposition and annual accumulation rate with the horizontal resolution of 1/4 degree were calculated. Five representative sedimentation areas were selected to testify the validity of the SSF, additionally quantify the annual accumulation rate by comparing with the measured data derived from the previous studies.

The suspended sediment flux driven by the circulation in the YSECS, which excluded the wave motion and tidal currents with short time scales (from seconds to hours), was attained via retrieval of SeaWiFS remote sensing data, statistical analysis of historical SSC data, and 3D ROMS numerical simulation of circulation velocity. The horizontal resolution of the SSF was 5' * 5'and the same as the ROMS numerical simulation for circulation. Due to resolution-dependent constraints, the resolution of net deposition or erosion in the YSECS was assumed as 15' * 15'. The monthly mean net deposition (positive) or erosion (negative) at each model grid was defined as the sum of the differences of SSF between two adjacent sections in the X and Y directions. The calculated results on deposition or erosion in the YSECS manifest that during the summer half-year (from May to Oct.), significant deposition (> 0.1 ton/s) only occurs near the coast, especially the Jiangsu coast and Changjiang Estuary, while during the winter half-year (from Nov. to next Apr.), significant deposition occurs not only near the coast, but also offshore areas with water depth >100 m, such as the East China Sea Cold eddy area, which is acknowledged as the only mid-shelf modern depocenter in the YSECS.

Five representative locations (2° * 2°) are chosen depending on their hydrodynamic features. No.1: East China Sea Cold eddy area (31°-33°N, 125°-127°E), No.2: cross-shelf sediment transport pathway, No.3: center of the southern Yellow Sea, No.4: Changjiang Estuary, No.5: Zhejiang Coast. The monthly mean net deposition of suspended sediment (See Table 1.) generated just by the circulation at five subareas implies the distinctive seasonal variation with high deposition in winter and low in summer except for the Changjiang Estuary, which is consistent with the viewpoint of riverine suspended sediment storing inshore in summer and transporting to offshore in winter in the YSECS.

Table 1. Monthly mean net deposition (ton/s) and annual accumulation rate (mm/yr) of suspended sediment at five representative locations in the YSECS.

No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Net deposit	Accumu. Rate
1	2.55	5.51	6.04	1.42	0.33	-0.2	-0.3	-0.3	0.02	0.32	1.60	3.56	20.6	0.51
2	6.90	3.27	2.36	1.28	0.78	0.39	0.42	0.25	0.61	0.40	0.78	1.12	18.6	0.45
3	-0.7	-0.3	0.31	0.54	0.23	0.28	0.35	0.60	0.58	0.33	0.01	-0.4	1.8	0.04
4	-0.6	15.3	9.72	17.1	13.8	21.9	25.3	12.8	5.31	9.22	4.87	13.1	147.7	3.62
5	24.5	28.2	12.3	9.65	5.67	3.41	4.04	3.14	10.5	13.2	17.6	24.1	156.2	3.83

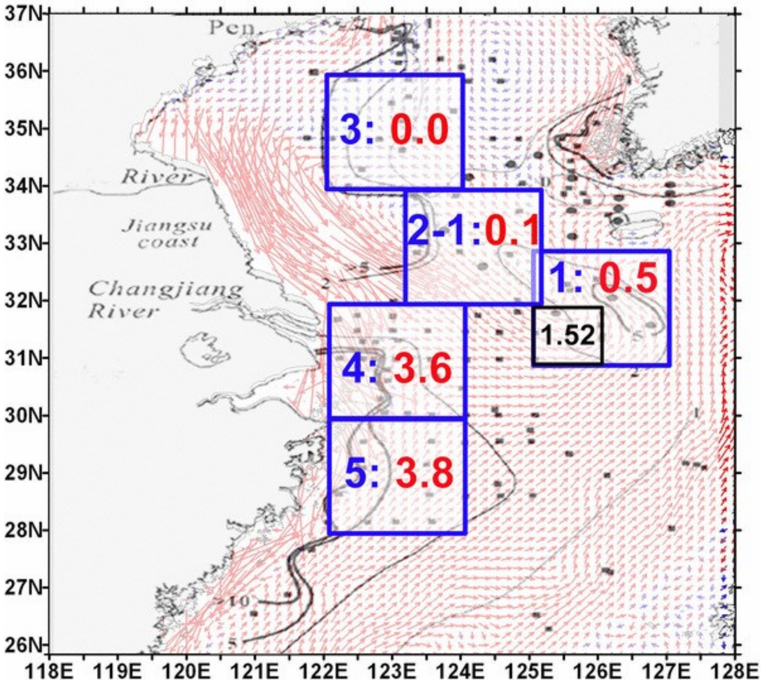

Figure 1. The location of five subareas and their annual accumulation rates (in red numbers) in the YSECS.

The arrows show the SSF vectors in January. The contour is the annual accumulation rate (mm/yr) described by Lim et al., 2007.

The annual accumulation rate (Table 1 and red numbers in Figure 1) at five representative locations, which is the sum of all seasons (unit: mm/yr), displayed that the highest rate existed at the Changjiang Estuary (No. 4 subarea) and the Zhejiang Coast (No. 5 subarea) due to the abundant sediment supply from the Changjiang River, the lowest rate being at the center of the southern Yellow Sea (No. 3 subarea) due to the far distance from the coast and almost no arrival of sediment. Just a little sediment accumulated annually at the cross-shelf pathway (No. 2 subarea), which was defined firstly by Yuan et al. (2008). Additionally, the location of west boundary of No. 2 subarea which was near the suspended sediment sources, was crucial to calculating the net deposition, thereby the accumulation rate at named as No. 2-1 subarea would be 0.11 mm/yr if the west boundary moved 10’ eastward, whereas the rate at No. 2-2 subarea would greatly increase to 0.76 mm/yr if it moved 10’ westward. Although the East China Sea Cold eddy area (No. 1 subarea) was farther away from the coast, and deeper than 100 m, its accumulation rate was not the lowest. Furthermore the rate in the southwestern part of No. 1 subarea which was indicated as No. 1-1 subarea, even could reach to 1.52 mm/yr. During the winter half-year (from Nov. to next Apr.), under the action of winter monsoon the re-suspended sediment derived from the Old Huanghe Estuary was delivered by the Yellow Sea Coastal Current across the shelf, and subsequent route to the No. 1 subarea, where the re-suspended sediment was caught and convergent by the East China Sea Cold eddy, eventually accumulated.

As shown in Fig. 1, the estimated accumulation rates only driven by the circulation in the YSECS agreed with the measured ones (presented in Lim et al., 2007) reasonably well. Nevertheless, the discrepancy might be yielded by the inaccuracy in simulated circulation, and the other excluded dynamic controlling factors, for example wave motion and tidal currents.

References

Pang C. G, Yu W, Yang Y, and Han D. X. 2011. An improved method for evaluating the seasonal variability of total suspended sediment flux field in the Yellow and East China seas. International Journal of Sediment Research, 26(1): 1-14

Lim D. I, Choi J. Y, Jung H. S, Rho K. C, and Ahn K. S. 2007. Recent sediment accumulation and origin of shelf mud deposits in the Yellow and East China Seas. Progress in Oceanography, 73: 145-159

Yuan D. L, Zhu J. R, Li C. Y, and Hu D. X. 2008. Cross-shelf circulation in the Yellow and East China Seas indicated by MODIS satellite observations. Journal of Marine Systems, 70: 134-149

Morphodynamic Evolution in the Mouth of the Elbe Estuary: Effects of the Training Wall Construction "Kugelbake"

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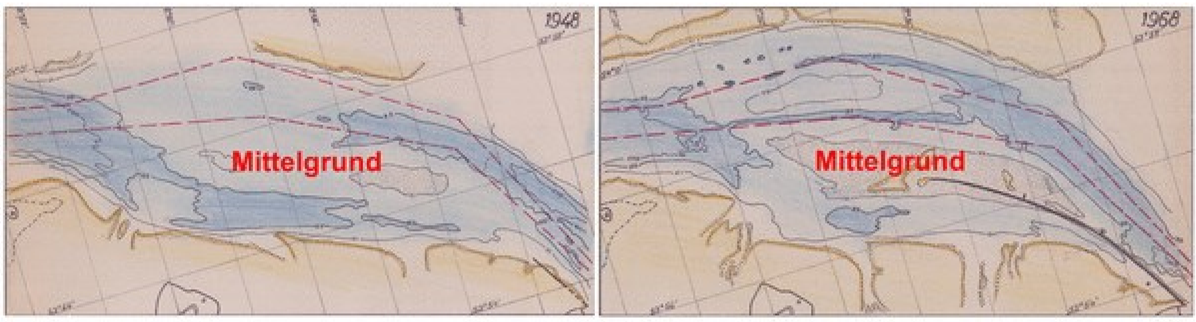
Keywords: Morphodynamics, Training wall, dam, Construction, erosion, Sedimentation, Elbe estuary

The mouth of the Elbe estuary is one of the most morphodynamic active regions in the German Bight. Furthermore the fairway in the mouth of the Elbe is a major gateway for container ships connecting the harbor of Hamburg to the world. Hence it is important to investigate the effect of man-made measures in terms of the morphodynamic reaction.
Between 1950 - 1973 and 1975 - 1978 the "Kugelbaken"-dam was constructed in the mouth of the Elbe estuary. The reason was to prevent the delta-like opening of the Elbe estuary from developing a naturally formed "three channel" configuration. This has also been observed in the adjacent outer Weser-estuary.
After finishing the main dam for a length of about 10 km and several short cross-groynes, morphological reactions have been observed in the vicinity. Amongst other reasons, the construction resulted in a deepening of the main channel and the development of many scours around it.
Many efforts are needed to sustain the current configuration of the dam and the local bathymetry, which is mainly accomplished by dumping of dredged material near the dam and repairing the rock-fill embankment.



bathymetry situation before (1948) and after dam construction (1968)

Scope
The present study compares conditions before the construction was done (1948) and the situation after finishing the dam building in the 1950-ies. Both states are analyzed and modelled with respect to the development of the different bathymetric conditions.
Additionally the subsequent adaptation of the bathymetry, which means the morphological changes, is analyzed based on a timevariant digital bathymetric model.
Process-based hydro-morphodynamic model studies have been done to demonstrate cause and consequences of the dam building in the past.
Moreover, as the functionality of the dam is still questioned today, process studies are performed in representing a dam failure or the removal of the dam at all.

Procedure
In a first step the reasons and the natural consequences of the construction in 1950 is evaluated. Therefore, a bathymetry was implemented which has been reconstructed from historic sea charts. Based on this topography a numerical model is run to obtain the hydro-morphodynamic conditions at that time.

The following reaction of the bottom was monitored via echo soundings. Herein, the migration and morphodynamic changes of channels, gullies and wadden areas are well documented. The data collection and analyzing are needed to build up a basis for calibration of the following morphodynamic model runs.
The second step calculates the consequences of a failing of the dam, either for some parts of the whole structure or the removal of the whole dam. Here, the main question is: Will the adjacent tidal flats retreat and how will small trenches and channels react after that event? Several morphodynamic calculations with different scenarios will be carried out and documented.
The numerical basic concept for both approaches is to set up a model, which comprises the tidally influenced area of the Elbe estuary and a seaward part which is far away from the construction und investigation.
A detailed analysis of bathymetric and sedimentological changes will complete the predictions from the hydrodynamic and morphodynamic calculations.

Conclusion

This modelling concept is a first attempt to evaluate the sustainable impact / morpho-dynamic reactions after constructing a large dam in the branching mouth of an estuary. The dam comprises a length of about 10 km and several groynes and is located directly beneath the fairway.
The scenarios presented here provide a basis to consider the effectiveness of dam-constructions in the mouth of an estuary at all. Beyond that, the effects of a (partial) failure in the dam structure are documented.

A Coupled Sediment Transport Model for Flow over Movable Bed

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Keywords: Sediment-transport, Dam-break, Finite volume method, Coupled model, Approximate Riemann Solvers

A numerical approximation for bed load sediment transport due to shallow-water flows is studied. Flows over an erodible bed are solved by assuming that the dynamics of the bed load problem is described by two mathematical models: the hydrodynamic model, represented by the depth integrated shallow-water equations, and the morphological model: Exner equation. The model solves the coupled shallow-water and Exner equations, with the interface fluxes evaluated by a Harten-Lax van Leer-Contact (HLLC) approximate Riemann solver for hydrodynamic part and HLL scheme for morphological part. The domain is discretized by triangular grid system which facilitates representing complex domains. A special treatment of the source terms by surface gradient method makes the scheme stable and physically balanced. The model employs Godunov- type finite volume algorithm, with second-order accuracy in space and time. Spatial second-order accuracy is guaranteed by employing multidimensional gradient reconstruction method; and predictor-corrector scheme is used to ensure a second-order accurate solution in time. Finally, some numerical tests are presented to verify the applicability and accuracy of the proposed numerical model.

Analysis of Morphodynamic Processes in Coastal Areas by Image Processing Methods Applied to Multibeam Data

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Keywords: Morphodynamics, Multibeam Sonar System, Image Processing, Structure Tensor

Introduction

The precise and highly resolved mapping of underwater bathymetries using multibeam or side-scan sonar systems has become the observational standard in the last decade. In shallow coastal waters, this allows the understanding of the dynamics of underwater dunes over scales ranging from meters to several km depicting very clearly the highly non-linear nature of the underlying processes of the bed sand transport. Lefebvre et al. (2011) obtained first results with spectral methods, assuming spatial homogeneity. Still, the full potential of full two-dimensional information has not been exploited so far. A Digital Terrain Model DTM may be regarded as an image with the water depths as grey values. There exist now a broad range of robust image processing algorithms that have been applied for many applications in science and industrial manufacture (Jähne, 2004). They allow, among others, the decomposition of the image in different scales and directions, the measuring local and global features of structures or the significance of features by calculating their magnitude of coherence, making them very interesting for the study of morphological features. In this paper we demonstrate for the first time the rigorous application of a number of image processing tools on coastal shallow water DTM's. Study Area

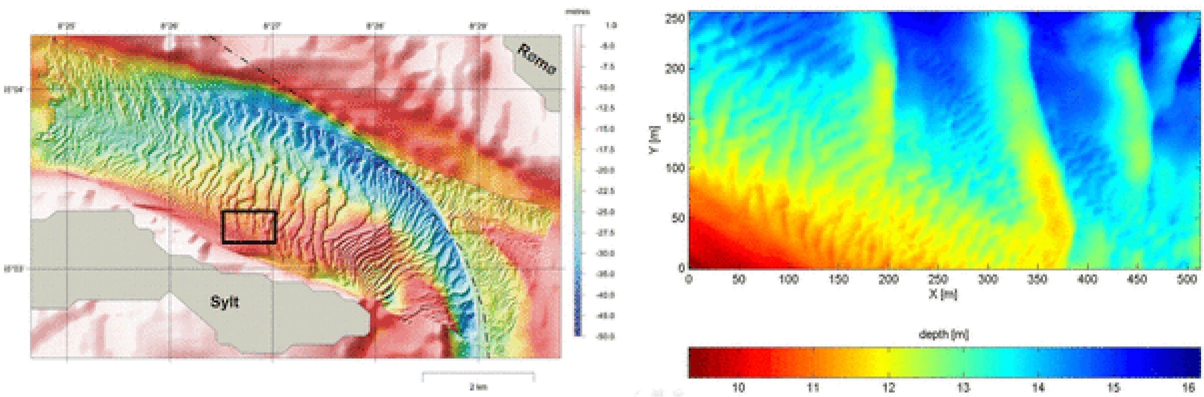

Figure 1. Left panel: DTM of the Lister Deep from a mapping survey in June 2008; Right panel: Subarea with three large ripples outlined in the digital elevation map (left). The applied image processing algorithms are tested on this subarea.

The Lister Deep, outlined in Figure 1 is a tidal inlet that separates the North Frisian islands of Sylt and Romo located in the Southern North Sea. The typical water depth along its central axis is 25 m, tidal range is in the order of 2.5 m and ebb and flood currents approach nearly 2 m s-1. The region is characterised by strong morphodynamical activity beaches. Cliffs on its western side of Sylt and particularly at the northern and southern hooks of the island are eroded during heavy storms. Stabilisation of the coastlines requires regular and significant sand nourishment to attenuate and buffer high wave energy. It is assumed that the eroded sand is mainly transported towards North, but the transport pathways, the actual transport volumes across the Lister Deep and their temporal patterns are still very little known. Between 2001 and 2009, a number of multibeam surveys in the Lister Deep yielded a number of high precision Digital Terrain Models (DTM) of the seabed. From these, three main sand transport domains were identified: (1) its southern part characterised by continuous and transversal dunes of 100 m length, more than 5 m height and W-oriented stoss sides indicating flood current and sand transport dominance; 2) its northern part with similar dunes, but the stoss sides oriented in the opposite direction indicating ebb dominance; (3) its central inner part marked in the

North/North East by a steeply inclined, major erosional scar. In addition, smaller scale dunes with orientations inclined by up to 45 degrees overlay the large transport bodies pointing to a different geophysical mechanism of emergence.

Image Processing Methods and Results

The DTM of the Lister Deep shows nicely the spatial variation of the underwater sand dunes dominant length scales, orientations and asymmetries. From the image processing point of view, these multi-scale features require decomposition in spatial scale and orientation. Possible methods are provided by wavelet and image pyramid analysis. In this paper the results are obtained with a Laplace pyramid. A Laplace pyramid essentially is a sequence of bandpass filter applied to a sequence of down-sampled versions of the original image, i.e. a fine to coarse scale scheme. The orientations of the crests of the sand dunes are estimated using the structure tensor method. The orientation angle is defined to be perpendicular to the local gradient vector.

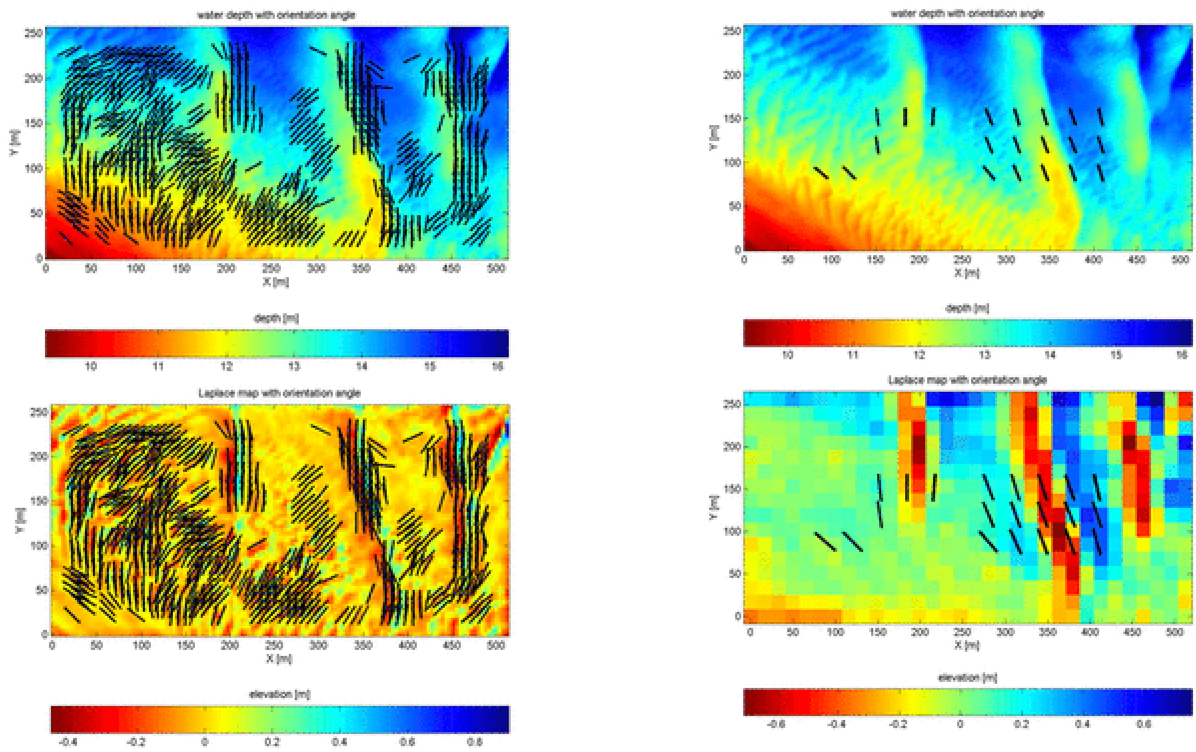

Figure 2. Orientations of the underwater sand dune crests calculated on a fine (left: Laplace pyramid level 2) and coarse (right: Laplace pyramid level 4) spatial scale. The calculated orientations are indicated as lines, which are mapped on the original DTM (top) and on the corresponding pyramid levels (bottom).

The characteristic length scales are estimated from the local gradient of the image phase which is retrieved from the DTM using a two-dimensional Hilbert transform.

The movement of the dunes is calculated from the spatial pattern shift of the features from a sequence of two DTMs taken within a time distance below their propagation period. The applied technique is the optical flow analysis, that determines the difference of the image phases, interpreted as phase speed, by assuming a nearly conservation of grey values from image to image, i.e. a persistence of dune forms over time.

Summary Outlook

It was shown that image processing methods are appropriate for the retrieval of quantitative measures, i.e. orientation angle, length scales and phase speed of the morphodynamic features. As an example it was demonstrated that the orientation of small and large scale dune structures deviate from each other. Other quantities are the characteristic feature length scale and phase speed. A further parameter of relevance is the spatial asymmetry For the estimation of this parameter the authors have obtained first promising results.

References

Lefebvre, A., Ernstsen V. B. and Winter, C., Bedform characterization through 2D spectral analysis. Journal of Coastal Research, SI 64 (Proceedings of the 11th International Coastal Symposium), 781-785, Szczecin,
Poland, ISSN 0749-0208, 2011.

Jähne, B., Practical Handbook on Image Processing for Scientific and Technical Applications, Second Edition,
CRC Press, 2004.

Numerical Study of Morphodynamics and Ecological Parameters Following Alternative Groyne Layouts at the Danube River

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Keywords: Numerical model, Sediment transport, Bed load, Groyne, Ecology, Danube River

A comprehensive numerical study of the impact of different groyne layouts and shapes on the flow field as well as morphodynamic and ecological conditions at the Danube River in Austria is presented. Two sections of the river located between Vienna and Bratislava, ranging between 2 and 4 km in length, served as study sites. In general, the river bed at the study sites is characterized by a long-term degradation rate of 2-3 cm per year, hence various measures were initiated to stabilize the river bed and improve the navigation conditions as well as the overall ecological situation (Habersack et al., 2012). In order to study their influence on hydrodynamics, morphodynamics and fluvial ecology, the parameters groyne length, groyne spacing, base shape and crest elevation were varied within reasonable bounds in a 3D numerical model. Moreover, the impact of groyne inclination was studied by investigating attracting, orthogonal and repelling groynes. In an additional analysis, the groyne root was lowered to create an artificial nearshore bypass channel.
Hydrodynamics were calculated using the numerical code RSim-3D (Tritthart, 2005) which solves the Reynolds equations by means of the Finite Volume Method on a mesh of arbitrarily shaped polyhedrons. Sediment transport and morphodynamic simulations were performed with the model iSed (Tritthart et al., 2011), which was specifically developed to compute non-uniform sediment transport in gravel-bed rivers based on the underlying hydrodynamics being delivered by an external model. The iSed model calculates suspended sediment transport and bedload transport in separate modules. Moreover, an arbitrary number of bed layers can be used in the model. Both the hydrodynamic model as well as the sediment transport model were calibrated and validated using extensive data sets from various field measurement campaigns conducted at the study sites since the year 2005. The ecological assessment of the groyne impact was performed by means of a water age analysis based on particle tracing methodology (Tritthart et al., 2009), complemented by the application of a mesohabitat evaluation model (Hauer et al., 2011).
It was found that an increase of the groyne length as well as a decrease of the groyne spacing lead to rising water levels, thereby benefiting navigation. However, these measures also increase bedload transport rates, resulting in substantial erosion at the center of the river. From an ecological perspective, the measures reduce exchange processes between river and groyne fields, thus increasing water ages. In turn, a sedimentation effect in the fairway is obtained by an increase of the groyne spacing and a reduction of the groyne length. This also corresponds to an increase of mass exchange between river and groyne fields due to the occurrence of two gyres instead of one. Further, also groynes in orthogonal and repelling layouts initiate substantial erosion in the center of the river while attracting groynes cause sedimentation. Moreover, it was found that the highest sensitivity of all groyne parameters in terms of morphodynamic processes is exhibited by the crest elevation. Therefore it can be concluded that an optimization of the crest elevation is essential for achieving the aim of a dynamic equilibrium of the river bed.

References

Habersack, H., Liedermann, M., Tritthart, M., Hauer, C., Klösch, M., Klasz, G., Hengl, M. (2012). Maßnahmen für einen modernen Flussbau betreffend Sohlstabilisierung und Flussrückbau - Granulometrische Sohlverbesserung, Buhnenoptimierung, Uferrückbau und Gewässervernetzung. Österreichische Wasser- und Abfallwirtschaft, 64 (11): 571–581.

Hauer, C., Unfer, G., Tritthart, M., Formann, E., Habersack, H. (2011). Variability of mesohabitat characteristics in riffle-pool reaches: Testing an integrative evaluation concept (FGC) for MEM-application. River Research and Applications, 27 (4): 403–430.
Tritthart, M. (2005). Three-dimensional numerical modelling of turbulent river flow using polyhedral finite volumes. Wiener Mitteilungen Wasser-Abwasser-Gewässer, 193: 1–179.
Tritthart, M., Liedermann, M., Habersack, H. (2009). Modelling spatio-temporal flow characteristics in groyne fields. River Research and Applications, 25 (1): 62–81.
Tritthart, M., Schober, B., Habersack, H. (2011). Non-uniformity and layering in sediment transport modelling 1: Flume simulations. Journal of Hydraulic Research, 49 (3): 325–334.

Large-Scale Sediment Inflow and Bed-Variation from 12th Typoon (2011) in the Asahi River Basin

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Keywords: Sediment inflow, Sediment transport, Debris flow, Slope failure, Numerical model, Stony-bed river, Bed variation, Grain size distribution

A heavy rainfall from 12th typhoon (2011) generated large-scale floods and slope failures in the Asahi River basin. Sediment supply to the Asahi River due to slope failures changed the channel shapes and grain size distributions of the river bed remarkably in the short period of time. Estimation of the amount of the sediment supply of the debris flows by slope failures and understanding of sediment transports during the flood are important problems for the river management.
Figure 1 shows plan form of the Asahi River basin. The Asahi Dam is located at about 6.0km point of the Asahi River. The sediment flushing bypass tunnel indicated by the red line in Figure 1 was constructed to mitigate the long-term turbid water and reservoir sedimentations in the Asahi Dam reservoir.
The Asahi River is a stony-bed river with a wide range of grain-size distributions. Osada et al (2012) investigated the recovery mechanism of riffles and pools and flushing mechanism of reservoir sedimentation by using the two dimensional flood flows and bed variation analysis in stony-bed river. However, the sediment inflows from mountain streams were not considered in this model, because the flood discharge was relatively small compared with the 2011 flood comparable to three times of the annual maximum flood discharge. The slope failures and debris flow simulation model to estimate the sediment inflows from mountain streams has been proposed by reserchers. In this study, the sediment runoff due to the slope failures was calculated by the kinematic wave runoff model and slope failure model using infinite slope stability analysis. The sediment supply from mountain stream was simulated by using debris flow equations which correspond to each regime such as debris flow, immature debris flow, and bed load (Takahashi, 2001; Ichikawa, 1999). They were combined with the two dimensional flood flows and river bed variation analysis model(Osada et al., 2012) to clarify the relationship between flood flows and sedimet transports including the large amount of sediment supply of debris flows in the Asahi River basin during the 2011 floods.
Figure 2 shows the longitudinal distributions of the average and deepest elevations of the river bed observed before and after the flood. Large-scale slope failures was identified at the Miya valley which flow into the river channels at about 4.0km point (see Figure1). The average river bed elevations increased about 1.5m and deepest river bed elevations increased about 3.0m around the exit of the Miya valley.

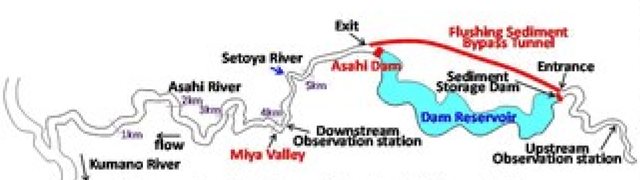

Figure 1 Plan form of the Asahi River basin

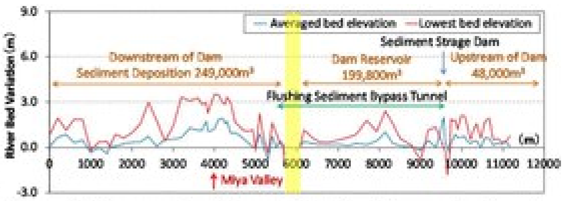

Figure 2 Averaged and Lowest bed elevations and sediment deposition

Figure 3 shows the observed hourly rainfall and calculated sediment runoff volume by the slope failures. The hourly rainfall more than 10mm/hr continued about three days in the 2011 floods. The slope failures were caused at the third peak of the rainfalls and the sediment runoff volume was estimated about 215,000m^3.

Figure 4 shows the calculated sediment inflow from the Miya valley to the Asahi River, and its total volume. The total volume of the sedement inflow was estimated about 195,000m^3. The total volume of sediment inflow is equivalent to about 78% of volume of the sediment deposition in the river channel at the down stream of Asahi Dam (249,000m^3, see Figure 2).

Figure 5 shows the comparison between the calculated and observed river bed variation contours before and after the flood. The height of the calculated sediment depositions was about 1.0m lower than the observed one through the area shown in Figure 5. However, the calculated bed variations reproduce the sediment depositions trends of the observed data, especially the sediment depositions and temporal river channel blockade around the exit of the Miya Valley.

The calculated volume through the sediment bypass tunnel was 17,3000m^3. It is equivalent to about 87% of volume of observed reservoir sedimentation (199,800 m^3, see Figure 2).

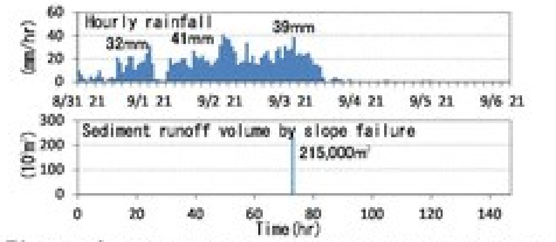

Figure 3 Observed hourly rainfall and calculated sediment runoff volume at the Miya Valley

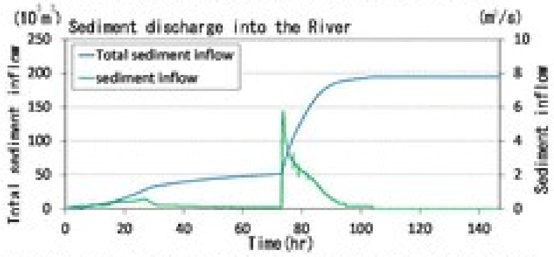

Figure 4 Calculated sediment inflow from the Miya Valley

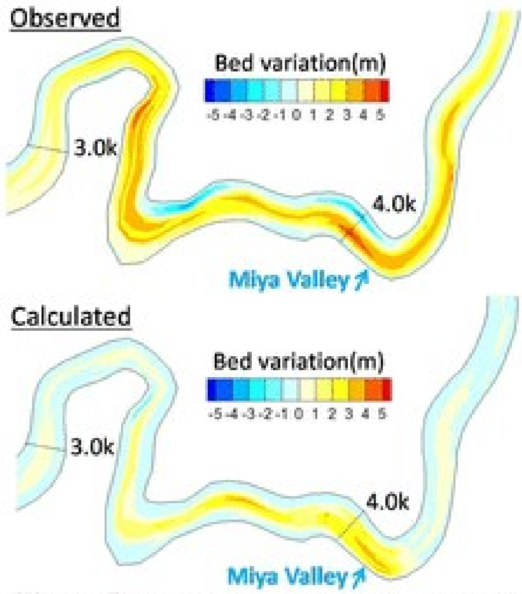

Figure 5 Comparison between calculated and observed river bed variation(After the flood)

From these results, we clarified the sediment transports mechanism including the large sediment supply of the debris flows due to the slope failures in the Asahi River basin during the 2011 flood. It was shown that the flushing sediment bypass tunnel effectively mitigated the reservoir sedimentation.

References

Takahashi T., Inoue M,. Nakagawa H and Satofuka Y.: Prediction of Sedimentation Process In A Reservoir using a Sediment Runoff Modell, Annual Journal of Hydraulic Engineering, JSCE, Vol. 45(2001), pp. 841-846.

Ichikawa Y., Satoh Y,. Shiiba M,. Tachikawa Y and Takara K.: Development of Water and Sediment Flow Model for a Mountains Area, Prev. Res. Inst., Kyoto University, 42 B-2, pp. 211-224, 1999.

Osada K., Fukuda T,. Yamashita K. and Fukuoka S.: Study on Flushing Mechanism of Dam Reservoir Sedimentation and Recovery Riffles-Pool in Downstream Reach by a Flushimg Bypass Tunnel, Annual Journal of Hydraulic Engineering, JSCE, Vol. 56(2012), pp. I_1105-1110.

Medium Term Time-Dependent Morphodynamic Modelling of Beach Profile Evolution in Ada, Ghana

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Keywords: XBeach, Numerical model, Profile model, Morphodynamics, Cross-shore erosion, Ghana

Ada Foah and other surrounding villages located at the east coast of Ghana have been suffering from ongoing erosion for a very long period of time. The Ghanaian government decided to protect the coast in Ada with a combination of groynes and beach and dune nourishments. Hydrodynamic and morphological modelling has been undertaken to obtain better insight in the governing coastal processes and to support the design of the coastal protection.

A process based time-dependent morphodynamic model, such as Xbeach, has been used for this purpose. Xbeach has been proven to reproduce and predict morphological changes during storm conditions (on a time scale of hours or days) and has been developed based on wave climates and beach properties similar to the Dutch coast (Roelvink et al., 2009). In the study for Ada a longer time scale of one year is envisaged to analyse the coastal protection design. The beach is also located in a different hydrodynamic environment dominated by swell waves (IMDC, 2013).

Therefore a 1DH Xbeach model has been applied to examine the profile evolution of a beach cross-section in the project area after a one year wave climate including normal to lower extreme waves. As Xbeach tends to overestimate erosion and underestimate accretion, especially for mild wave conditions (Van Rooijen, 2011), the calculations are not intended to reproduce exact erosive and accretive conditions during the one year cycle but rather reproduce the overall beach shape and slopes evolution. Results are compared with the measured equilibrium beach. The relevant processes and key parameters to capture the evolution have been investigated and parameter settings have been calibrated. This investigation included a sensitivity analysis of wave conditions, tidal currents and grain sizes on the sediment transport. Parameters known to impact the cross shore transport that are examined are wave asymmetry/skewness (Pender and Karunarathna, 2013), dune avalanching triggers (Splinter and Palmsten, 2012) and the applied wave breaking module. An extra benefit could be achieved by activating the groundwater module.

Beach profile evolutions after one year based on different parameter settings for wave asymmetry and wet slope are presented in Figure 1. This figure shows that the default parameter settings in Xbeach (run01) lead to an overestimation of erosion to the point where it is unrecognizable from the initial profile. Calibrating the key parameters leads to a better simulation of the profile variability with more realistic foreshore slopes and berm developments (run02). The use of the superfast mode in Xbeach seems justified (run03). The final calibrated parameter settings have been used by other studies in the project. Further improvements have been found in applying the groundwater module where a more stable profile has been found using different conductivity parameters (run03 and run04 in Figure 1).

This paper will support research in coastal sustainability by presenting the use of a process based morphological model on a longer time scale and the governing parameters to apply it under different conditions.

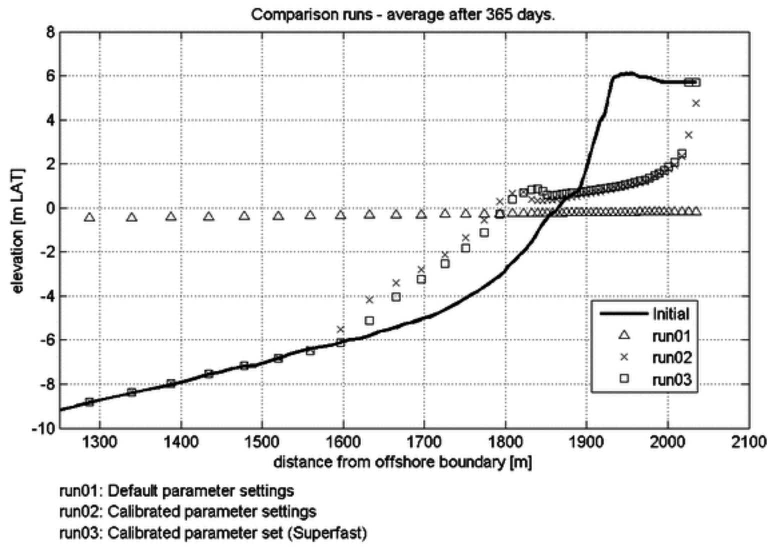

Figure 1. One year evolution of the beach profile based on the default Xbeach parameter settings (run01), the calibrated model (run02) and its superfast version (run03).

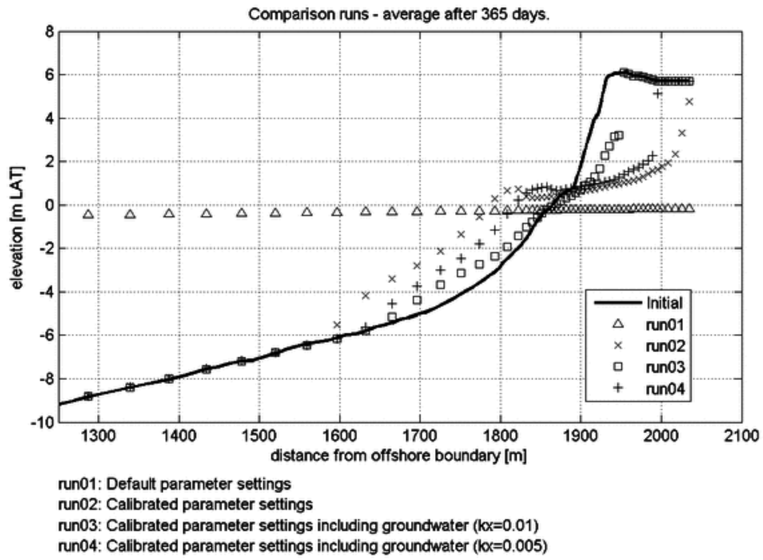

Figure 2. One year evolution of the beach profile based on the default Xbeach parameter settings (run01), the calibrated model (run02) and applying the groundwater module with differenct conductivity parameters (run03 and run04).

References

IMDC (2013). *Ada Coastal Protection Works Phase II: Wave Modelling*, RA13159, v1.0.

Pender, D., Karunarathna, H. (2013). *A statistical-process based approach for modelling beach profile variability*. Coastal Engineering, Vol. 81, p 19-29.

Roelvink D., Reniers A., van Dongeren A., van Thiel de Vries J., McCall R., Lescinski J. (2009). *Modelling storm impacts on beaches, dunes and barrier islands*, Coastal Engineering, Vol. 56, p.1133-1152.

Splinter K.D., Palmsten M.L. (2012). *Modelling dune response to an East Coast Low*, Marine Geology 329–331, p. 46–57.

Van Rooijen A.A., (2011). *Modelling Sediment Transport in the Swash Zone*, Msc Thesis, Delft University of Technology, Delft, The Nederlands.

A Laboratory Study for Gravity Erosion of the Steep Loess Slopes under Intense Rainfall

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Keywords: Slope landform, Landslide volume, Topography Meter, Laboratory test

Gravity erosion is a common and destructive phenomenon in mountainous areas throughout the world, especially on the Loess Plateau of China. Nevertheless lacking of measurable data has become a huge obstacle for the study of gravity erosion due to limited observation techniques. This study closely simulates the gravity erosion processes of 7 model slopes with different slope gradients and heights, and quantitatively observes the amounts of collapse, landslide, and mudflow, respectively. An experimental model landscape, with the steep slope of 60o–80o and a gentle slope of 4o, was developed. 5–10 events of rainfall events, with an intensity of 2.0 mm/min and the duration of 30 min, were applied on the slope in turn. The Topography Meter was used to monitor motion of the surface of the failure mass under rainfall simulation. Erosion data during rainfall event were calculated according to the videos caught by the Topography Meter, including the volume of each slided mass, the total amount of soil loss eroded by overland flow, etc. The experimental result is shown as follows: 1) The form of the gravity erosion was decided by the slope gradient of the gully wall. For the initial slope with same height but different gradient, when the slope became precipitous, the amount of collapse might grow and the amount of landslide might decrease. Especially when the slope gradient was between 70° and 80°, the amount of gravity erosion would be more sensitive to the slope gradient. 2) For the slopes with the same height, the amount of collapse increase with the enlargement of the slope gradient, but the amounts of landslide and the total gravity erosion are different. For the slope with the height of 1.0 m, when the slope gradient rose from 60° to 70°, the amounts of collapse, landslide, and the total gravity increased 74.7%, -93.7%, and -53.6%, respectively. Nevertheless, when the slope gradient rose from 70° to 80°, the amounts of collapse, landslide, and the total gravity increased 163.4%, 342.2%, and 182.0%, respectively. 3) For the slopes with the same slope gradient, the amount of collapse increase with the enlargement of the slope height, but the amounts of landslide and the total gravity erosion are different. When the slope height rose from 1.0m to 1.5m, for the slopes with the gradients of 60°, 70°, and 80°, the amounts of collapse increased 52.8%, 184.9%, 18.2%, the amounts of collapse increased -28.4%, 463.8%, 74.8%, the amounts of collapse increased -9.1%, 213.9%, 27.4%, respectively. 4) As the loess gully wall is eroding, the amount of gravity erosion is jointly impacted by the water content and the landform. The latter includes the slope gradient, height, and broken degree, etc. 5) for the same initial landform, the slope gradient will become gentle as the rainfall events continue, and thus the amount of landslide will increase but the amount of collapse will decrease.

Analysis of Some Common Theoretical and Empirical Relationships between Sinking Velocity of a Sediment Particle as a Function of Particle Size and Water Temperature and Development of new Empirical Nonlinear Regression Equations

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Keywords: Sediment transport, Fluid flow, Settling velocity, Empirical equation

One of the most important problems in irrigation canals is sedimentation of floating particles which, in the long-run may inhibit the canal's flow debit. Up-to-date the sedimentation science argues about the proper laws that govern the physics of the sedimentation process, namely, the sinking velocity vs of a particle in a fluid flow, which is very much determined by the interaction between the fluid (e.g. water) and the sediment body. Although the fundamental law, describing this falling velocity, i.e. Stoke's (1851) law, has obviously been known for some time, many scientists have been working in this field since then, to come up with more precise descriptions of the sedimentation process and sedimentary transport, in general. One essential key to do this properly is the exact definition of the physical properties of the fluid (water) nd of the solid particles.

In this study, eight related equations describing the sinking velocity vs of a particle in a fluid - Stokes (1851), Zanke (1977), Chang (1984), Zhang (1989), Van Rijin (1989), Rubby (1993), Julien (1995) and Soulsbey (1999) >>chronological order<< - have been studied and compared to each other. More specifically, for each of these eight equations, vs as a function of the temperature T of the fluid (water) and of the diameter d of the sedimentary particle has been computed. Summary statistics, such as mean, standard deviation and confidence intervals (using t-statistics) of the vs (T,d) - results have been calculated. The results show that the sediment particles' falling velocities lie all within the specified confidence interval, except those obtained for the Rubby equation for temperatures of 0, 10, and 20oC and particle diameters d > 2mm.

For a given temperature T, nonlinear polynomial regression equations for the average (mean) falling velocity mean (vs) as a function of the sediment particle diameter d have been computed. As very good model fits with R2 >0.98 are obtained, it is recommended to use these newly developed empirical equations in future flow sedimentation studies.

Refrences

Yang, C.T. (1996). Sediment transport: theory and practice. McGraw-Hill Companies, Inc., New York, NY.

Ranieri . G (2002). “The Measure of the Average Fall Velocity of Costal Sediments,” ERB and Northern European FRIEND Project 5 Conference, Demänovská dolina, Slovakia.

Zhiayao.S. , Tingting.W. , Fumin.X. , Ruijie.L. (2008). “A simple formula for predicting settling velocity of sediment particles” Water Science and Engineering, Mar. 2008, Vol. 1, No. 1, 37– 43.

B. Fentie, B. Yu and C.W. Rose.(2004)” Comparison of seven particle settling velocity formula for erosion modeling” ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004.

Jimenez.J.A., Madsen.O.M. (2003) “ A simple formula to estimate settling velocity of natural sediments” JOURNAL OF WATERWAY, PORT, COASTAL AND OCEAN ENGINEERING © ASCE / MARCH/APRIL 2003.

Interaction between Offshore Utilisation and the Environment

Coupled Analysis of Soil and Quay Walls Interaction under Wave Loading by Mixing FEM and FVM

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Keywords: FEVM, Nonlinear Wave,Ttwo Way Interaction, Quay walls, Seismic Loading, Coupled interaction of Soil and Structure

Optimal Design of quay walls against seismic forces has become a challenge for engineers. For Countries which are placed on the Earthquake Belt it is very important to investigate the strength and the behavior of quay walls against earthquakes. In this study we have investigated the behavior of cantilever quay concrete walls which has been placed on the saturated cohesive soil by finite element method. The pattern of the interaction between the soil and the structure is complicated and also consideration of the effect of interactions between soil and structure under the seismic forces would make the problem much more complicated. In this study we considered the height of the quay walls, soil type, strength and the duration of the earthquake on the Bending moment against the wall and also pressure contribution behind the wall has been investigated.

Introduction

Quay walls utilize to protect the coastal line in these areas. One of the methods which could analyses loads caused by Seismic forces against the quay walls is the numerical method. In this modeling method we could investigate the interaction between soil and structure. If in the modeling process soil continues long enough, far from the structure as the result of reducing the finite effect of the Computational domains our analyzed model would be much accurate and compare to the other methods much closer to the reality.

In this regard, classic methods by (1992) Futaki [1], (1970) Seed and Whitman [2], Rowe[3] have been exerted for this problem. Also Substrate reaction method has been exerted by (1867) Winkler [4] et al. (1996) Terzaghi [5] and Dewaikar and Halkude (2006) [6]. In the year 1986 and then in 1995 Halliburton [7] and Simon [8] have used this method for analyze of the quay walls respectively. In this study by Assumption of the elastic behavior of the quay walls we investigated the effect of the height, type and rigidity of the walls on this behavior and the distribution of the pressure and the anchor through.

Results

From figures we can see the results of the investigation which includes the normal stress, quay stress, soil deformation and the von Masses stress for the quay wall with the height of 15 meter which have illustrated as Graphics. At these analyzes we have used the Kobe and el center earthquakes and also two different kind of soils.

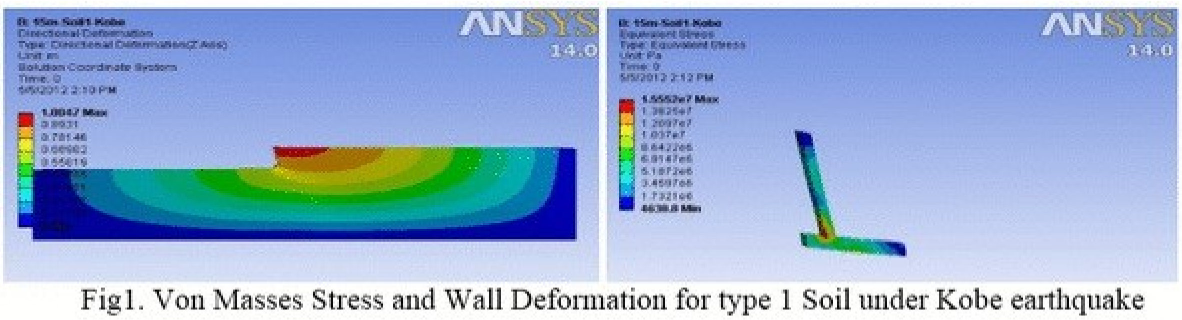

Fig1. Von Masses Stress and Wall Deformation for type 1 Soil under Kobe earthquake

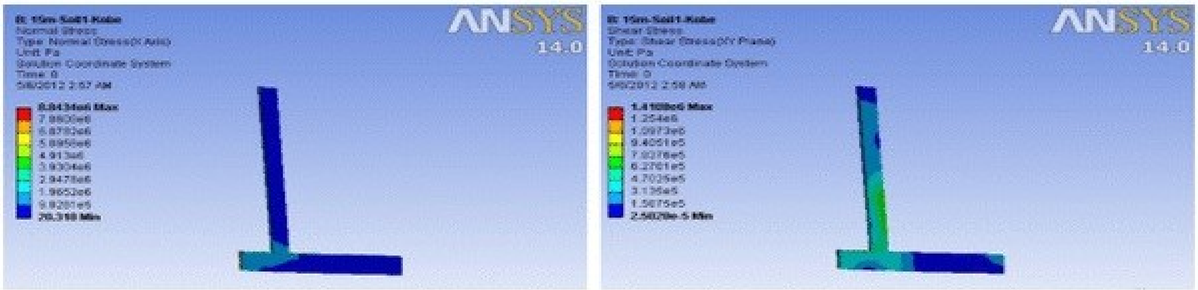

Fig2. Shear and Normal Stress for Soil 1 under Kobe earthquake

Investigation on the effect of the wall depth

The effect of the quay wall height on the submission, quay and the pressure behavior has been illustrated. the effect of the increasing depth on the distribution of the soil pressure have been illustrated in figure3.as you can see from this diagram as the depth increases the value of the average and maximum pressure forcing on the soil would be increases too. As you can see with the increasing wall height the maximum submission over the wall would increase too. In figure (4) we have illustrated the quay stress changes in relation with the height of the wall.

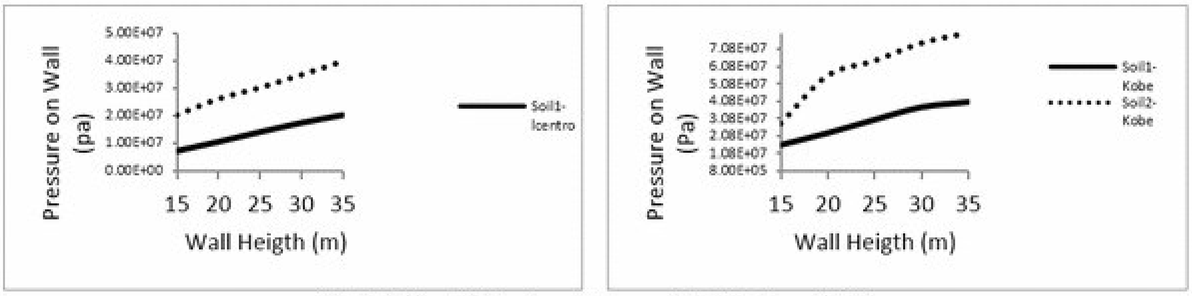

Fig3. Effect of Depth on Pressure Distribution of Soil

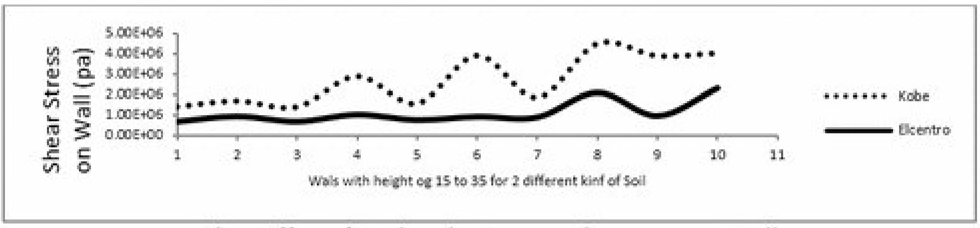

Fig4. Effect of Earthquake Type on Shear stress on Wall

References

[1] Futaki, M. (1992), Behavior of the cantilever quay wall under seismic loading, Tenth World Conference of Earthquake Engineering.
[2] Seed, H. Whitman, M. (1970), Desing of earth quay structures for dynamic loads, Journal of American Scociety of civil engineering, pp. 103-147.
[3] Rowe, P.W. (1955), a theoretical and experimental analysis of sheet pile walls, Proc Ins, 32 - 69.

Large-Eddy Simulations of a Sediment-Laden Buoyant Jet Resulting from Dredgers Using Overflow

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Keywords: Trailer Suction Hopper Dredgers, Turbidity plumes, Large-eddy simulation, Computational Fluid Dynamics

The increase in the number of offshore and port development projects has led to rising dredging activity throughout the world. In order to minimise disruption of natural systems, environmental legislation regulating impacts of dredging works has become more extensive subsequently. Turbidity caused by dredging works with Trailing Suction Hopper Dredgers (TSHD) using an overflow is one of the main environmental concerns being assessed in the phases of planning, design and execution. At sensitive areas near the project, turbidity and sediment depositions rising above the allowed thresholds need to be prevented. Numerical modelling tools are used at the present day to predict circulations in coastal seas as well as advection, settling and diffusion of turbidity plumes (Figure 1).

Figure 1. Example of a TSHD overflow plume with higher turbidity compared to the surrounding waters.

Prediction of the increase in turbidity in the far-field is possible by means of large scale hydrodynamic and sediment transport models. These models, however, are not designed to solve the complex near-field processes in the vicinity of the dredger and require a sediment source term to account for overflow in the form of a distribution of sediment flux over the water depth. Until today, the determination of this distribution has been rather arbitrary. In this study, detailed numerical simulations solving the full three-dimensional Navier Stokes equations coupled with sediment transport equations allow to predict the sediment plume being released by the overflow pipe underneath the dredging vessel. A laboratory flume was equipped to release scaled dredging plumes. A multiphase large-eddy simulation (LES) model at experimental scale has been validated with laboratory measurements. The plume trajectory, plume width and turbulent statistics compare well with the experimental data.

The present paper describes the upscaling process of the laboratory-scale LES model to prototype scale, as well as the implementation of a realistic dredging vessel geometry in the model. In a first step, the validated laboratory-scale LES model is upscaled to prototype dimensions, while keeping an identical geometry compared to the laboratory experiment. Using similarity laws, the upscaled model results can be compared with the experimental plumes and small-scale LES results. Furthermore, it is verified whether a sufficient amount of the turbulent kinetic energy is still resolved in the LES model after upscaling the model dimensions. In a second step, the geometry of a TSHD is implemented in the model. The properties of the overflow mixture are taken into account: sediment concentration, grain size distribution, outflow velocity, air bubble fraction and volume discharge. These properties are boundary conditions to the presented model and can be derived from hopper sedimentation models developed in the past, which are using dredger production rates and sea bed grain size information. Combined with data on bathymetry, sailing speed and tidal current flow velocity, detailed three-dimensional computations of the distribution of sediments are executed with the LES model (Fig. 2). The model simulations are compared with the observed sediment distribution during an in situ measurement campaign of a TSHD at work.

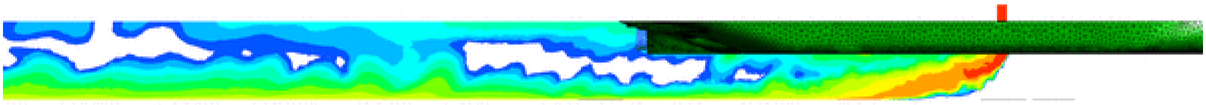

Figure 2. Sediment distribution resulting from the multiphase LES model with water, sediment and air bubble phases.

The developed model can be applied in two ways. First, it becomes possible to perform detailed near-field simulations of the flow around the (complex) geometry of a dredging vessel at work. The model results can then be coupled with a large-scale circulation model and more accurate predictions of the far-field turbidity impact can be obtained. Secondly, the detailed model can be used to produce samples for a multivariate parameter study. In this way, the computationally expensive LES simulations can be avoided in some cases by using a parameterised model when needed, for example during operational forecasting and monitoring. In this way, the presented model contributes to avoiding both environmental calamities and imposed downtimes due to turbidity threshold violations.

Calculation of Emissions and Transport of Elements from Lean Concrete around Underground High-Voltage Power Line Routes

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Keywords: Underground conduct construction, Emission, Numerical modelling, Groundwater hydraulic

The object of this report is to present a recent study about aspects of leaching from a water-saturated fresh lean concrete structure of an underground high-voltage cable tray towards soil and groundwater. The spreading of the environmentally relevant substance in the underground of the nature reserve (Proposed Sites of Community Interest = FFH-area) was modeled with a numerical groundwater software FEFLOW (mobile species transport). FEFLOW is an acronym of finite element subsurface FLOW simulation system and solves the governing flow, mass and, heat transport equations in porous and fractured media by a multidimensional FEM for complex geometric and parametric situations including variable fluid density, variable saturation, and free surface(s). In the context of the `Source-Pathway-Receptor´ principle FEFLOW simulates the 3D groundwater pathway. The numerical model is based on the Galerkin-FEM method. As we have large ranges of element sizes in the mesh, we used the algebraic multigrid solver SAMG. The groundwater body is a porous sediment aquifer. The substance emission are suspected of destroying the dunes vegetation (receptor) and hence the ecosystem service. The major unique selling point of the study is the object of inquiry itself and the combination of concrete manufacturing aspects and the groundwater hydraulic aspects of the lean concrete construction on a regional field scale.

The development of offshore marine renewable energy is rapid and extensive and creates stressed conditions. Unfortunately it is not possible to completely avoid invasions of nature and the landscape when constructing power lines and substations. TenneT's and other grid operators objective is to optimize the routes in consideration of all protection and conservation issues and minimize negative effects for humans and the environment. Of course nature sanctuaries, landscape preservation areas, and protected sections of the landscape; natural and cultural monuments as well as FFH and bird sanctuaries are taken into consideration. The power cable from the offshore wind parks in the North Sea (e.g. BorWin 2 (800 MW), BorWin 1 (400 MW), Dolwin 2 (900 MW, spring 2015) and Dolwin1 (800 MW, beginning 2014)) cross the mud flat, then the underground of the North Sea island Norderney and the coastal marshlands (Hilgenrieder Watt). The 1.5 km long, so-called conduct construction crossing the island Norderney was completed in spring of 2008, allowing the cable for connection of the wind park to be pulled in. The first cable for connection of Alpha Ventus (first German offshore grid link, 60 MW) was pulled into this underground conduit by spring 2009.

The core study area is the middle part of the island Norderney around the undergrounding cable. The conduct construction (PE-pips or ducts) with the cables (d.c. line) are surrounded with lean concrete (a gravel-cement composite: 8:1-relation). A road runs above the cable track. Lean concrete is especially suitable for underground lying high and extra-high voltage cables. Various thermally stabilised lean concrete has been developed in particular as backfill for underground high and extra-high voltage cables. In our case, the undergrounding cable route lies in the saturated zone. The positive effect is that the groundwater is effective in combating soil desiccation, resulting in lower operating temperatures. This way loss of energy is prevented over the long term while maintaining steady transmission capacity. The lean concrete backfill combats the irreversible desiccation of the soil in the area surrounding the cable consistently and prevent heat-related loss of energy. On the other hand there is a likely potential for leaching of emitted substances to soil and groundwater in the vicinity with the result that the pH value will raise evidently.

The principles for assessing the effects of construction products on soil and groundwater of the Deutsches Institut für Bautechnik provide a guideline for the implementation of the Model Building Code for the protection of the natural resources soil and groundwater. The assessment criteria are

derived, where available, from the so called insignificance thresholds for groundwater (Geringfügigkeitsschwellenwerte für das Grundwasser) established by LAWA (Working Group on water issues). For safety reasons it was not possible at this point in time to take drill-out cores out of the conduct construction for leaching tests and Direct-Push-tests. So, for an initial risk assessment estimated source term for five elements (Ca, K, Mg, Cl, SO) are used for the mass transport boundary (reactive single-species transport). Measured pH-values, temperature, electrical conductivity and hydraulic heads in the contact groundwater and in the near-field used to calibrate the groundwater flow and mass transport model. The transport initial conditions provided the groundwater monitoring program, the Dirichlet boundary conditions at the lean concrete structure it uses are drawn in the main form published laboratories testing.
At the end several simulation examples for the groundwater dynamic and the transport of pollutants in the island groundwater are shown. As viewed from the physical side a moving mesh for free-surface calculations and an unstructured meshing, thus better representation or adaption of features of the conduct construction in the hole mesh are very helpful. The results on the study area Norderney can make a contribution for another underground high-voltage power line projects in vulnerable coastal regions or natural protected areas. It is widely accepted that the leaching behavior from lean concrete needs to be assessed, in the best case by field experiments. To the present state of knowledge – does not represent any actual risk - but particular the long-term concrete degradation processes still giving cause for reasonable grounds for concern. Shows the monitoring abnormalities, drill-out cores out of the conduct construction for leaching tests and Direct-Push-tests are unavoidable. A calibrated numerical groundwater model is available and usable.

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Performance of an Oscillating Water Column Device with Different Bottom Profiles Subjected to Random Waves

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Keywords: Random waves; Wave amplification; Hydrodynamic efficiency; Wave energy; OWC

Due to continuous demand for alternate sources of energy due to the depletion of conventional energy resources, apart from solar energy, the Ocean is considered as a source of abundant energy. Of the different sources from tides, current, wind and waves, there has been tremendous progress in Research and development of wave energy and offshore wind energy as they are considered to be clean energy. In wave energy conversion, an interface device is needed to convert energy in the waves to mechanical energy prior to its conversion into electric energy. These devices are known as Wave Energy Converters (WECs). Numerous concepts have been proposed; with power rating ranging from a few Watts to mega Watts capacity. The existing concepts in WECs are broadly classified into three main categories; overtopping devices, wave activated bodies and Oscillating Water Column (OWC). Among these OWC has the unique distinction of having turbine, the only moving component above the water surface, thus its operation and maintenance being simple and easier.

In its working an OWC device consists of a vertical caisson having an opening on the wave beaten side and an air chamber above the water surface. The dynamic pressure under the ocean wave near the opening causes flow oscillations inside the air chamber. The rise of water inside the chamber compresses the air to develop pneumatic power. Thus, it can cause air flow at high velocity through a duct that can rotate a turbine on its path. In the second phase as the water falls down creates vacuum in the chamber which absorbs air through the duct. Thus, a bi-axial air turbine placed in the duct can convert the cyclic pneumatic power into unidirectional movement of turbine for generating electricity.

The present paper mainly focuses on the performance of OWC model in random wave field. For this purpose, four different bottom configurations, viz., flat, circular arc of radius 300mm, a slope of 1:1 and 1:1.5 were considered for the tests. Experiments were conducted in a wave flume 72.5m long and 2 m wide. One end of the flume installed with a computer controlled wave maker is capable of generating random waves another end with wave absorber. The wave flume was longitudinally divided into four compartments to facilitate simultaneous testing of the four models as mentioned above. The test set-up was located at a distance of 45m from the wave maker. The models were made of 12mm thick acrylic sheet, each of which of dimensions 471 x 300 mm in plan with a height of 900mm. The depth of the front wall of each of the model was 600mm from the top and front wall opening was 300mm. For each of the models, an air vent was maintained as 0.68% of the plan area of the device. Each chamber has three pressure transducers. One at the top is used to measure the air pressure. The other two transducers placed on the front lip wall measured the water pressure inside and outside the chamber. Run-up meter placed on the rear wall of the chamber measured the water level fluctuations inside the chamber.A view of the OWC units with four different bottom profiles in the wave flume is projected in Fig.1.

Figure 1. Four different bottom profile of OWC.

In the experimental work the performance of each of the OWC device with the different bottom configuration were measured in a water depth, d of 0.5m for a wide range of wave characteristics, with frequencies ranging between 0.33Hz and 1.0Hz such that wave steepness, Hs/Lp ranged from 0.014 to 0.062 and relative water depth, d/Lp ranged from 0.078 to 0.330, where 'Hs' and 'Lp' are the significant wave height and peak wave length respectively. The attempts have been made to study the effect of system parameters in performance of the device due to random waves. In order to understand interaction effects between frequency components on energy conversion the spectral width parameter range on incident wave, front wall outside pressure, front wall inside pressure and air chamber pressure werestudiedas a function of relative water depth d/Lp. To bring in more clarity over the wave structure interaction the ratio of zeroth spectral moment of front wall outside pressure, front wall inside pressure, air chamber pressure to that of zeroth spectral moment of incident wave were analyzed as a function of relative water depth d/Lp. Then the hydrodynamic characteristics considered are power conversion efficiency inside the air chamber, wave amplification over the mouth and phase variation between excitation pressure and air pressure. The OWC with a flat and circular arc bottom yields maximum efficiency compared to the other models.The details of test set-up, testing facility, parameters of model, test procedure, analysis of results and discussion are reported in this paper.

Climate Change, Adaptation and Long-Term Predictions

A Consistent Return Level Assessment Considering Present Day and Future Mean Sea Level Conditions

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Keywords: Numerical model, statistical analyses, North Sea

Storm surges are among the most hazardous geophysical risks in coastal regions and are often associated with significant losses of life and property (von Storch, 2012). The North Sea, and the German coastline in particular, has a long history of severe storm surges. For example, a large storm occurred in the German Bight in 1962 when more than 300 people lost their lives (Bütow 1963; von Storch and Woth 2006). It is thus essential that the flood risk is accurately evaluated and defences are upgraded where necessary (Coles and Tawn, 2005).

The design of coastal defences is often based on some form of statistical models (Dixon and Tawn, 1994). These models are mostly based on extreme value statistics, a special discipline in probability theory that deals with rare events, such as coastal floods (Coles, 2001). Over the last five decades, several different extreme value analysis (EVA) methods for estimating the heights (i.e. return levels) and occurrence probabilities (i.e. return periods) of extreme water levels have been developed (see Haigh et al., 2010 for an overview). There is, however, currently no universally accepted method available. Instead, different methods have been applied on transnational but also on national level scales resulting in a heterogeneous level of protection. As a result, it is difficult to assess the level of protection offered by defences across the different states. To provide coastal protection of consistent standard, design levels need to be consistently calculated based on an objectively defined model setup. This is why Arns et al. (2013) investigated the general performance of the two main direct extreme value analysis methods (i.e. the block maxima (BM) method and the peaks over threshold (POT) method) and their applicability to water level records in the German Bight. They provide recommendations on objectively using such methods. The return level and return period assessment in this study is based on these recommendations.

Furthermore, an accurate assessment of return water levels using traditional extreme value analysis methods requires records of sufficient length (> 30 years; Haigh et al., 2010), indicating one of the largest pitfalls of extreme value models, as the availability of measured water levels is limited in many regions. In the German Bight, multi-decadal records of high and low waters exist at several sites, but for some regions (e.g. at some small islands in the German Wadden Sea) no or only very short and incomplete water level measurements exist. In practical applications it is often assumed that at-site (i.e. using local water level records from a tide gauge station) estimates can be transferred to un-gauged surroundings. Nevertheless, water levels in the German Bight can differ significantly between stations as they are strongly influenced by shallow water effects and the complex topography of the coastline (see e.g. Jensen and Müller-Navarra 2008). Simply transferring information about the likelihood of extreme water level events from gauged to surrounding un-gauged sites may thus cause erroneous return level estimates. This is why more elaborate procedures to adequately transfer water level information are required.

In a full paper we present a combination of numerical and statistical methods to estimate present day return water levels at sites where only little or even no water level records are available. A similar method has recently been applied along different stretches of coastlines around the globe (see e.g. Haigh et al., 2013). This approach was adopted and modified to satisfy the characteristics along the entire coastline of Schleswig-Holstein in northern Germany. It is shown that water levels derived from a hydrodynamic model can be used to calculate reliable return water levels. Regions with no or only few tide gauge stations can especially benefit from this approach. However, a precondition is to adequately correct the bias that is generated with the numerical simulations. The bias-correction is performed first at each individual station where water level observations exist. Then the correction is transferred to the neighbouring grid points using an Inverse Distance Weighting interpolation method. As a result, regionalized return water levels at un-gauged sites are obtained, that account for locally confined coastal attributes. An assessment showed that return water levels that are estimated using the approach presented in this study are highly consistent with the return water levels from at-site analyses.

The return water level assessment is not only uncertain regarding the heterogeneous assessment procedures or the limited water level information but also with respect to possible future projections related to climate change. Recent analyses highlight that global MSL rose by 2.0 mm/ year from 1971 to 2010 (IPCC, 2013). As consequence from an increased ocean warming and the increased loss of mass from glaciers and ice sheets, future rates of sea level rise (SLR) are expected to very likely exceed those observed during 1971 to 2010 (IPPC 2013). Until recently, most coastal protection strategies assumed that changes in extreme water levels during the 21st century will be dominated by changes in MSL by raising design water levels to an amount equivalent to the projected SLR (Smith et al., 2010). These results are limited to the assumption of a similar long-term behaviour between mean and extreme water levels. In the German Bight, however, Mudersbach et al. (2013) showed that trends in extreme high water levels differed significantly from those in MSL from the mid-1950s to approximately 1990, indicating the presence of nonlinear interactions between the different sea level components (i.e. MSL, tide, surge). This is contrary to most other locations around the world, where observed changes of extremes are equal to those of the MSL. In order to plan adequate adaptation strategies to cope with climate change challenges it is therefore essential that reliable projections of extreme water level changes become available.

To account for possible future changes, this study also investigates the impact of a 0.54 m SLR on future extreme water levels along the coastline of Schleswig-Holstein (a federal state in Germany). We will show that future extreme water levels could be significantly larger than expected from SLR alone. These differences are mainly caused by changes in shallow water and frictional effects, altering the tidal component of the total water levels (for more details see Arns et al., in review). Furthermore, we will show that return levels of extreme water levels will considerably reduce, i.e. a water level of given return period occurs more frequently in future as e.g. the 200 year return level, which will be 3 year return level at some locations in the SLR scenario.

A combination of individual parts of this study can be used to objectively and reliably estimate regional to local return levels for current and future SLR conditions. These methodologies enable to estimate return levels for an entire coastline helping to obtain water level information in un-gauged areas. The results can be used for the design of coastal defences of for risk analyses.

Approach of Characterizing Changes in the Sectors Subjected to Climate Change. Characteristics of Climate Indicators for Forestry Sector of Latvia

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Keywords: ENSEMBLES, Down-scaled numerical climate projections, Indicators, Forestry

We present the approach of using an ensemble of the downscaled numerical climate projections to characterize the impact of climate change on a particular sector – forestry. The methodology demonstrates the impact of climate change using the assessment of the changes of the specific indicators of the sector.
The set of indicators characterizing the forestry sector was developed in the presented analysis. It includes the phenological indicators like average dates of the latest spring frosts and the earliest autumn frosts, index related to lasting dryness and fire hazards, the number of days and the sum of degree days below -5° C, the total precipitation during the vegetation period, length of vegetation period and others. Methodology can be generalized for characterization of necessary adaptation to climate change in other climate sensitive sectors of the economy.
A set of 20 model runs from the ENSEMBLES project is used in the study. Temporal resolution of 1 day and spatial resolution corresponding to 55 irregularly located grid points (the locations of the selected meteorological stations) in the territory of Latvia is used.
The chosen method includes:

- Acquisition of bias corrected ensemble of data series for meteorological parameters – daily average, minimal and maximal temperatures and daily precipitation intensity in the selected set of grid points (data series for each model run from the model ensemble and each meteorological parameter);
- Calculation of 30-year average values of the indicators. Three focus periods (time slices) have been selected: 1961-1990 (control period), 2021-2050 (near future period), 2071-2100 (far future period). Indicator values for each model run of the model ensemble and each focus period are calculated;
- Determination of changes of indicators till 2021-2050 and 2071-2100 with the respect to control period. Changes for each indicator and each model run of the model run set are computed;
- Solving the uncertainty between the models - computation of three inter-model percentiles (13%, 50% and 83%) that are referred to as mild, medium and strong change of indicators due to the climate change. This approach is applied for data sets obtained in above points 2. and 3. to characterise projected indicator values and projected indicator changes until 2071-2100.Each of the selected 30-year periods is characterised by the maps of phenological indicators or its change (between the focus periods).

Calculations handle exceptions related to possible climate changes as, for instance, multiple vegetation periods per year, the first autumn frosts occuring in the winter etc.
Methodology allows to make quantitative and measurable evaluation of the importance of the climate change for the forestry. It allows to plan adaptation process by analysing the present situation in the regions outside Latvia where the present values of the indicators matches the future values of indicators in Latvia.

Trends in Hydrological Series: Methods and Application

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Keywords: Trend; Hydrological time series; Hypothesis testing; Wavelet analysis; Stochastic modelling

Initial studies aiming to analyze hydrological time series statistical stationarity date back to the early 1970s, motivated by linear stochastic models increasing applications. Over the years, papers were elaborated solely for the purpose of analyzing how nonstationarity manifests in hydrological series. Of these, the majority considers the presence of linear trends in the records as possible indicators of change in the hydrological regime.

Two causes are often pointed as disturbances inductors in hydrological series: (i) anthropogenic activities in watersheds and (ii) climate change or variability. In the first case, changes in watersheds land use mainly caused by agricultural fields and urbanization are highlighted. The second aspect is related to greenhouse gases emission, possibly reflecting in a gradual increase of global temperatures.

Emphasizing the growing number of studies in the area and the fertile discussions originated by its results, this paper aims to develop a critical analysis of the most common methods for detecting trends in hydrological series. A thorough literature review allowed identifying parametric and nonparametric hypothesis testing as most used techniques for this purpose. Frequency domain analyses are also employed, either in time series decomposition or spectral properties evaluation.

Among the various techniques used, six are discussed: (i) linear regression (OLS) with significance test over the adjusted slope, (ii) Student’s t test (t) for difference between means of two subsamples, (iii) Mann-Whitney (also known as Wilcoxon rank sum test - W) for differences between medians of two subsamples, (iv) Spearman's rho test (S), (v) Mann-Kendall (MK) test and (vi) wavelet transform. The choice of such methods was guided by the number of studies that used them.

Generally, there is a clear preference in using nonparametric tests (S and MK), for no defined data probability distribution is required (e.g. normal). On the other hand, they are less powerful than the parametric tests (OLS, t and W). Of common concern to both classes of tests is data autocorrelation, often expressed by long periods of amounts above or below the series mean value (aka “Joseph Effect”), leading tests to indicate a trend when they do not exist. These nuances induce criticism in using hypothesis inferences; as alternate approach, some authors indicate wavelet transform, after which it is possible to analyze contributions that processes of different velocities or scales give to the time series.

In order to illustrate the discussed techniques, a case study applied to the Iguaçu river basin (area 70800 km²) is presented. Iguaçu river is an important tributary of the Paraná river (La Plata river basin), in southern Brazil. Due to its large hydroelectric power use, it was chosen a gauging station located before any dam, avoiding its influence on streamflow series. Besides, this gauging station operates in a highly dense demographic area, being subject to land use changes. All six aforementioned methods were applied to mean, maximum and minimum annual streamflow series (1936 to 2005) and to total annual precipitated amounts (1941 to 2012) of Porto Amazonas gauging station, in Parana state.

Subsample division for t and W tests was made in two ways: (i) central, resulting two equally sized samples and (ii) reserving the last 30 years and testing against the remainder of the series. Hypothesis (ii), also considered in OLS analysis, was elaborated in order to evaluate the possible land use changes effects on streamflow. Moreover, it is assumed that this window length is enough to represent climatic fluctuations. For the parametric tests, log transform was applied to make the data approximately normal distributed. MK test, specifically, was applied both in its traditional form as in sequential format in which it is possible to identify a possible starting point for the trend (if any). In all tests, autocorrelation influence was eliminated by means of pre-whitening. Lastly, spectral analysis was elaborated through continuous wavelet transform, using Paul as mother wavelet, which has good temporal resolution in comparison to other functions.

For streamflow series, nonparametric tests revealed a positive trend ($p<0.05$) mainly in maximum series. OLS, when applied over the complete sample, corroborated these results, however when applied singly on the subsamples did not show statistically significant trends ($p<0,069$ and $p<0,130$, respectively). Also, equality of means (t) and medians (W) among subsamples were rejected ($p<0.05$). From these results, one can infer that the maximum series suffered a step change between 1970s and 1980s. In turn, means series exhibited significant trends only on nonparametric tests and OLS over the complete sample ($p<0.05$). Minimum series presented positive trend on OLS over the complete sample solely. Finally, sequential MK and wavelet transform confirmed a positive trend on streamflow since early 1970s, agreeing with prior results.
Given the above, one may conclude that positive trend was a land use change consequence, as some local studies suggest. Nevertheless, total precipitated amounts analysis on the same gauging station revealed an extremely similar pattern and statistical significance, mainly on the subsample formed by hypothesis (ii). Thus, to specify causes for positive trend on Iguaçu river streamflow series is a difficult task. Evidently, positive trends in precipitation involve other questions, much more complexes than the ones related to streamflow series and are beyond the scope of this work.
Few are the studies that use distinct approaches techniques on hydrological series trend assessment. Results obtained here showed that conclusions based on isolated methods can be equivocated, especially considering each method particularity and sample selection uncertainty. In modeling terms, this problem magnifies and is left for hydrologist's subjectivity.
The paper ends with comments about multiple scale stochastic process approach, which considers hydrological time series fluctuations as its expected behavior. Thereby, trends are modeled as a stochastic component, in contrast to traditional methods.

Analysing the Effects of Climate Change on Wave Height Extremes in the Greek Seas

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Keywords: Climate change, Bias correction, Non-stationary GEV, Monthly maxima, Time-dependent quantiles, Annual return levels

Over the last decade there is growing evidence that climate change has a significant effect on extremes of marine variables, affecting the human society of the coastal areas in a rather detrimental way. Coastal flooding and erosion phenomena around the globe become more frequent and seem to have severe impacts on the coastal societies. The proposed work aims at quantifying the possible effects of climate change on the severity and frequency of extreme wave height events in selected areas of the Greek seas (Thracian Sea, Eastern Aegean, Western Aegean, Northern Crete, Eastern Ionian Sea).
The wave height datasets to be used are computed by means of the SWAN (Ris et al. 1999) wave model for the time period 1950-2099. The model input consists of wind field data (wind velocity and direction at 10m over the sea level), available through the data base provided by the Regional Climate Model (RCM), RegCM3 (Dickinson et al, 1989). RegCM3 is downscaled to a spatial analysis of 10x10 km for the Aegean Sea in order to detect more satisfactorily the local characteristics of the study area. The SWAN model is calibrated with available in situ measurements and satellite data.
RCM simulations of the wind field, used to force the wave model, are often subject to significant biases. These biases can be increased, when the wind field is utilized as input to a wave model, such as the one used to produce the data of the present work. Therefore, before analyzing wave height extremes, bias correction is implemented to the wave dataset produced by the SWAN model at selected locations of the Greek Seas. The datasets used for correction are wave height simulations available from the WAM model using meteorological forcing for a time period of 10 years. The methods for bias correction used in the present work include the development of parametric, as well as non-parametric quantile - quantile transformations. The former transformations include linear, polynomial and scale functions. Within the non-parametric framework, the empirical distribution functions of the “control” or observed data and of the data resulting utilizing the forcing of the RCMs, are represented by means of tables of empirical percentiles, while the values between them are assessed by means of a monotonic tricubic spline function (Gudmundsson et al. 2012).
The simulation period is then divided in three periods of fifty years (1950-1999, 2000-2049 and 2050-2099) and each one is studied separately in terms of extreme events, to find the possible effects of climate change on such events. For each one of these three periods, the monthly maxima of the significant wave height are selected. The selected monthly values should be separated by a time interval of at least two to three days, to be considered to belong to separate storm events. The analysis is conducted utilizing a non-stationary GEV model that simulates the variability within a year of the wave height monthly maxima. The parameters of the GEV distribution are modeled as harmonic functions of time. Twenty six non-stationary GEV distribution functions with up to two harmonic functions in all the parameters of the model, are fitted to the data at each location and time period. In the present work, the maximum number of harmonics within each parameter is set to two. The selection of the number of harmonics depends critically on the minimization of the Akaike Information Criterion with correction for small sample size (AICc) (Hurvich and Tsai, 1989), and also on the deviance statistic function, D (Coles, 2001).
The non-stationary GEV distribution function used in the present work is able to model the entire variability of extreme events within a year, taking account of such events in all seasons. It considers more than a single event per year, it uses information from neighbouring months and thus includes natural variability in the simulation procedure and it is also threshold independent. Inference for return levels is produced using time-dependent quantiles within a period of one year (Méndez et al., 2007),

as well as annual quantiles (Menéndez et al., 2009; Frías et al., 2012). A comparison of the extracted return levels among the three time periods for each location studied is performed and discussed.

References

Coles, S.G. (2001). An introduction to statistical modelling of extreme values. Springer, London, 209 pages.

Dickinson, R., Errico, R., Giorgi, F., Bates, G. (1989). A regional climate model for the western United States. Climate Change, Vol. 15, No. 3, pp. 383-422.

Frías, M.D., Mínguez, R., Gutiérrez, J.M., Méndez, F.J., (2012). Future regional projections of extreme temperatures in Europe: A Nonstationary seasonal approach. Climatic Change, Vol. 113, pp. 371-392.

Gudmundsson, L., Bremnes, J.B., Haugen, J.E., Engen Skaugen, T. (2012).Technical Note: Downscaling RCM precipitation to the station scale using quantile mapping - a comparison of methods. Hydrology and Earth System Science Discussions, Vol. 9, pp. 6185-6201.

Hurvich, C.M., Tsai, C. (1989). Regression and time series model selection in small samples. Biometrika, Vol. 76, pp. 297-307.

Méndez, F.J., Menéndez, M., Luceño, A., Losada, I.J. (2007). Analyzing monthly extreme sea levels with a time-dependent GEV model. Journal of Atmospheric Ocean Technology, Vol. 24, pp. 894-911.

Menéndez, M., Méndez, F.I., Izaguirre, C., Luceño, A., Losada, I. (2009). The influence of seasonality on estimating return values of significant wave height. Coastal Engineering, Vol. 56, pp. 211-219.

Ris, R.C., Holthuijsen, L.H., Booij, N. (1999). A Third-Generation wave model for coastal regions. 2. Verification. Journal of Geophysical Research, Vol. 104, pp. 7667-7681.

Impact of Climate Change on the River Discharge of Omo Gibe Basin Using SWAT

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Keywords: Climate change, HadCM3, SDSM, SWAT, Cascade hydropower plants, Omo Gibe river basin

Climate change in Ethiopia has great impact on extreme hydrological variability and seasonality which have an adverse effect on the past economic and social development by negatively threat the crop production mainly through droughts and by destroying roads and other infrastructure like dams (i.e., constructed for hydropower, irrigation and water supply) due to flooding. Climate variability is driving force for unreliable rainfall patterns, uneven distribution of water resources, and in turn has a significant effect in the physical parameters of river regime for example discharge and on hydraulic structures. Most of the studies, based on historical data, have indicated that there are strong relationship between climate variability and streamflows. But future projections of climatic changes are critical for understanding of the change of the physical parameter of the river and hence to mitigate the river basin through integrated water resource management particularly in this study area Omo Gibe river basin. And this climate change has also an ability to extrapolate their associated effects on energy production of the cascade hydropower plants in the basin.

This study analyzes the impact of climate change on river flows at the inflow of cascade reservoirs for the period 1970-2031. Future climate data were projected by global circulation models (GCMs) under HadCM3 emission scenarios and then analyzed to meteorological variables at local scale using the climate model SDSM (Statistical Downscaling Model). For this purpose large scale atmospheric variables i.e., General Circulation Models (GCMs) of Ethiopia particularly for the watershed region were applied for future prediction of maximum and minimum temperature, and precipitation.

As much of this observed climate recorded data suffered from inaccuracies, inconsistencies and missing gaps, a great deal of effort had to be devoted and SDSM was applied to fill the missed daily climate base time series data from 1970-2000. To predict the future maximum and minimum temperatures, and precipitation, the climate model is used using the downscaled predictors from GCMs. For the calibration of the downscaled models, observed as well as National Centers for Environmental Prediction (NCEP) climate data in the 1970-2000 reference periods were used. With the input data filled and cleaned, the future climate data were generated; and subsequently the trend of the maximum and minimum temperature, and precipitation were tested using Mann-Kendall test analyzer of R program. The Man-Kendall tests indicate that the maximum and minimum temperatures have statistically an increasing trend for most of the stations in the region and meanwhile for precipitation even though it has no trend, in the future the precipitation is decreasing.

In estimating the river flows at the entrance of the cascade reservoirs, the semi-distributed physical based hydrologic model, SWAT is used and then applied to evaluate the impacts of the predicted future climate parameters on the river flows in the main and tributaries of the river. The 1970-1990 time periods is used for calibration of SWAT model and the 1991-2000 periods for validation whereby the gauged flows in the head- and tail water sub-catchments are the calibration targets. The hydrograph of the time series plots, as well as statistical measures, such as the coefficient of determination (R2) and the Nash-Sutcliffe efficiency (NS) parameter between observed and simulated streamflows are computed on daily and monthly time scales and both of them indicate a good performance of the final calibrated SWAT model.

The results of the future simulations of river flow in the basin, using SDSM downscaled output in SWAT indicates that climate changes brings decline of the future Omo Gibe River flows and expectedly these have adverse effects on the inflow and pool level of the cascade reservoirs of the Omo Gibe river basin. In addition to this, the effect of climate change will be projected onto the existing and future planned cascade hydropower plants and other water resource projects (i.e., irrigation and water supply) at the downstream of the lower Omo Gibe basin in meeting the water availability demand of the region.

On the Coastal Dynamics of Sea Level Rise in the Northern Gulf of Mexico

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Keywords: Sea level rise, Ecological modeling, Storm surge, Tidal hydrodynamics

Sea level rise (SLR) has the potential to affect coastal environments with a multitude of consequences including inundation of wetlands, erosion, and increased flooding during storm events. To plan for changes under future sea levels, coastal managers need substantial information to make informed decisions for managing human and natural communities. The U.S. Gulf Coast contains habitats and nurseries for many economically and ecologically significant species that are at risk under rising sea level. The Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico (EESLR-NGOM) is a five year interdisciplinary effort funded by the National Oceanic and Atmospheric Administration (NOAA) to assess the physical and biological responses of the Northern Gulf of Mexico (NGOM) coast to future SLR scenarios, with particular focus on three National Estuarine Research Reserves (NERRs). The three NERRs, namely Apalachicola, FL, Grand Bay, MS, and Weeks Bay, AL represent a variety of estuarine types including fluvial (Apalachicola), marine (Grand Bay) and mixed (Weeks Bay). Each NERR contains a myriad of plant and animal species which support commercial fisheries. Due to unique morphology and hydrodynamic influences in each NERR, it is likely that each basin will respond differently to SLR, with various effects to the coastal wetlands and organisms within them.

Coastal responses to SLR are nonlinear processes and therefore should be modeled using a dynamic approach to capture interactions that may otherwise be excluded with a static or "bathtub" approach (Hagen and Bacopoulos, 2012; Bilskie et al., 2014; Passeri et al., 2014). In this study, a suite of predictive models is used to simulate hydrodynamic and biological processes, and assess the dynamic response of each system to various SLR scenarios under normal and extreme conditions. Evaluating changes in tidal hydrodynamics under future scenarios gives insight to potential changes in inundation, circulation patterns, and sediment transport processes. A large-scale two-dimensional hydrodynamic model is used to simulate astronomic tides under present and future scenarios. Future scenarios include projected sea levels using different SLR rates, as well as projected morphology including shoreline changes (erosion and accretion) and marsh accretion. Comparison of present and future simulations illustrates the hydrodynamic response of each system to a changing landscape through examination of variables including tidal constituents, tidal range, mean high water (MHW), mean low water (MLW), circulation patterns and inundation areas. In addition, inter-comparison of results for each estuary indicates factors influencing estuarine vulnerability to SLR.

To observe storm surge response to projected changes in sea level, a wind-wave and hurricane storm surge model that spans 1,100 km of the NGOM shoreline from Apalachicola, FL to Waveland, MS, and encompasses nearly 18,000 km2 of overland area was constructed. The model was validated for eight historical hurricanes, which indicates the model is capable of recreating past events with high skill. Similar to the tidal hydrodynamic comparison, the model is modified to reflect projected changes to the landscape, including surface roughness characteristics for projected coastal urbanization via land use land cover (LULC) change. Over thirty synthetic hurricanes are derived from storm surge response functions and joint probability with optimum sampling techniques. These storms are used in conjunction with a set of SLR scenarios to simulate hurricane storm surge and generate floodplain inundation maps for each scenario.

Dynamic processes influencing salt marsh productivity in each estuary are simulated using a hydro-marsh model, which consists of a two-dimensional hydrodynamic model coupled with a parametric marsh model. The hydrodynamic portion of the integrated model is used to simulate astronomic tides under various SLR scenarios to obtain spatially-dependent MHW and MLW values. Tidal dissipation over the marsh platform is variable depending on the platform elevation and local biomass density, which results in nonlinear changes in MHW and MLW with SLR (Hagen et al., 2013). Values of

MHW and MLW in conjunction with the elevation of the marsh platform are utilized in the parametric marsh model to determine marsh productivity. The parametric marsh model updates the marsh platform elevation through time by calculating the sediment accretion rate, which is a positive function of the marsh productivity. As mean sea level fluctuates with SLR, the marsh constantly adjusts itself to a new equilibrium in which there are optimal ranges of relative SLR and inundation depth that increase productivity. However, a critical rate of SLR exists at which the marsh will eventually drown out. Model results are compared and contrasted for each estuary to determine the relative vulnerability of the marshes to SLR.

The various scenarios used herein are not meant to predict future conditions, but rather to exemplify potential changes to improve decision-making under the uncertainty of SLR. Findings will be used in assessments that will aid in management decision making and adaption planning. Understanding changes to marsh productivity aids in establishing priority of land acquisition to allow for the migration of marshes under SLR. Identification of vulnerable shorelines gives better insight for shoreline stabilization and nourishment projects to reduce erosion. Storm surge assessments can aid in infrastructure planning and design, managing flood control, and land acquisition to mitigate storm damage. Areas vulnerable to increased inundation under normal and extreme events may be prohibited from future development or modification and designated as protected regions. Ultimately, the outcomes of this project will allow coastal managers and policy makers to make more informed decisions that address specific needs and vulnerabilities of each particular estuary, the NGOM coastal system, and estuaries elsewhere with similar conditions.

References

Bilskie, M. V., Hagen, S. C., Medeiros, S. C. and Passeri, D. L. (2014). "Dynamics of sea level rise and coastal flooding on a changing landscape." *Geophysical Research Letters*, 41: 1-8.

Hagen, S. C. and Bacopoulos, P. (2012). "Coastal Flooding in Florida's Big Bend Region with Application to Sea Level Rise Based on Synthetic Storms Analysis." *Terr. Atmos. Ocean. Sci.* 23: 481-500.

Hagen, S. C., Morris, J. T., Bacopoulos, P. and Weishampel, J. F. (2013). "Sea-Level Rise Impact on a Salt Marsh System of the Lower St. Johns River." *J. Waterway, Port, Coastal, Ocean Eng.* 139(2): 118-125.

Passeri, D. L., Hagen, S. C., Bilskie, M. V. and Medeiros, S. C. (2014). "On the significance of incorporating shoreline changes for evaluating coastal hydrodynamics under sea level rise scenarios." *Natural Hazards* (under review).

Long-Term Changes of the Tidal Amplitudes and Phases in the Elbe Estuary

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Keywords: Sea Level Rise, Harmonic Analysis, Tidal Amplitudes, Tidal Phases, Numerical Modelling

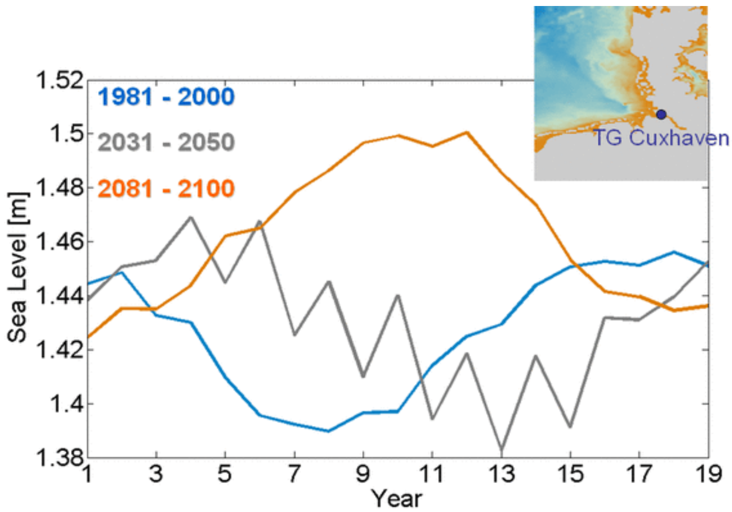
Introduction

During the last century the response of the oceans to tidal forces has changed significantly, changes of tidal amplitude and/or phase have taken place over large scales (Müller et al., 2011). So, it is a legitimate question asking for changes of the tidal constituents at coastal sections or inside estuaries. Therefore, we use long-term regionalized coupled numerical modelling of the North Sea and the Elbe estuary. The model results are validated and compared by 15 year long tide gauge records, which are recorded in a temporal resolution of 1 minute.

The Elbe River is one of the largest rivers in Europe (1144 km), the tidal influence in the estuary reaches 140 km inward from the coast to the weir in Geesthacht. The hydrological regime of the Elbe estuary is dominated by tides, mainly by the M2 and their overtides. The amplitude of the M2 in the Elbe estuary is about 1.5 meters. The amplitudes of the M2-overtides are one fourth of that. The S2 is also prominently detectable with an amplitude of 0.3 meters.

Methods

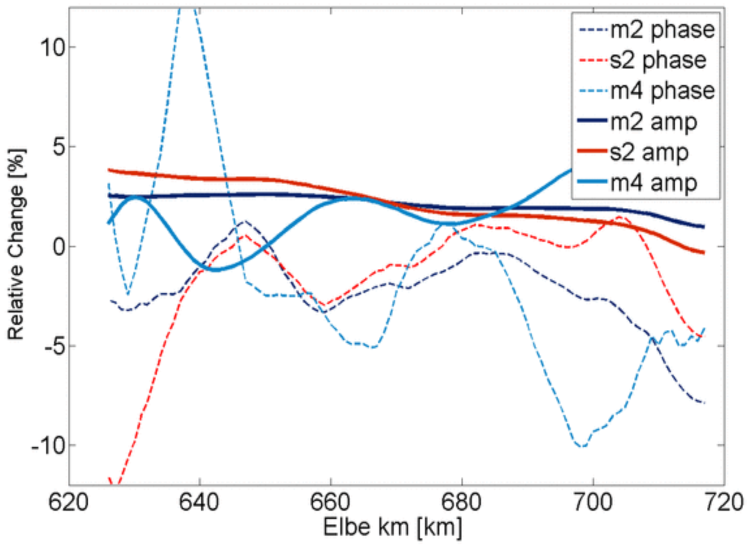
Continuous long-term simulations of the Elbe estuary are discussed for present-day conditions as well as for future conditions. The simulations are conducted with a limited area model of the Elbe estuary, which is offline nested into a model of the North Sea. In the North Sea and the estuary currents and sea-levels are modelled by the hydro-numerical HAMburg Shelf Ocean Model (HAMSOM; Backhaus, 1985). It is a three-dimensional, prognostic-baroclinic, frontal- and eddy-resolving model with a free surface. The numerical scheme of HAMSOM is defined in z-coordinates on an Arakawa C-grid. The governing equations for shallow water combined with the hydrostatic assumptions are implemented.



The basic descriptions of the North Sea Model can be found in Pohlmann (2006) and citations therein. The model version for the Elbe estuary is optimized for the use in estuarine regimes (Hein et al. 2007; Hein, 2011; Hein et al. 2013) and recognizes also horizontal sub-grid processes, e.g. drying (Hein et al. 2012), friction, horizontal turbulence (Hein, 2008). The fast numerical schemes allow simulating hundreds of years - or the permutation of parameters, numerical algorithms, resolution and boundary conditions. The Elbe model has scalable resolutions between 80 m - 600 m in the horizontal and 4 m – 12 m in the vertical.

The long-term run is forced by a regional climate model (REMO). Future discharges are included from improved rainfall-runoff modelling of the catchment area of the Elbe River (Lingemann, 2012). The fundamental study of Mathis (2013) induce estimations of the different components of global sea level rise (SLR) and continually add them onto the sea surface elevation at the open boundaries of the North Sea model, which results in agreement with the IPCC upper limit, which is 55 cm SLR until the end of the century. Additionally to the long-term run a parameter permutation experiment investigate into uncertainties. The model data are processed by spatially and temporal solved Harmonic Analysis.

Results and Discussion



The results of the long-term modelling confirm the larger scale estimations of Müller et al. (2011). Physical inherent changes of tidal phases and amplitudes have been proved in the Elbe Estuary. Figure 1 shows an example of the M2-Tide over three 19 year cycles near Cuxhaven. The importance of the Nodal cycle is noticeable. Also the increase of the amplitude of the M2-Tide due to SLR must be noted. Figure 2 illustrates how the change along the estuary has to be expected in a high end scenario until the end of the century. The amplification of the tidal amplitudes continues in the estuary. However, for the first M2 overtide, the M4, the amplitude in the estuary decreases with pronounced changes in the spatial pattern. This is documented in the amplitudes as well as in the shift of the tidal phases. With SLR, the wave speed and wave length increase, causing changes in the reflections of the tides. Additionally energy dissipation by bottom friction is reduced. These mechanisms in combination result in the migration of complex patterns of non-linear changes in the tides with SLR (Pickering et al. 2012). Despite uncertainties associated with the SLR over the next century, modifications of the tides in coastal areas and estuaries implicate modifications of the coastal management by estimation of adapted design levels, in the availability of tidal renewable energy and dredging requirements (Pickering et al. 2012).

References

Backhaus J. O. (1985) A three-dimensional model for the simulation of shelf sea dynamics. Dt. Hyd. Z.38, 165–187.Hein, B. (2013). Processes of stratification and destratification in the Mekong ROFI-seasonal and intraseasonal variability. PhD Thesis, http://ediss.sub.uni-hamburg.de/volltexte/2013/6369/.

Hein, H., Karfeld, B., Pohlmann, T. (2007) Mekong water dispersion. Measurements and consequences for the hydrodynamic modelling, J. of Water Res. and Env. Eng., Special Issue, August 2007, 21 – 28.

Hein H., S Mai, U Barjenbruch (2011) Interaction of Wind-Waves and Currents in the Ems-Dollard Estuary, The International Journal of Ocean and Climate Systems 2 (4), 249-258.

Hein, H., S. Mai, & U. Barjenbruch (2012) Uncertainties of drying periods of coarse coastal climate impact models, Proc. 2nd IAHR Europe Congress, München.

Hein, H., Hein, B., & Pohlmann, T. (2013). Recent sediment dynamics in the region of Mekong water influence. Global and Planetary Change. 110, 183-194.
Lingemann, I, Nilson E., Krahe P. (2012), „Änderungen des Abflussregimes im 21. Jahrhundert: Aktuelle Ergebnisse des Forschungsprogramms KLIWAS“, Kolloquium, Dresden.
Mathis, M., (2013), Projected Forecast of Hydrodynamic Conditions in the North Sea for the 21st Century, http://ediss.sub.uni-hamburg.de/volltexte/2013/6169/
Müller, M., Arbic, B. K., & Mitrovica, J. X. (2011). Secular trends in ocean tides: Observations and model results. Journal of Geophysical Research: Oceans (1978–2012), 116(C5).
Pickering, M. D., Wells, N. C., Horsburgh, K. J., & Green, J. A. M. (2012). The impact of future sea-level rise on the European Shelf tides. Continental Shelf Research, 35, 1-15.
Pohlmann, T. (2006) A meso-scale model of the central and southern North Sea: Consequences of an improved resolution. Continental Shelf Res. 26, 2367-2385.

Application of Multi-Site Stochastic Daily Climate Generation to Assess the Impact of Climate Change in the Eastern Seaboard of Thailand

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Keywords: Stochastic weather model; Daily weather generator; Multi-site; Downscaling; Impact study

In the assessment of climate change impacts on future meteorological and/or hydrological regimes, downscaling of large-scale climate/weather variables from GCMs or RCMs is widely applied. Since the daily climate can describe the particular impact related to shorter-term behavior, e.g., storms and floods, that monthly and seasonal statistics cannot achieve, a projection of climate variables on a daily scale is required in many impact studies. However, the direct use of daily climate predictions from one GCM is usually not reliable enough to represent the full variability of the climate variable's time series, namely, extreme behavior. Notwithstanding that daily GCM climate predictor variables are available for some models, the downscaling outcome is very sensitive to small changes in the daily predictor. For this reason, downscaling of monthly predictor data may be more recommendable, as it is more reliable. However, the subsequent step to generate daily series from this downscaled monthly climate series becomes then more tricky. Here we present a novel "daily-climate-regeneration-approach" to do this properly.

The regeneration of daily climate series which is able to reflect the full variability of a climate variable on a daily scale, while still respecting its intra-month variability, is essentially done by re-sampling the monthly series on a daily scale. This is achieved by using various stochastic techniques which basically synthesize daily climate from several ensembles of daily series which respect the relevant statistical attributes of the monthly climate series, such as its probability distribution, as well as mean and variance. This multi-realization of synthetic daily climate can exhibit a broad spectrum of climate variability that can be useful in a practical climate assessment, as this approach provides also some uncertainty measure.

The daily weather (climate) -generator (DWG) proposed here processes the daily precipitation (PCP)- and temperature- (T) series separately, wherefore for PCP both the monthly downscaled rainfall intensity and the probability of rainfall occurrence and for T the monthly temperatures are employed. In addition, the observed daily time series of precipitation and temperatures are used to define the basic statistical parameters of the respective climate variable's distribution. During this generation process, firstly, the sequences of rainfall occurrence, either wet or dry state (%Wet) on each day, are synthesized. Then, secondly, the amount of daily rainfall is generated on the synthetic wet days. Afterwards, the maximum and minimum temperatures are generated, whereby, depending of the rainfall state, i.e., wet or dry days, two different temperature distributions are used.

One particularly unique feature of the DWG proposed here is that it can, unlike other methods, which are usually applied to a single-site weather station, also be applied to a multi-site climate station network across a region, taking into consideration the spatial correlation of the observed weather pattern between the individual stations. Doing so results in a better representation of the regional climate, than would possible by a single-site weather-generation approach.

This novel multi-site daily weather generator (DWG) is applied to climate time series' of daily and monthly rainfall and maximum and minimum temperatures observed at a station network with 24 rainfall- and 4 temperature sites in the Eastern Seaboard industrial zone of Thailand (EST) between 1971-2000. More specifically, the method is calibrated for the 1971-1985 time period and validated during 1986-2000, by examining the synthetically generated data for %Wet, PCP, Tmax and Tmin against the respective observed ones. A good agreement between the distributions of the two is obtained. Moreover, the analyses of the extremes of the daily synthetic and observed rainfalls result, for the 100-year return period - critical values, in a bias of only 15% for the simulated one.

Finally, the novel DWG is combined with a multiple-linear regression (MLR) downscaling method to downscale years 1971-2000 monthly GCM-model climate (past) predictions in the study region; i.e. first, spatially, with MLR, on the monthly scale, and then, temporarily, with DWG, to daily scale. The results show that, compared with the well-known classical SDSM and LARS-WG downscaling models, this combined MLR+DWG method shows the best performance in downscaling daily climate.

Usefulness of High Resolution Regional Climate Model Data for Hydrological Applications

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Keywords: Climate Change, Water resources, Downscaling, WRF, Hydrology

Rapid urbanization in many megacities in Southeast Asia (SE Asia) has been accompanied with severe flooding and ecological problems. Often, the most common causes are lack of or short rainfall record to derive Intensity-Duration-Frequency (IDF) curves for optimal storm drainage designs or to set-up a well-calibrated rainfall-runoff model for catchments in general, transboundary catchments in particular. This paper focuses on finding proxy for rainfall data for the present climate. The proxy data comes from dynamically downscaled Re-Analysis data for the domain of interest. In this study, a Regional Climate Model (RCM), WRF, is used for the entire SE Asia. The aforementioned proxy data for the current climate is derived from WRF, driven by the Re-Analysis data ERA, for the SE Asia domain at high spatial resolution of 30x30Km.

Developing IDF curves for SE Asia can be challenging especially for data sparse sites. Many of these poorly gauged regions are also among regions that are highly vulnerable to climate change. One of the anticipated changes is the increase in extreme rainfall intensities and their respective frequencies. The increase in extreme rainfall requires an update on the IDF curves that in turn necessitates larger drainage dimension.

For ungauged sites it is absolutely crucial to first derive the IDF curves for the present climate. The proposed approach has been successfully demonstrated and implemented at several regions in SE Asia. More testing is conducted to show the robustness of the approach.

Issues related to challenges in rainfall data sharing, among neighboring countries, in transboundary catchments inevitably yield inaccurate rainfall-runoff models. Here, again, downscaled Re-Analysis data are demonstrated to be excellent proxies for 'missing' rainfall stations' data from the neighboring countries. This paper shows a trans-boundary catchment, Da River catchment, where upstream is in the Chinese territory while downstream is in the Vietnam territory. A SWAT model is applied; upstream region's rainfall data are derived from the WRF/ERA from 'stations' that are represented as grid points in the WRF model. Three downstream flow-gauging stations are used as performance measures in the model calibration and verification.

The above two examples show how proxy rainfall data stemming from downscaled Re-analysis data can help to resolve the much needed rainfall data for storm drainage designs and rainfall-runoff models for trans-boundary catchments.Rapid urbanization in many megacities in Southeast Asia (SE Asia) has been accompanied with severe flooding and ecological problems. Often, the most common causes are lack of or short rainfall record to derive Intensity-Duration-Frequency (IDF) curves for optimal storm drainage designs or to set-up a well-calibrated rainfall-runoff model for catchments in general, transboundary catchments in particular. This paper focuses on finding proxy for rainfall data for the present climate. The proxy data comes from dynamically downscaled Re-Analysis data for the domain of interest. In this study, a Regional Climate Model (RCM), WRF, is used for the entire SE Asia. The aforementioned proxy data for the current climate is derived from WRF, driven by the Re-Analysis data ERA, for the SE Asia domain at high spatial resolution of 30x30Km.

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Modeling Surface Mass Balance and Glacier Water Discharge in Tropical Glaciers of La Coordillera Blanca, Peru

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Keywords: Mass balance, Tropical glaciers, Energy balance models

Climate change produces large variations in the regional pattern of solar radiation, temperature and precipitation which, in turn, may modify the mass balance of glaciers. As a consequence, retreats of many glaciers around the world, namely, in the tropics, have been reported. Indeed, due to their specific geographical conditions, tropical glaciers have a more rapid response to climate change than glaciers in mid and high latitudes. Since high-altitude tropical glaciers are often the “feeding ground” of water resources for densely populated lowland river basins in many tropical countries of the world, future glacier retreat will affect the livelihood and the economy of large populations there.

Such could be the fate for the Andes mountain Rio Santa river basin in the Ancash district of Peru which is water-fed by the glaciers of the neighboring La Cordillera Blanca, which has the biggest extension (~26% of the global tropical glacier area) of tropical glaciers in the world. Studies done to-date reveal, indeed, large retreats of the La Cordillera Blanca’s glaciers over the last seventy years.

In the present contribution intermediate results of an ongoing study of the dynamic interaction of the regional climate with the La Cordillera Blanca glaciers Artesonraju, Uruashraju and Yanamarey and, in particular, of the effect of possible climate changes on the glaciers’ surface water discharge are presented. As lack of data is often a problem in this kind of studies, prior to the modeling of the glacier dynamics per se, much effort had to be devoted to the cleaning and restitution of the time series of the relevant climate- and glacier variables. To that avail, advanced methods of structural time series which take the auto- and cross-correlation properties of the measured variables into account, have been applied. The two glacier models used in the subsequent dynamic analysis are an energy balance- and a temperature index model. Although energy balance models represent the physics of the glacier accumulation/ melting processes rather well, they require a lot of measured variables, especially radiation fluxes. However, as the latter have been available here only over a short period of time, the simulation of glacier runoff by this method could be accomplished just over a few-years period. On the other hand, the less sophisticated temperature index model requires only variables temperature and precipitation as input. So, it is found to be more suitable, in general, for the long-term simulation of glacier dynamics. Comparisons of the performances of these two glacier models to predict measured discharges to glacier lakes, which, eventually, will feed the Rio Santa river, will be presented.

Effect of Sea Level Rise in Gulf of Khambhat, West Coast of India

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Keywords: Tidal constituents, Bottom friction, Gulf of Khambhat, TELEMAC-2D

Sea level change is one of the main factors which cause major impacts along the global coastlines and it vary widely in the past few decades due to global warming. Global sea level change is usually caused by melting of land-based ice and thermal expansion, as water warms. It is estimated that the sea-level for the year 1990-2100 will be rise to 280 to 340mm (Church, 2006). However, as per NOAA data, the global mean sea level variation is estimated to be order of 3.16±0.4mm/year. As the global warming based sea level rise (SLR) is alarming in ocean waters, it is increasingly important to assess the effect of the same in all the coastal processes.

Gulf of Khambhat is located along the west coast of India, and having a coastline of more than 750kms which is a dynamic natural sea basin. Gujarat states occupies more than one sixth (1,600kms) of Indian coastline, which includes Gulf of Khambhat and having several ports and other infrastructural facilities along the Gulf. The range of tidal fluctuations along the Gulf varies from 1m to 12m and subsequently the tide induced currents exceed 2.2 m/sec (Broos and Wiersema, 1998). In this study, an attempt is made to understand the tidal hydrodynamics of Gulf of Khambhat by defining the different bottom friction zones. The effect of SLR on the tidal levels and respective currents, along the Gulf of Khambhat is also estimated. The percentage difference in the levels and currents due to the SLR with respect to the present day conditions are estimated for selected diurnal and semi-diurnal tidal constituents (K1, O1, P1, M2, N2, and K2). The detailed tidal hydrodynamic investigation has been taken up through a finite-element based numerical modelling, TELEMAC-2D (Hervouet, 2000), which is capable of simulating free-surface flows in the two dimensions of horizontal space and solves the Saint-Venant equations.

For the numerical model study, relatively a large area of about 660x770km, including part of Arabian Sea is considered (Figure 1). The entire area is discretised into triangular grids, with a largest size of 50km along the offshore boundary and smallest size of 2km near the coastline. The first part of the study is to arrive at appropriate bottom friction values for different zones in Gulf of Khambhat. The offshore boundary is forced with tidal constituents, obtained from global tidal models (Haigh, et al 2011). To find out the bottom friction, the hydrodynamic results were calibrated with the available observed data for various locations along the gulf.

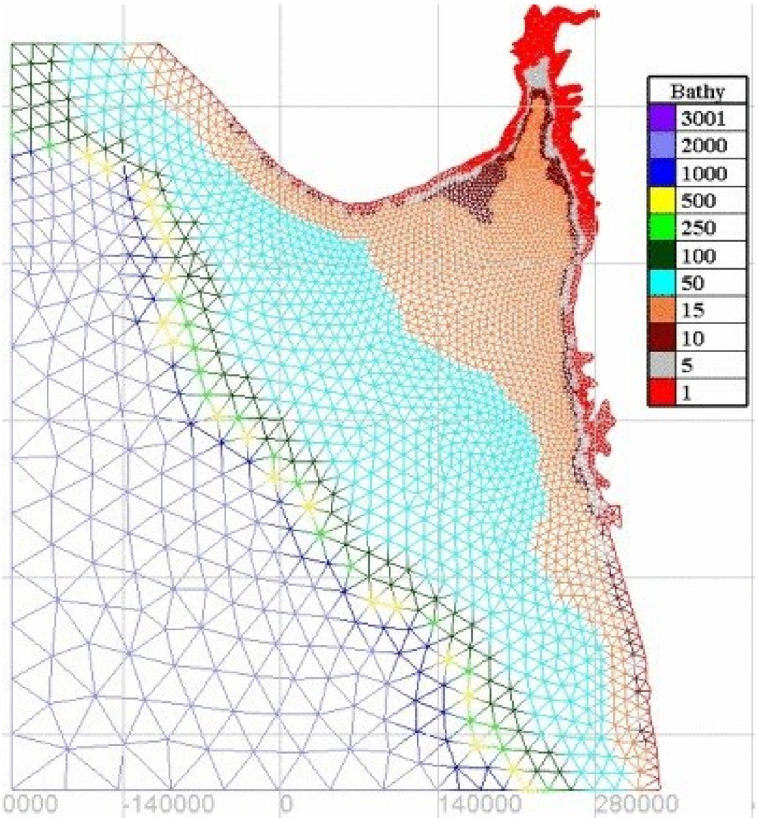

Figure 1. Bathymetry of the study area - Gulf of Khambhat.

Based on the calibration, Gulf of Khambhat has been divided into five zones with different bottom friction values. As the entire gulf is of relatively shallow depth, the bottom friction influences the tidal levels and currents. After establishing the bottom friction values, the numerical model is run for present scenario and the numerically estimated results were compared with the available observed data from the literatures. Comparison of water levels and currents, extracted at selected locations of Hazira, Pipavbandar, Dhuvaran, Apollo Bandar, Bhavnagar, Daman, Navapur, Umergaon, Dahanu and Bmbay high showed the good agreement. It is observed from the model results that M2 and K1 are predominant tidal constituents (Unnikrishnan, 2010) in the study area followed by the other constituents S2, O1, N2 and P1. Tidal propagation was predicted for the above mentioned six tidal constituents with and without sea level rise conditions. Three sea level rise scenarios (0.1m, 0.5m and 1m) had been introduced with the existing tidal constituents. The amplitudes and velocities of individual constituents, extracted along a specific stretch of gulf are compared with that of no SLR condition, to obtain the percentage variations.

In general, it is observed from the results that the percentage variation is significant in the nearshore region compare to offshore. The variations in the amplitude of constituent, due to SLR, appear to the same pattern for all four tidal constituents except M2 and P1. A maximum percentage increase in the tidal amplitude is observed to be 26% for N2 with a 1m SLR condition. Whereas, a maximum increase in the tidal current of about 55% is observed for P1 with 1m SLR condition. The study reveals that the nearshore region along the gulf will be affected significantly because of sea level rise.

References

Broos.E.J and Wiersema.K.J (1998), Closure of the Gulf of Khambhat.

Church, J. A., and White, N. J. (2006).A 20th century acceleration in global sea-level rise, Vol.33, pp.94–97.

Haigh, I. D., Eliot, M., and Pattiaratchi, C. (2011). Global influences of the 18. 61 year nodal cycle and 8.85 year cycle of lunar perigee on high tidal levels, Vol.116, pp.1–16.

Hervout, J.M. (2000), Hydrodynamics of free surface flows: Modeling with the finite element method, John Wiley & Sons Ltd., England.

Unnikrishnan, A. S. (2010). Tidal propagation off the central west coast of India. Indian Journal of Geo-Marine Sciences, Vol.39, pp.485–488

Prediction of Climate Change Impacts on Groundwater Storage by Analysis and Modeling of Hydrograph Recession Curves: Application to BarWatershed, Iran

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Keywords: Climate change, Recession curve analysis, Groundwater reserve, Bar watershed, Iran

Climate change is any long-term and irreversible changes in weather conditions emerging during decades or thousands of years. There are different factors causing climate change. Nowadays, as the main cause of climate change is an increase in greenhouse gases. Climate change will vary the other hydrologic parameters (hydrological cycle) like runoff and groundwater resources. The aim of this study was to investigate the climate change impacts on the groundwater stored above the discharge level by using groundwater depletion analysis in Neishabur Bar Watershed. At first, for this reason using GCM models presented by IPCC and downscaling methods such as LARS- WG and SDSM, the climate situation was projected under specific scenarios. The results showed that mean annual maximum and minimum temperature will be increased equally under the scenario A2 Hadcm3 model by 1.1, 3.2 and 4.6 ◦c during the projected periods 2010- 2039, 2040- 2069 and 2070- 2099 respectively compared to the observed period (1970-2010). Whereas, based on the scenario A2 Hadcm3 model, precipitation will be decreased by 16.4, 17.6 and 31.4 percent receptivity in comparison with the observed data for the predicted periods mentioned above. With the purpose of forecasting of the Bar river discharge under different climate scenarios, a rainfall- runoff model was developed by IHACRAS model. Accordingly, the projected and downscaled climate variables were inputted into the IHCRAS model and then annul hydrographs were forecasted for the studied periods. In this regard, results indicated that the discharge will be abated by 9, 44 and 66 percent respectively during the projected periods namely 2010-2039, 2040- 2069 and 2070- 2099 compared to the observed period (1970- 2010). Afterwards using annual hydrograph recession curve analyses, climate change impacts on the groundwater reserve above the discharge level were forecasted and as such Groundwater storage will be dropped up to 36.9, 52 and 61 percent respectively during the projected periods in comparison to the base period.

References

Bovolo, C.I., Parkin, G., Sophocleous, M., 2009. Groundwater resources, climate and vulnerability. Environ. Res. Lett. 4 (3), 035001.

Green, T.R., Taniguchi, M., Kooi, H., 2007b. Potential impacts of climate change and human activity on subsurface water resources. Vadose Zone J. 6 (3), 531–532.

Holman, I.P., 2006. Climate change impacts on groundwater recharge-uncertainty, shortcomings, and the way forward? Hydrogeol. J. 14 (5), 637–647.

Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N.I., Barnola, J.M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V.M., Legrand, M., Lipenkov, V.Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E., Stievenard, M., 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399 (6735), 429–436.

Sophocleous, M., 2004. Climate change: why should water professionals care? Ground Water 42 (5), 637.

Seasonal Sea Level Changes in the Gulf of Mexico and the Implications for Coastal Flood Risk

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Keywords: Gulf of Mexico, Seasonal sea level, Tide gauge, Atmospheric reanalysis, Multiple linear regression, Satellite altimetry, Flood risk

The seasonal cycle is an energetic component in the sea level spectrum and dominates the intra-annual sea level variability outside the semidiurnal and diurnal tidal bands in most regions of the world. It consists of semi-annual and annual components, which are more or less pronounced depending on the geographic location [e.g. Tsimplis and Woodworth, 1994] and primarily driven by meteorological and oceanographic processes. Changes in the annual or semi-annual amplitudes or phase lags have an immediate impact on marine coastal systems. Increases (or decreases) in the amplitudes or phase shifts towards (or away from) the storm surge season may for instance exacerbate (or reduce) the risk of coastal flooding and/or beach erosion. Changes in the seasonal sea level cycle (SSLC) may furthermore impact the health of ecological valuable and productive estuarine systems and coastal wetlands by altering the salt balance of intertidal sediments and, in turn, the primary production [e.g. Morris, 2000]. The temporal variability in coastal SSLC has mostly been examined at the regional scale and fluctuations on inter-annual to decadal time scales in the amplitudes and phase lags have been found. This study focuses on the Gulf Mexico coastline (and later the entire basin) which is low-lying with sensitive ecosystems and hence particularly vulnerable to even small changes in the intra-annual sea level variability. From investigating temporal changes in the seasonal harmonics, we found a significant increase in the amplitude of the dominating annual cycle, which is strongest in the eastern part of the Gulf along the coastline of West Florida. This amplification of up to 30% has almost doubled the flood risk from hurricane surges associated with sea level rise over the last two decades, i.e. instead of 5 cm increase in sea level (the best global estimate from coastal tide gauges) we saw 10 cm increase in the summer month when hurricanes occur. In an area which is densely populated and where coastal flood protection measures (such as dikes or dunes) do not (or rarely) exist, such information is highly relevant for decision makers (in order to develop adaptation strategies accordingly), coastal engineers and managers (e.g. to plan coastal protection measures and beach nourishment projects), insurance companies (when defining the flood plain), and also for marine biologists and geochemists (as it affects the ecological health of estuaries and coastal wetlands).
Using the concept of multiple regression along with various ancillary data sets from an atmospheric reanalysis and reconstructions of the sea surface temperature and steric sea level component, we show that the increase in the amplitude of the annual cycle was mainly driven by changes in the air temperature towards warmer summers and colder winters and in the sea level pressure with higher values in the winter and smaller values in the summer. For the analyses we used long records from 13 tide gauges covering the US Gulf coast. Despite the relatively dense tide gauge network in place in this area, there are still long coastline stretches in-between for which the observational data base from in-situ measurements is insufficient. Therefore, we complement the analyses and results presented by Wahl et al. [2014] based on the tide gauge records with satellite altimetry data covering the last 20 years, i.e. exactly the period for which the amplitude increase was detected. There is still concern that such data is of poor quality in the near coastal zone, but enormous efforts over the recent years (and still on-going) have significantly improved the accuracy of coastal altimetry data. We validate the (spatially) high resolution satellite data by comparing the results from analyzing the seasonal cycle with those obtained from the tide gauge records. This allows us to draw conclusions about the behavior of the SSLC along unobserved coastline stretches and will also provide a much better spatial

picture of the entire basin. The latter is important in order to examine whether the observed changes are confined to the shallow coastal waters or also appear in the deep ocean.
The statistical models that will be presented can also be used in combination with the output of regional or global climate models allowing the assessment of potential future changes in the SSLC which may be of high importance to policy-/decision makers and researchers from various scientific fields.

References

Morris, J. T (2000), Effects of sea level anomalies on estuarine processes. Pages 107–127 in J. Hobbie, editor. Estuarine science: a synthetic approach to research and practice. Island
Press, Washington, D.C., USA.
Tsimplis, M. N., and P. L. Woodworth (1994), The global distribution of the seasonal sea level cycle calculated from coastal tide gauge data, J. Geophys. Res., 99(C8), 16,031–16,039, doi:10.1029/94JC01115.
Wahl, T., F. M. Calafat, and M. E. Luther (2014), Rapid changes in the seasonal sea level cycle along the US Gulf coast from the late 20th century, Geophys. Res. Lett., 41, doi:10.1002/2013GL058777.

Evaluation of Reservoir Sediment Load under Climate Change

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Keywords: Reservoir sedimentation, Climate change, SDSM, EPM, HadCM3

Reservoir dams are often under threat from sedimentation initiated and accumulated in the upstream basin. Reservoir sedimentation reduces the efficiency and the designed expected life of the reservoir while endangering hydroelectric and water supply systems. From a hydrological perspective, sediment load specifically affected by climate change considerations are particularly important at basin scale studies. Here, the EPM model has been utilised to determine the annual sediment volume in the basin under study for its appropriate responses to climate variations. To assess the effects of climate change the HadCM3 climate model data have been utilised under the A2 and B2 scenarios sought as most appropriate scenarios for the basin under consideration. The SDSM model has been used next for downscaling and the results were formatted as input into the EPM model. A series of possible future variations were considered. Available daily rainfall data for the period 1967-1985 were used for model calibration and verification of model performance was achieved using the data for the period 1986-2001. Results indicate a reduction of 8.6 % and 8.9 % in the annual sediment volume for the period 2020-2030 under the circulation scenarios A2 and B2 respectively compared to the base values for the period 1986-2001. Sediment management scenarios were then developed based on sustainable development criteria. Practical strategies stemming from social, economic and environmental considerations were addressed in proposition of the scenarios. Examination and ranking of the scenarios using a Multi Criteria Decision Making (MCDM) tool has provided the basis for planning and decision making on the eventual reservoir sedimentation loads under climate change effects.

Sources of Uncertainty in Climate Impact Modeling at the Example of a 3D Hydrodynamic Model of the Weser Estuary

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Keywords: Climate change impact, 3D hydrodynamic model, Estuary, Weser, Uncertainty

Background and Objectives

The change in global climate in the 21st century, as predicted by the Intergovernmental Panel on Climate Change (IPCC) will affect coasts through mean sea level rise (MSLR), changes in the storm surge climate and the river runoff. In order to keep the coastal protection system at the present level of safety, research on the impact of climate change on the coastal systems has become increasingly important. However, today's knowledge is still limited and the projections are made with a certain amount of uncertainty.

As it takes decades to plan and build new constructions, early planning decisions have to be made under uncertainty and the explicit investigation of the level of uncertainty in climate impact research is becoming increasingly important. In the latest assessment report, suggestions are made on how to communicate the level of confidence on the results in climate modeling or impact studies. Sources of uncertainty are categorized by model uncertainty, boundary condition uncertainty and uncertainty caused by natural climate variability. Some recent impact studies have discussed aspects of this (cmp. Gaslikova et al., 2012, Huang et al., 2013, or Lewis et al. 2011).

The work presented here is part of a climate impact research cooperation funded by the German State of Lower Saxony. Its aim is to study the impact of climate change on a regional basis, with a focus on the impact of hydrodynamics and salinities of the Weser Estuary. This contribution focuses on different sources of uncertainty in the investigation of climate change impact.

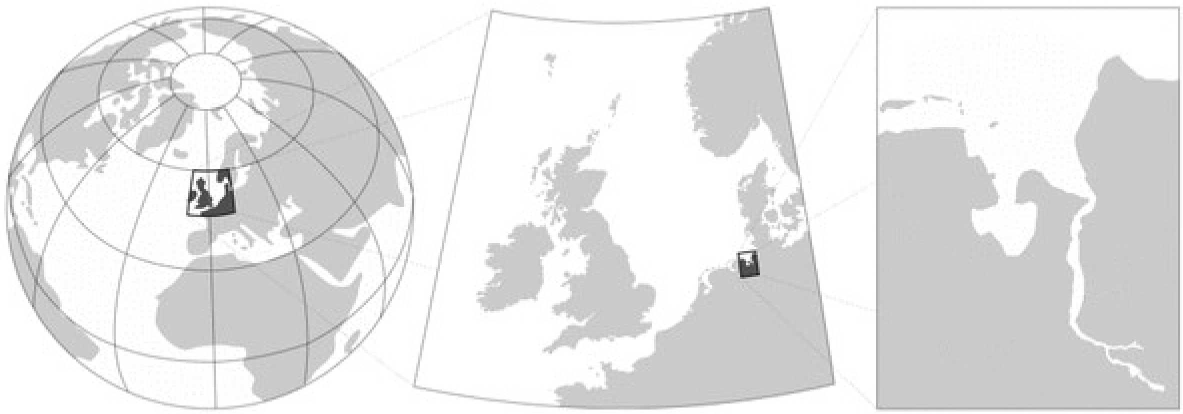

Figure 1. From global climate change to regional impact - What are our uncertainties? (from left to right: Globe, North Sea, Weser Estuary).

Methods and Computational Domain

To simulate climate change responses of the Weser estuary, the baroclinic circulation modeling tool SELFE (Zhang & Baptista, 2008) is applied. It solves the Reynolds averaged Navier-Stokes equations with shallow water assumption and Boussinesq approximation, following a semi-implicit Eulerian-Lagrangian finite-element approach.

The research area encompasses the tidally influenced part of the Weser from the weir in Bremen up to the 25 m depth line in the German Bight, including Jade and tributaries (see Fig. 1, right). A numerical model of the research area is developed, focusing on capturing small-scale bathymetric features in the inner estuary while remaining computationally efficient by choosing a coarse resolution in the Wadden Sea. The model is calibrated and validated against measurements along the estuary, resulting in good agreement between observed and simulated time series (Zorndt et al., 2013, in review).

Results and Outlook

This contribution focuses on the mean sea level rise as the main source of impact on the estuary. For the translation of the global projection of the IPCC for different representative concentration pathways down to changes of water levels and salinity intrusion in the Weser, different sources of uncertainty are exemplarily investigated, among which are changes of the tidal dynamics and in salinity of the North Sea (see Fig. 1, middle) affecting model boundary conditions, changes in sedimentation patterns affecting bathymetry and model roughness as well as internal variability.

Results quantify the influence of the different sources of uncertainty and provide their respective relative impact. The importance of internal variability as one major source of uncertainty is confirmed. The contribution provides valuable insights for coastal planners and indicates directions for research to further decrease uncertainty in climate impact studies.

References

Gaslikova, L., Grabemann, I., and Groll, N. (2013). Changes in North Sea storm surge conditions for four transient future climate realizations. Natural Hazards, 66(3):1501–1518.

Huang, S., Hattermann, F. F., Krysanova, V., and Bronstert, A. (2013a). Projections of climate change impacts on river flood conditions in Germany by combining three different RCMs with a regional eco-hydrological model. Climatic Change, 116:631–663.

Lewis, M., Horsburgh, K., Bates, P., and Smith, R. (2011). Quantifying the Uncertainty in Future Coastal Flood Risk Estimates for the U.K. Journal of Coastal Research, 27:870–881.

Zhang, Y. J. and A. M. Baptista. 2008. SELFE: A semi-implicit Eulerian-Lagrangian finite-element model for cross-scale ocean circulation, Ocean Modelling, 21, 71–96.

Zorndt, A. C., Zhang, Y. J. and Schlurmann, T. (2014). Modeling salt intrusion into the Weser Estuary with a semi-implicit Eulerian-Lagrangian finite-element approach. Ocean Dynamics, in review.

Eco-Hydraulics and Eco-Hydrology

The Residence Time in the Elbe River Focussing on the Estuary

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Keywords: Residence Time, Tracer Concentrations, Numerical Modelling, Elbe River, Elbe Estuary

Introduction

The residence time is the time that a parcel of water remains in a defined section of a river, for example in the estuary, the main branch, assorted side branches, etc.. Several studies use residence times to define biological timescales and to assess nutrient exports and imports and to estimate primary production (e.g. Lucas et al. 1999, Hein et al. 2013). While the mayor focus is on the tidal influenced area, this study estimates the residence time in the Elbe River from Schmilka toward the mouth near Cuxhaven by the means of modelling studies and measurements of tracer distributions. In rivers the discharge itself is the main transport process, in addition in estuaries the processes that transport a parcel of water depends on several lower-frequency residual flows, e.g. river flows, baroclinic currents, or wind driven currents, but the regime is dominated by tidal flows.

Numerical methods for the estimation of residence time

The whole model area is between Elbe-km 0 (border between the Czech Republic and Germany) and Elbe-km 727 (Cuxhaven, North Sea) comprising the Elbe River (km 0 to km 585) and the Elbe Estuary (km 585 to km 727). For determining the residence time in the river the water quality model QSim (Kirchesch und Schöl 1999) is used. It is offline coupled with HYDRAX as hydrodynamic driver. HYDRAX is a one dimensional hydrodynamic model to simulate unsteay flows in a network of water bodies (Oppermann 1989). In HYDRAX the equations of Saint Venant are solved numerically. In the estuary currents and sea-levels are additionally modelled by the hydro-numerical HAMburg Shelf Ocean Model (HAMSOM; Backhaus, 1985). The actual model version (Hein, 2013) is optimized for the use in estuarine regimes and recognizes also horizontal sub-grid processes, e.g. drying (Hein et al. 2012) or horizontal turbulence (Hein, 2008). The model has a dynamic resolution of 200 m in the horizontal and 5 m in the vertical. Processes like drying or friction are calculated on a grid of 40 m. The residence time Θ is defined as the time taken by a numerical tracer entering and leaving a river section S.

Results and discussion

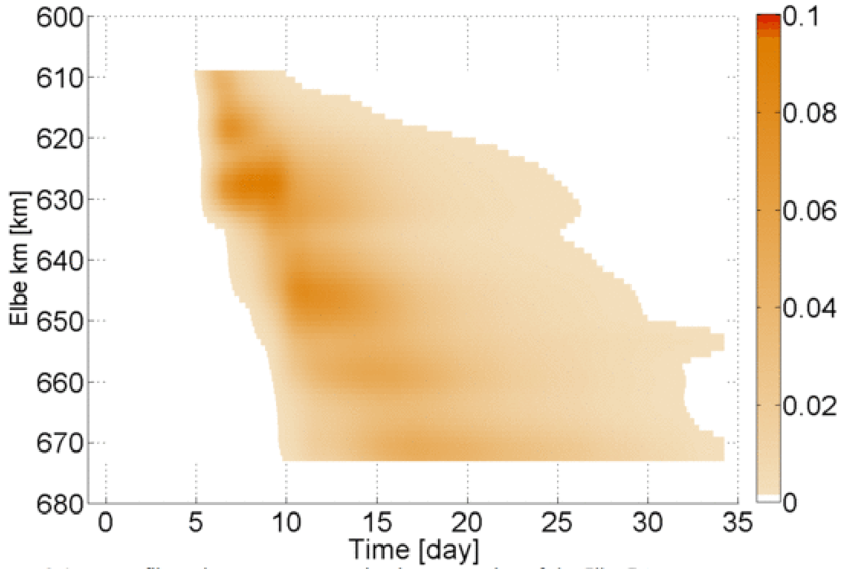

Figure 1: Lowpass filtered tracer concentration in one section of the Elbe Estuary.

In comparison to the estuary the residence time in the riverine part of the Elbe is relatively short. One portion of water needs O(10) days for the river stretch from Schmilka to Geesthacht. This section has a length of 585 km. Due to diffusive processes the spreading of the signal changes from 10 h towards O(2) days. The results agree well with observation (Mai et al., 2006). The tracer concentration in one 60 km long section of the estuary (km 610 – km 670) shows two significant differences (Figure 1). Θ being O(30) days, which means the double magnitude than Θ of the whole middle part of the river. The tidal signal is visible (Figure 2) in the tracer concentration. The spreading of the concentration is more pronounced than in the middle part, the asymmetry in the distribution of the concentrations becomes evident. The main transport processes in the estuary are more dispersion related than advection related, which is the main process in the riverine part of main rivers (Deng et al., 2010). Θ depends on both temporal and spatial scales. In terms of the spatial scale, the distribution of Θ is channel-size dependent (Deng et al., 2010), together with the tidal dispersion effects this explains the changes in the estuary. The simulation of estuarine or tracer circulations yield several numeric requirements to the model (Hein, 2007). In one model experiment we compare different numerical algorithms to solve the transport equation. Future in situ tracer experiments must confirm our result that the second order flux limiting (2OFL) scheme performs best. In the simulations of salinity fields, 2OFL algorithm seems practicable (Gross, 1999). However, differences because of different numerical artificial diffusion in the tracer concentration are followed by differences in Θ.

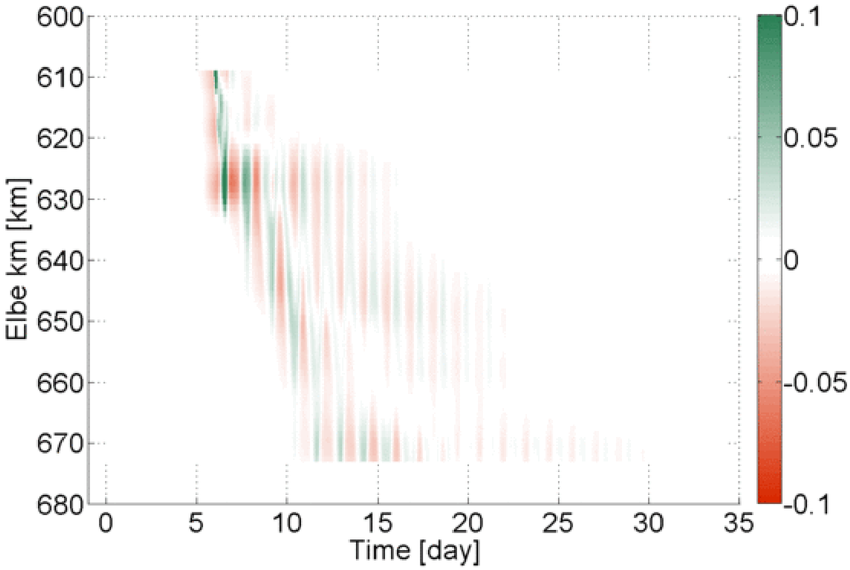

Figure 2: Highpass filtered tracer concentration in the Elbe Estuary

Conclusions

In brief, it has been found that the residence time changes significantly in magnitude and structure in the tidal influenced area. In the Elbe Estuary Θ is a mutable of Θ in the riverine part and additionally diffusion processes become important, both ensure certain consequences for the tracer simulations: Numerical schemes with rather low artificial diffusion are appropriate, as well as the eddy diffusion tensor must be estimated by sub-grid schemes. However, Θ depends in the same way on both, the riverine and the estuarine part of the Elbe River, on river discharges.

References

Anderson, E. J., & Phanikumar, M. S. (2011). Surface storage dynamics in large river. Water Resources Res., 47(9).

Backhaus J. O. (1985) A three-dimensional model for the simulation of shelf sea dynamics. Dt. Hyd. Z.38, 165–187.

Deng, Z. Q., Jung, Ghimire, (2010). Effect of channel size on solute residence time distributions in rivers. Adv. in W. Res., 33(9).

Gross, E. S., Koseff, Monismith, (1999). Evaluation of advective schemes for estuarine salinity simulations. J. Hyd. Eng. 125,32-46.

Hein, B. (2013). Processes of stratification and destratification in the Mekong ROFI-seasonal and intraseasonal variability. PhD Thesis, http://ediss.sub.uni-hamburg.de/volltexte/2013/6369/.
Hein, H., Karfeld, B., Pohlmann, T. (2007) Mekong water dispersion. Measurements and consequences for the hydrodynamic modelling, J. of Water Res. and Env. Eng., Special Issue, August 2007, 21 – 28.
Hein, H. (2008) Vietnam Upwelling - Analysis of the upwelling and related processes in the coastal area off South Vietnam, PhD Thesis, http://www.sub.uni-hamburg.de/opus/volltexte/2008/3931/.
Hein, H., Mai, Barjenbruch (2012) Uncertainties of drying periods of coarse coastal climate impact models, IAHR2012, München.
Hein, H., Hein, B., Pohlmann, T., & Long, B. H. (2013) Inter-annual variability of upwelling off the South-Vietnamese coast and its relation to nutrient dynamics. Global and Planetary Change, 110, 170-182.
Lucas, L. V., Koseff, J. R., Monismith, S. G., Cloern, J. E., & Thompson, J. K. (1999). Processes governing phytoplankton blooms in estuaries. II: The role of horizontal transport. Marine Ecology-Progress Series, 187, 17-30.
Mai, Lippert, Barjenbruch 2006; Studies of Tracer Transport in the River Elbe, ICHE 2006, Philadelphia, USA.
Oppermann (1989)Eindimensionale Simulation allmählich veränderlicher instationärer Fließvorgänge in Gewässernetzen.VfB, Berlin.
Kirchesch, V. & Schöl, A. (1999): Das Gewässergütemodell QSIM - Ein Instrument zur Simulation und Prognose des Stoffhaushalts und der Planktondynamik von Fließgewässern. Hydrologie und Wasserbewirtschaftung 43, 302-308.

Revisiting the Relationship of Transient-Storage and Aggregated Dead Zone Models of Longitudinal Solute Transport in Streams

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Keywords: Solute Transport, Water Quality Modeling, Data Based Mechanistic, Aggregated Dead Zone Model

Introduction

Data based mechanistic, DBM, environmental models able to accurately reproduce input-output behavior of natural and man-made systems are still required in practical water quantity and quality real-time control applications, due to their low computational cost and high efficiency. DBM models are also efficient and sufficient accurate tools to be used as the basis of complex decision support systems for the integrated management of water resources at the catchment scale. In this work, theoretical relationships between the one-dimensional distributed transient storage solute transport model (TS, Bencala and Walters, 1983; Runkel and Chapra, 1993) and the lumped, aggregated dead zone model (ADZ, Beer and Young, 1983; Young and Wallis, 1993; Camacho and González, 2008) were obtained. These relationships allow ADZ model parameters to be reliably derived from TS model parameters and vice versa. Assuring the equivalence between the ADZ and TS model parameters a close representation of advection, dispersion and biochemical processes in rivers and streams under both frameworks is demonstrated. The lumped ADZ framework, represented by an ordinary differential equation, allows effective and efficient use of powerful methods of system identification, parameter estimation and uncertainty analysis to be carried out. An additional advantage relies on the ADZ measurable and observable parameters using data of field tracer experiments and therefore its underlying potential application to indirectly estimating the space-average parameters of the distributed TS framework.

Relationships between TS and ADZ frameworks

Using a moment matching technique of conservative solute transport ADZ and TS model responses, Lees *et al*. (2000) obtained mathematical relationships between the different modelling frameworks parameters. Those authors used explicit equations found by Czernuszenco and Rowinski (1997) for the TS temporal moments, considering an upstream boundary condition defined by $C(0,t)=A0(t)$, where $A0(t)$ is a breakthrough concentration-time distribution at $x = 0$. Later, Schmid (2002, 2003), using the same boundary condition, obtained different expressions for the first three temporal moments. Comparisons carried out in this work, show that Schmid's (2002, 2003) equations produce better results than those of Czernuszenco and Rowinski (1997) according to the ADZ temporal moments equations (Lees et al. 2000).

Methodology

Several numerical tests using synthetic data under different flows and longitudinal dispersion conditions and channel geometry data were conducted to compare the dynamic response of the lumped ADZ model with the distributed TS model. Non-conservative reactive first order decay transport was considered. Both models were executed under the same upstream boundary conditions. The ADZ model with non-integer *n* identical mixed cells in series and first order reaction was programmed and executed using MATLAB (The MathWorks, 2009). The TS model equations were numerically solved using OTIS (One-dimensional transport with inflow and storage, Runkel, 1998). In order to guarantee equivalent conservative solute transport parameters, the theoretical relationships developed by

Lees *et al.* (2000) using temporal moments for the TS response reported by Schmid (2002, 2003) were applied. The ADZ model parameters were obtained from prescribed TS model parameters.

Results

The results show the ability of the data based ADZ model to represent identical reactive transport simulated responses obtained by the physically based TS model. Also a general expression relating the ADZ model dispersive fraction (*DF*) to TS model parameters was obtained. A theoretical behavior analysis for the dispersive fraction as a function of stream flow using Lees *et a*l. (2000) relationships was carried out. This work shows that using a constant value of 2/3 for the *DF* will enable identical solute transport simulation results between the ADZ and the Advection-Dispersion Equation model (ADE, Taylor, 1954). Furthermore, theoretical analysis to compare the response of the solute transport models under steady state conditions (well-mixed, plug-flow, and mixed-flow reactors) was performed.

Conclusions

This research work extensively demonstrates that both, steady state and dynamic solutions of reactive transport, using the TS and the ADZ modelling frameworks are equivalent if correct mathematical relationships between the conservative solute transport model parameters are used first. The latter can be achieved through the relationships proposed by Lees *et al*. (2000) using temporal moments for the TS model response reported by Schmid (2002, 2003).

This results highlight the ADZ modelling framework potential to be used as an efficient and effective alternative to traditional distributed approaches based on the one-dimensional advection-dispersion equation. This potential is particularly useful for real time control applications and water quality decision support tools at the catchment scale where computational cost is still an issue. There is an additional advantage, since it has been demonstrated that the data based mechanistic ADZ model parameters are observable, measurable and have physical meaning (Camacho and González, 2008), and the numerical solution of the resulting ordinary differential equation is very efficient.

References

Beer, T., & Young, P. C. (1983). Longitudinal dispersion in natural streams. Journal of Environmental Engineering, 109(5), 1049-1067.

Bencala, K. E., & Walters, R. A. (1983). Simulation of solute transport in a mountain pool-and-riffle stream: A transient storage model. Water Resources Research, 19(3), 718-724.

Camacho, L.A. & González, R.A. (2008). Calibration and predictive ability analysis of longitudinal solute transport models in mountain streams, Journal of Environmental Fluid Mechanics, 8, 5, 597-603

Czernuszenko, W. P., & Rowínski, P. M. (1997). Properties of the dead-zone model of longitudinal dispersion in rivers. Journal of Hydraulic Research, 35(4), 491-504.

Lees, M. J., Camacho, L. A., & Chapra, S. C. (2000). On the relationship of transient storage and aggregated dead zone modeles of longitudinal solute transport in streams. Water Resources Research, 36(1), 213-224.

Runkel, R. L. (1998). One-dimensional transport with inflow and storage (OTIS): A solute transport model for streams and rivers. U.S. Geol. Surv. Water Resour. Invest. Rep. 4018, 73 pp.

Runkel, R. L., & Chapra, S. C. (1993). An efficient numerical solutions of transient storage equations for solute transport in small streams. Water Resources Engineering, 29(1), 211-215.

Schmid, B. (2002). Persistence of Skewness in Longitudinal Dispersion Data: Can the Dead Zone Model Explain It After All? Journal of Hydraulic Engineering-asce, 128(9), 848-854.

Schmid, B. H. (2003). Temporal moments routing in streams and rivers with transient storage. Advances in Water Resources, 26, 1021-1027.

Taylor, G. I. (1921). Diffusion by continuous movements. Proceedings of the London Mathematical Society, Series A, 196-211.

Young, P. C., & Wallis, S. G. (1993). Solute transport and dispersion in channels. In K. J. Beven, & M. J. Kirby, Channel Network Hydrology (pp. 129-174). New York: John Wiley.

Scour Characteristics Downstream of In-Stream River Restoration Structures: Log and J-Hook Vanes Comparison

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Keywords: Log-Vane; J-Hook; Hydraulic Structures; River Restoration; River Grade-Control; Scour

River and stream restoration structure's design features has been an active field of research for hydraulic engineers. Generally, these low-environmental impact structures minimize the impact on natural contexts in needless of frequent human interventions during the operation and are used for riverbank protection, river grade controlling and improving the aquatic habitat. The main objective of this paper aims to compare scour downstream of two different low-head control structures; Log-Vane and J-Hook vane. The analysis contains the results of laboratory experiments conducted at the PITLAB hydraulic laboratory of University of Pisa and a detailed comparison of scour hole characteristics, highlighting similitudes and differences in the respective ranges of application. All tests have been done in clear water conditions using uniform sand as channel bed material. Figure 1 shows one of the J-hook rock vanes installed in the Upper Shavers Fork River in West Virginia State, USA. Figure 2 shows a Log-vane installed at Jocko River in Montana state, USA.

Figure 1. J-hook vanes, Upper Shavers Fork River in West Virginia, USA.

Figure 2. Log-vane installed at Jocko River in Montana state, USA.

Validation of LSPIV to Acquired 2D Surface Flow Fields in Vegetated Lowland Rivers

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Keywords: Image techniques, Large-scale particle image velocimetry, Validation; Field application, Vegetated river, Flow patterns

Prediction and control of the hydrodynamic conditions in vegetated rivers are a key in river management. To this end, it is necessary to understand the functioning of plant-flow interactions which determines species distribution and abundance. 2-D numerical models are an useful tool to study heterogeneous flow fields in vegetated rivers. However, numerical models need to be calibrated with detailed field data to provide accurate results.
Classical flow measurement techniques using a propellers current meter yield accurate and high temporal resolution data. However, these classical point measurement techniques are very time consuming and labor intensive. In this paper, Large Scale Particle Image Velocimetry (LSPIV) is proposed as an alternative method to obtain flow surface cover information in vegetated rivers. This is an optical image technology which uses image time series to obtain the surface flow distribution at large scale.
Seasonal field campaigns were performed in a low land river in Belgium to collect the annual variability of surface flow velocity patterns determined by vegetation occurrence. Since LSPIV has not been used in vegetated conditions, surface flow measurements obtained with a current electromagnetic device (ECM) are used to validate the LSPIV technique. LSPIV and ECM flow measurements are compared over the river cross sections during the three main stages: non-vegetated, submerged vegetation and high density of submerged and floating vegetation. Overall, a good ECM-LSPIV agreement is observed in both non-vegetated and submerged vegetated conditions. Larger discrepancies arise during the maximum vegetation cover stage. Undulant movements of the floating vegetation increase the flow unsteadiness, leading to more inaccurate measurements.
The results presented in this paper show the advantage of using LSPIV to gain new insight in developing flow velocity fields in vegetated rivers. LSPIV is evaluated as a cost efficient technique which provides high resolution data at a large scale. However, further sensitivity analysis is necessary to unravel the reasons of the ECM-LSPIV discrepancy and inaccuracy of the measurements.

Prediction and Analysis of Eutrophication in a Reservoir Using Three-Dimensional Modeling: Application to the Planned Abolabbas Reservoir, Iran

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Keywords: Eutrophication, numerical model, ELCOM, CAEDYM, Abolabbas reservoir, Iran

Eutrophication in lakes and reservoirs plays a key role in aquatic environments and water quality management by affecting oxygen and nutrient cycles, especially in very deep and large impoundments. Prediction of eutrophication will give valuable information to water resources planners on how to control and limit the most effective factors causing eutrophic conditions in reservoirs. The complex biochemical processes of eutrophication, as well as the complex hydro- thermodynamic mechanisms of thermal stratification as the most important factors determining eutrophication, require a very detailed and comprehensive evaluation. Numerical modeling is a reliable tool to predict and analyze the factors affecting eutrophication in aquatic ecosystems. In this study the three-dimensional hydrodynamic model (ELCOM), coupled with a dynamic ecosystem model (CAEDYM) has been used to simulate the oxygen and nutrient cycles in order to analyze the eutrophication processes in a future planned deep reservoir in southwest Iran (Abolabbas reservoir). Three scenarios for normal and drought conditions have been simulated to evaluate the effects of different forcing conditions on the reservoir eutrophication. The first scenario mimics normal operation conditions, and the other two simulate the reservoir's performance during drought periods, wherefore for the latter observations of long-term hydrological river flow have been used. The life, metabolism and settling- re-suspension cycles for two groups of phytoplankton (cyanobacteria and chlorophytes) as the most important biochemical factors causing eutrophication, as well as the nitrogen-phosphorous-carbon and dissolved oxygen cycles within the water column have been simulated. For the analysis of the eutrophication the Vollenwieder model and the TSI- index have been employed. The results of the numerical simulations show that under normal conditions the reservoir will stay in an oligotrophic-mesotrophic state. In contrast, the simulations of the drought scenarios indicate that, besides a general dropdown in water quality indices, the eutrophic conditions decrease to a mesotrophic-eutrophic or even to a full eutrophic state, depending on the drought severity. Furthermore, the reservoir then suffers from severe oxygen depletion, especially in the hypolimnion (the cool bottom layer in a reservoir). The simulations showed also that the concentration of phosphorus in the reservoir's inflow is the eutrophication-limiting factor in all of the scenarios. The sensitivity analysis of the most effective parameters determining the fate of the various nutrients and the oxygen cycle in the model demonstrates an acceptable level of uncertainty when changing these parameters over a wide range. Among the latter the fraction of light incidence and the sediment-oxygen exchange exhibit the highest sensitivities.

References

Hamilton, D.P., Schladow, S.G., 1997. Prediction of water quality in lakes and reservoirs. Part I – Model description. Ecological Modeling 96, 91-110.

Ji., Z.-G. 2008. Hydrodynamics and water quality: modeling rivers, lakes, and estuaries 1st Ed. John Wiley & Sons, Inc. USA.

Lawson R., Anderson M. A., 2007.Stratification and mixing in Lake Elsinore, California: An assessment of axial flow pumps for improving water quality in a shallow eutrophic lake. WATER RESEARCH 41 (2007) 4457 – 4467.

Mahab, Cons. Eng., 2007. Stratification and eutrophication studies of Sazbon reservoir. Technical report (in Persian).

Malmaeus J.M., Blenckner, T., Markensten H., Persson, I., 2005. Lake phosphorus dynamics and climate warming: A mechanistic model approach, Ecological Modeling 190 (2006) 1–14.
Mortsch, L.D., Quinn, F.H., 1996.Climate change scenarios for great lakes basin ecosystem studies. Limnol. Oceanogr. 41 (5),903–911.
Schladow, S.G., Hamilton, D.P. 1997. Prediction of water quality in lakes and reservoirs: Part II-Model calibration, sensitivity analysis and application. Ecological Modelling, 96: 11-123.
Vincent, W.F., Gibbs, M.M. and Spigel, R.H. 1991. Eutrophication processes regulated by a plunging river inflow. Hydrobiologia. 226: 51-63.
Zamani, B., 2012. Water Quality Modeling in Dam Reservoirs (Case Study: Abolabbas Reservoir). MSc thesis. University of Tabriz.

Three-Dimensional Hydrodynamic Modeling of Turbid Density Currents in a Complex Stratified Reservoir: Application to the Maroon Reservoir, Iran

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Keywords: Turbidity, Density current, 3D hydrodynamic modeling, Morphology, Maroon

Turbidity caused by plunging density currents directly affects the entire ecosystem in reservoirs, as well as in downstream sections by changing the light penetration in a vertical water column over a long period which, in turn, will alter adversely the primary production and the distribution of biotic organisms and fish there. When a flood enters a stratified reservoir, it usually entrains suspended solids as a turbid density current which then plunges from the riverine zone of the impoundment through the transition zone into the lacustrine zone, according to the density stratification. In order to control these turbid density currents and so to minimize the effects of increasing turbidity on the aquatic ecosystem, appropriate reservoir management strategies must be taken. A first step to do so consists in the numerical modeling of the hydrodynamics and thermodynamics of the flow processes in reservoirs with a particular emphasis on the proper simulation of the density currents. This will give valuable information on the proper design and operation of such a project which, in the very end, should be sustainable.

In this study a three-dimensional (3D) numerical hydro- thermodynamic model coupled with a particle dynamics model for reservoirs has been used to simulate the effects of propagation of a turbid density current in a very large stratified reservoir in southwest of Iran, the Maroon reservoir, which has a complex morphology and bathymetry. In fact, this reservoir is a combination of two main impoundments that are connected by a shallow and narrow canyon, which makes the numerical discretization, under consideration of various other accuracy and stability criteria in the code, a rather difficult task.

Fluid flow with multiple suspended sediment sizes (SS), determined by means of a grain- size analysis of the river-suspended sediments, has been simulated. In particular, the effects of flood events which happen relatively frequently in this, overall, dry-climate region, have been modeled under different operational conditions to evaluate the reservoir performance under such conditions. The results show a different response of the reservoir in the two connected impoundments, such that the upstream impoundment traps the largest part of the suspended solids and the downstream one receives only a very small amount of flow, with mostly fine-grained suspended sediments which are then released further downstream. The numerically simulated distribution of the suspended solids has been compared with field turbidity measurements by converting them to associated turbidity values, using site-specific, empirical SS-turbidity relationships. A good agreement between numerical and experimental turbidity values is obtained. The numerical model shows also a very good performance in simulating the propagation of the flood density currents in the reservoir, as well as its thermal structure, density stratification and various other mixing processes which are important for the understanding of the ecosystem-biology of this reservoir, the modeling of which is presently under way by the authors.

References

Chung, S.W., Hipsey, M.R., Imberger, J, 2009. Modelling the propagation of turbid density inflows into a stratified lake:

Daecheong Reservoir, Korea. Journal of Environmental Modelling & Software 24 (2009) 1467–1482.

Imboden, D.M., Wuest, A., 1995.Mixing mechanisms in lakes. In: Lerman, A., Imboden, D.M., Gat, J.R. (Eds.), Physics and Chemistry of Lakes. Springer, Berlin, pp. 83–138.

Ji., Z.-G. 2008. Hydrodynamics and water quality: modeling rivers, lakes, and estuaries 1st Ed. John Wiley & Sons, Inc. USA.

Lindim, C. , Pinho, J.L., Vieira J.M.P., 2010.Analysis of spatial and temporal patterns in a large reservoir using water quality and ydrodynamic modeling. Ecol. Model (2010) doi:10.1016/j.ecolmodel. 2010.07.019.
Martin, J.L., McCutcheon, S.C., 1999. Hydrodynamics and Transport for Water Quality Modeling. Lewis Publications, Boca Raton, FL, 794pp.
Mortsch, L.D., Quinn, F.H., 1996.Climate change scenarios for great lakes basin ecosystem studies. Limnol. Oceanogr. 41 (5),903–911.
Simpson, J. H., Brown, J., Matthews, J., Allen, G. 1990. Tidal Straining, Density Currents, and Stirring in the Control of Estuarine Stratification. Estuaries Vol. 13, No. 2, p. 125-132.
Straskraba, M., Tundisi, J.G., Duncan, A., 1993. State-of-the-art of reservoir limnology and water quality management. In: Straskraba, M., Tundisi, J.G., Duncan, A. (Eds.), Comparative Reservoir Limnology and Water Quality Management. Kluwer Academic Publishers, The Netherlands.
Tufford, D.L., McKellar, H.N., 1999.Spatial and temporal hydrodynamic and water quality modeling analysis of a large reservoir on the South Carolina (USA) coastal plain. Ecol. Model. 114, 137–173.
Zamani, B., Fakheri-Fard, A., Moridi, A. Three-dimensional Hydrodynamic modeling of a future reservoir to adapt to face global warming effect. The first international conference on dams and hydropower (ICDHP), Iran, Tehran, 2012.

Integrated Modeling of Hydro-Systems

Coupling Flood Inundation Models with Remotely Sensed Imagery and GNSS Field Observations for Near Real-Time Updating

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Keywords: Disaster management, Remote Sensing, Flood Inundation modeling, Flood forecasting

The Integrating GMES Emergency Services with satellite navigation and communication for establishing a flood information service (FLOODIS) is a collaborative European Community project, funded under the Seventh Framework Programme (FP7-SPACE-2013-1), to provide a flood information service that aims at better addressing and mitigating crisis situations arising before, during and after heavy flooding. The goal of FLOODIS will be to integrate the existing European Copernicus Services, i.e. GIO-EMS and EFAS, with high-accuracy, location-based information from Disaster Management teams, Civil Protection Agencies and citizens, acting as "human sensors", to produce alerting and management information before, during and after flood events. The FLOODIS solution aims to close a critical gap for Disaster Management teams and Emergency Response Units by providing a centralized comprehensive platform to collect, store and elaborate the information related to the emergency events coming from different sources, including user generated content and social networks analysis.

In order to achieve this, the FLOODIS system will depend on four key components:

- a web-based data management and support system that will act as the system back-end, to ingest and elaborate information and precisely geo-locate users' information through the EGNOS/EDAS services,
- an interface system to receive Earth Observations imagery and data from the Emergency Management Systems and a novel flood forecast model based on EO data and on-field user-generated information,
- a professional application for emergency response teams to support the emergency event management, and
- a smart phone application for citizens, with which users can contribute to the system ("human sensors") and receive alerting information.

A key and innovative capability of the system will be the ability of the user to send back actual information about the situation 'on the field' (e.g. text information and pictures of flooded infrastructures) to the FLOODIS back-end system for ingestion and subsequent dissemination to all other users. As such, it will serve to provide up-to-date local information to Disaster Management Centres (DMCs), Civil Protection Agencies (CPAs), Emergency Response Units (ERUs) as well as affected citizens.

In Europe, flood forecasting and alerting services are provided by European institutions and Member State agencies such as EFAS, run at the ECMWF, or by national flood forecasting centres like the German Federal Institute of Hydrology (BFG). Global flood alerts are provided by disaster monitoring portals such as GDACS. In the last few years, the preparedness of the local CPA's/DMC's has been significantly increased by the early warnings provided by these forecast centres. Nonetheless, the CPA's/DMC's must monitor different kinds of publicly available or restricted information in order to be able to estimate the possible flood extent and the progress of the actual flooding situation. Even in countries with state-of-the-art flood forecasting systems based on high resolution meteorological forecasts and spatially distributed hydrological models that provide the public with accurate point estimates of expected future river water-levels for any point along the river network, the discrepancy between the forecast and reality can be enormous. There are a number of reasons for such failures of the forecast system and could be caused by e.g. extraordinary weather phenomena, model misspecifications, human errors, or unpredictable dam breaks. For this reason, post-processing methodologies have been recently developed in order to minimize the error between model simulations (forecast) and the observed real-time measurements. For example, in the work of Bogner and Pappenberger (WRR2011), the series of observed and simulated river stream-flows were transformed into the wavelet domain and state-space models were applied in order to minimize the prediction error. The advantage of this combination of wavelet transformation and the state-space model is the possibility of taking into consideration the scale dependencies of all possible causes of error and to update the model output using the Kalman filter whenever new observed values are available. This novel approach will be further developed and adopted in the context of this project for spatial maps. Extending the post-processing methodology from points to spatial data would allow deriving decisions taking the most current and most reliable information available. By integrating the satellite image derived flood maps, the flood inundation maps produced by the hydrological/hydraulic forecast model could be post-processed, i.e. updated by minimizing the discrepancies in real-time. Consequently, the forecasts can be corrected in the same way and the CPA's/DMC's could be provided with the most reliable product to make critical decisions in a flood crisis.

FLOODIS will be monitoring these services and will be able to warn the relevant organisations based on the project technologies. Furthermore, FLOODIS will provide additional flood related geospatial information by combining acquired EO imagery and satellite navigation (GNSS) technologies. Thus, it represents one of the few projects to unite two different satellite technologies to deliver an up-to-date information service targeting the right people, in the right place and at the right time. Through this project, the civil protection community will become aware of EGNOS and subsequently also Galileo, to the credit of the European Commission.

In this paper the methodology of the coupling of remote sensing data and flood inundation models in near real-time by applying novel post-processing tools will be presented and first results based on the Elbe River flood event from June 2013 will be shown.

References

Bogner, K. and F. Pappenberger. Multiscale error analysis, correction, and predictive uncertainty estimation in a flood forecasting system. Water Resources Research, 47(7), 2011.

Daily Runoff Simulation of a Coastal Watershed of Southeast China based on SWAT Model

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Keywords: Daily runoff, Simulation, Calibration, Sensitive parameters, SWAT, Jinjiang watershed, China

The objective of this study is to evaluate the applicability of SWAT model for the daily runoff simulation in the coastal watersheds of Southeast China. Jinjiang watershed, which is located in south-eastern Fujian Province of China and has an area of 5042 km^2, was taken as a case study area. Three hydrological gauge stations, Shilong, Shanmei and Anxi, were used to calibrate the SWAT model at multiple time scales. Based on the measured daily runoff data of the three stations, the model was calibrated from 2002 to 2007, and validated from 2008 to 2010. The calibration and validation results were evaluated by Ens, R^2 and PBIAS.
Through One-factor-at-a-time (LH-OAT) global sensitivity analysis, seven sensitive parameters were identified including SOL_AWC, RCHRG_DP, CN2, GWQMN, ESCO, SOL_K, and CANMX (see Table 1). All the sensitive parameters were manually estimated, and the adjusted value range or optimal values of these parameters were listed in Table 1. High model performance was achieved. The comparison of simulated and observed runoff in Silong gauge station was shown as Figure 1. The evaluation index Ens and R^2 were both more than 0.9 for annual and monthly scales in all three locations, well above the minimum criterion 0.5 or 0.7, both for the calibration and validation periods. The relative errors were all less than 7 %. As for daily scale, the Ens and R^2 were both greater than 0.75, and PBIAS was less than 6.5 % for all locations and periods. As a result, the SWAT model was justified as a reliable representation of hydrologic processes and responses for the catchment studied.
The results show that the SWAT model performs well for the coastal watershed of Southeast China. It is natural that the daily indices are worse than the annual or monthly indexes, as there are more variability and instability in daily runoff processes. Compared with studies for other areas, the values of sensitive parameters were reasonable.

Table 1. Sensitive parameters and optimal values in Jinjiang watershed.

No	Name	Rang	Adjusted value
1	SOL_AWC	0 - 1	0.11 - 0.34
2	RCHRG_DP	0 - 1	0.3
3	CN2	35 - 98	44 - 94
4	GWQMN	0 - 500	30
5	ESCO	0 - 1	0.5 - 0.8
6	SOL_K	0 - 2000	0.2 - 79.2
7	CANMX	0 - 100	4

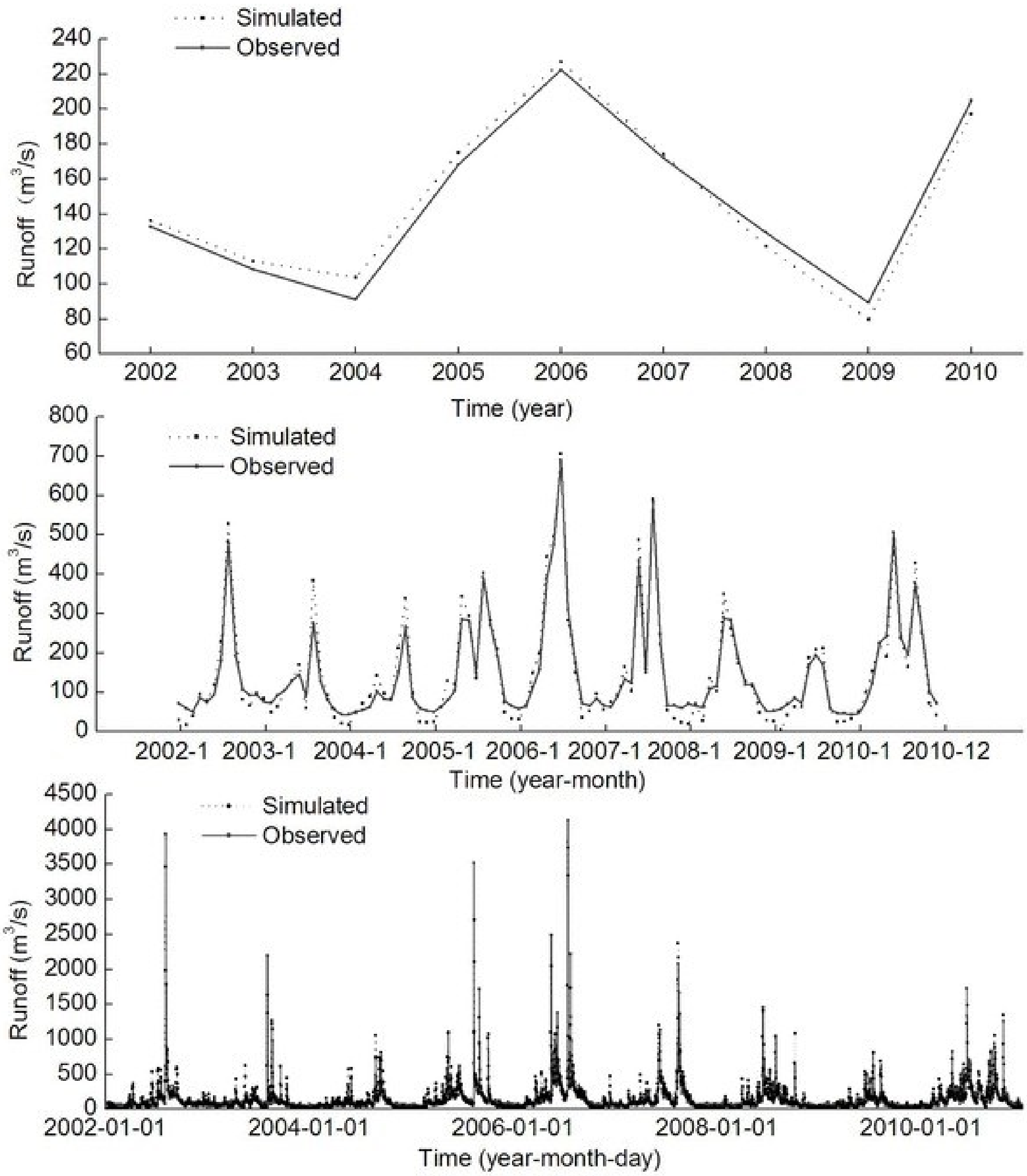

Figure 1. Comparison of simulated and observed runoff in Silong gauge station.

References

Baker, T. J., and Miller, S. N.: Using the Soil and Water Assessment Tool(SWAT) to assess land use impact on water resources in an East African watershed, J Hydrol, 486, 100-111, 2013.

Griensven, A. B., Meixner, T., Grunwald, S., Bishop, T., Diluzio, M., and Srinivasan, R.: A global sensitivity analysis tool for the parameters of multi-variable catchment models, J Hydrol, 324, 10-23, 2006.

Moriasi, D. N., Arnold, J. G., Vanliew, M. W., Bingner, R. L., Harmel, R. D., and Veith, T. L.: Model evaluation guidelines for systematic quantification of accuracy in watershed simulations, T ASABE, 50, 885-900, 2007.

Wang, L., and Chen, X. W.: Simulation of hydrological effects on vegetation restoration of degraded mountain in ecosystem with SWAT model. Journal of Mountain Science, 26 (1), 71-75, 2008.（in Chinese).

Cooling Water Discharge Impacts to an Ephemeral Stream: A Heat Transport Modeling Study

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Keywords: Water quality modeling, Surface water, WASP, Water temperature, Cooling water, ADV, Discharge rate measurement

The objective of this study is to determine the effects of cooling water discharge from a small scale power plant by using a 1-D numerical heat and solute transport model WASP 7. The goal of the modeling is to determine the effects of the discharge by estimating the difference in stream water temperature before and after release. The cooling water was released to an ephemeral stream that flows through an industrial zone, receives surrounding storm water and interacts in some parts with the underlying aquifer. The release rate was unsteady during the monitoring period of the study. Average temperature of the cooling water was 23.6 °C with a maximum of 35°C.

Field work was conducted to collect data that was necessary for the modeling stage. Flow rates were measured with an acoustic Doppler velocimeter at six transects of the stream. Water temperature, dissolved oxygen concentration and electrical conductivity were determined by collecting water samples at eleven monitoring points. Modeling results indicate that the warm water release is somewhat effective in the dry period up to 600 m downstream of the release location. The estimated stream water temperature does not exceed 22 °C, thereby complying with regulations.

References

Ambrose, R.B., Wool, T., Martin, J.L., 1993. WASP User's Manual, US Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia.

Leach, J.A., Moore, R.D., 2011. Stream temperature dynamics in two hydrogeomorphically distinct reaches. Hydrological Processes, 25(5): 679-690.

Norton, G.E., Bradford, A., 2009. Comparison of two stream temperature models and evaluation of potential management alternatives for the Speed River, Southern Ontario. Journal of Environmental Management, 90(2): 866-878.

Webb, B.W., Hannah, D.M., Moore, R.D., Brown, L.E., Nobilis, F., 2008. Recent advances in stream and river temperature research. Hydrological Processes, 22(7): 902-918.

The Predominant Processes Controlling Vertical Nutrient and Suspended Matter Fluxes across Domains - Using the New MOSSCO System from Coastal Sea Sediments up to the Atmosphere

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Keywords: Model coupling, Coastal system, Nutrient fluxes, Suspended matter

The dynamics of nutrient cycles and suspended matter in coastal seas result from an interplay of processes in a number of earth system domains, such as atmosphere/weather, waves, pelagic and benthic ecosystem, and sea sediment. An integrated approach for a coupled model study is essential to obtain a holistic understanding of key processes in the coastal system, such as erosion and sedimentation, atmospheric deposition, and denitrification. Diverse scientific groups have successfully developed models to describe the dynamics of these key processes. However, exchange of tested, numerical codes and non-invasive, efficient coupling of existing modules is barely practised.

The model coupling initiative MOSSCO (MOdular System for Shelves and COasts) provides new software infrastructure to manage modular, multi-way domain coupling of existing high-performance, numerical model codes. While making use of the model coupling framework ESMF, existing models are included through a thin wrapper layer of domain components. Biogeochemical processes get included into the ESMF components through a driver infrastructure for the established framework FABM (Framework for Aquatic Biogeochemical Models).

We present examples of coupling state-of-the-art models for hydrodynamics, the pelagic ecosystem, surface waves, weather, benthic geoecology, sea bed composition and early diagenesis in typical coastal sea applications. The interface between water column and sea sediments is predominantly controlling the tidal and seasonal variations of suspended matter concentrations. Additionally, the exchange fluxes at the sea bed interface decouple the simulated nutrient cycles as found in measurements at stations in the southern North Sea. Integrated modelling, using a modular, multi-way coupling scheme across domains as exemplified here, is shown to be a promising avenue to obtain realistic simulations of coastal systems.

Multi-Dimensional Numerical Simulation of Wind-Induced Flow and Transport Processes in an Urban Water System

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Keywords: Wind-induced flow, Numerical simulation, 2D and 3D flow and transport, TELEMAC modeling system

Motivation

Urban water systems are generally stressed by various contaminations coming from, for example, treated waste water, industry, households, runoff from streets. They consist of natural (e.g. rivers, lakes, groundwater) and technical compartments (e.g. wastewater treatment plants, sewer systems) which are often in strong inte ractions.

The Unterhavel water system in Berlin, Germany, has been chosen here in order to investigate the impact of the wind on flow and transport processes. This water system has complex geometry and is stressed among other things by treated waste water. It consists of shallow lakes (e.g. Wannsee) and small islands (e.g. Pfaueninsel). The lakes are shallow, the rivers are slow-flowing and carry little water. Especially in summer, the system may become ecologically very sensitive (JOURIEH and HINKELMANN, 2012). Wind may have strong impacts on water systems, especially when it is strong and when the water bodies are shallow, both being the case in the Unterhavel.

Numerical simulations

In the pre-processing stage, a 2D FEM grid with 71300 nodes and 99110 elements has been generated. For the 3D simulations, a grid was generated duplicating the 2D grid several times along the vertical and using the σ-method which allows grid refinement close to the surface and bottom. Thus, a 3D mesh consisting of 17 planes, 1212100 nodes and 1540870 prisms was obtained.

The TELEMAC modeling system has been chosen (HERVOUET, 2007), and the 2D and 3D numerical simulations were carried out including various flow (mean, low, high discharge) and wind conditions (different intensities and directions). In this study the spreading of a passive tracer which is transported by advection and diffusion (physical, turbulent) is investigated.

Results

Two scenarios are considered taking into account the wind influence: south wind with a velocity of 5.3 m/s and west wind with a velocity of 15.5 m/s, representing mean and maximum conditions of a 10 years series.

The 2D results show that the velocities induced by south and west wind are considerably higher compared to cases without wind. As the flows are in opposite direction for the case with and without wind in some areas, this has a strong influence on the tracer transport. Of course, the 2D simulations are not capable to give insight into wind-induced vertical flows.

3D flow and transport simulations have been carried out without and with wind. For the maximum wind, strong 3D flow and transport effects occur with different flow directions in a profile at the surface (following the wind direction) and opposite flow direction at the bottom as well as complex horizontal and vertical circulations (Fig. 1). Figure 2 indicates that the wind has a strong impact on the distribution of the concentration at the free surface spreading in wind direction as well as in other parts of the cross section.

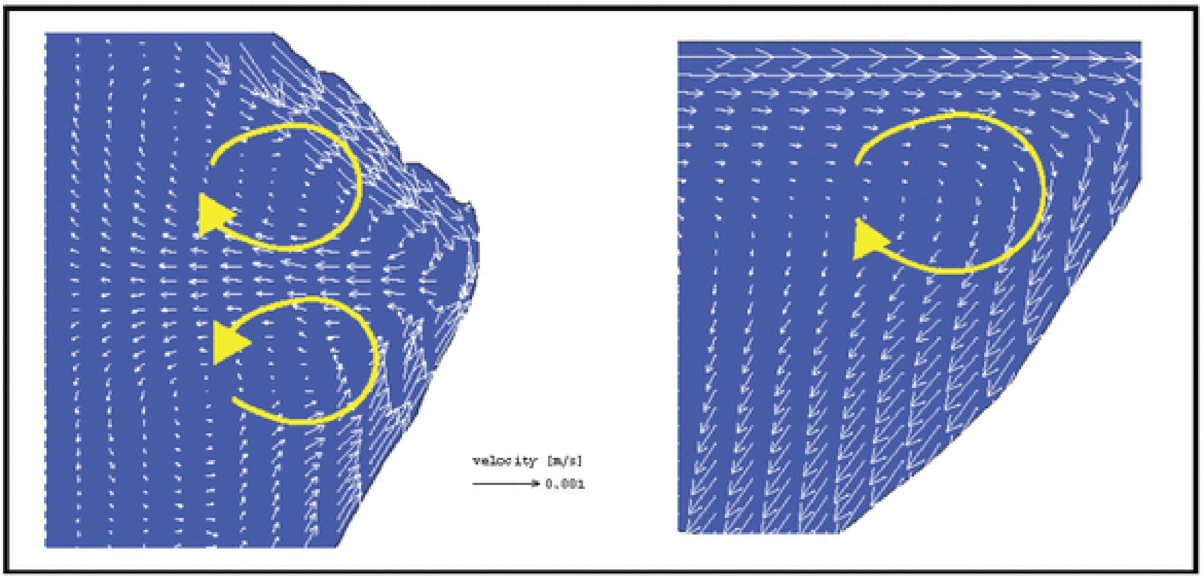

Figure 1. Velocity field and circulation in horizontal section (left) velocity field and circulation in vertical section (right).

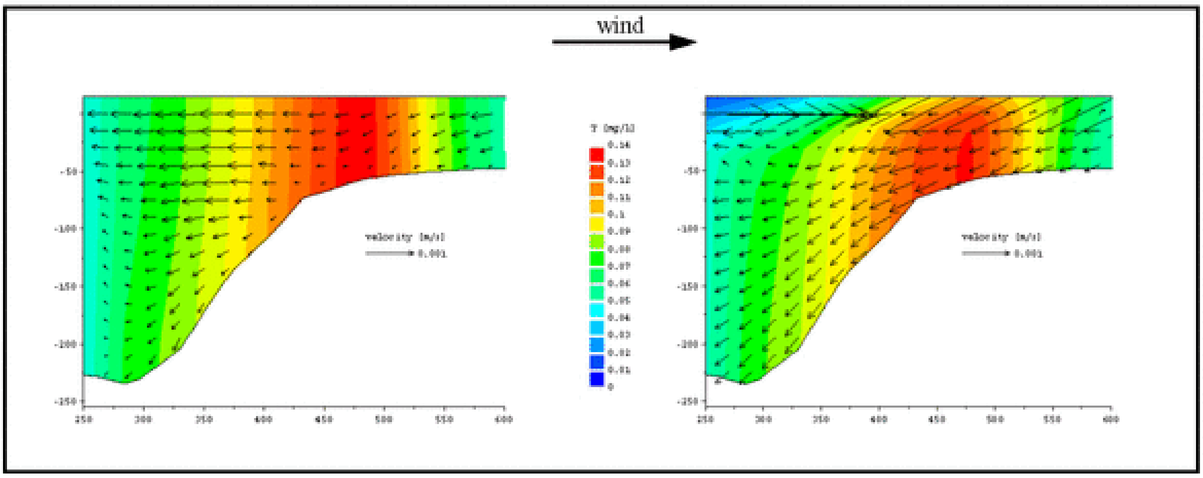

Figure 2. Vertical distribution of tracer and velocity (left: without wind, right: with west wind).

References

HERVOUET, J., 2007. Hydrodynamics of Free Surface Flows: Modelling with the Finite Element Method. Wiley.

JOURIEH, A., HINKELMANN, R., 2012. Multi-dimensional Numerical Simulation of Hydrodynamics and Transport Processes in the Unterhavel River. Proceeding of the 2nd IAHR, European Congress, Munich, Germany.

Development of an Innovative Water Hazard and Risk Management Strategy based on a Pilot Integrated Modeling Tool on the Sensitive Thau lagoon in France

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Keywords: FEVM, Nonlinear Wave, two Way Interaction, Quay walls, Seismic Loading, coupled interaction of Soil and Structure

The lagoon of Thau, located in the South of France, is a famous area, particularly attractive thanks to its geographical and economical context that is based on fishing and marine cultures, balneology and seaside tourism. The development process of the 14 municipalities that are located on its watershed is then completely bounded to the lagoon pollution control.
The lagoon was downgraded couple of years ago for not having reached the required quality conditions. Because of its environmental and economical pressure, the SMBT has been created in order to improve the situation through an efficient and adapted water hazard and risk management on the watershed. The office decided to develop and implement an innovative approach based on an integrated modeling of the entire water system.
An integrated superficial flow model was developed on the whole watershed and combined with the lagoon model. This pilot superficial flow model includes the sewer systems as well as the watersheds and rivers on the same interface. The water quantity and quality, including Nitrogen, Phosphorus and Ecoli, can be simulated in any part of the territory through a 1D or 2D approach. The dynamics of the flow as well as the pollutant behaviors can be estimated anywhere, including in the lagoon. The model was successfully calibrated on various continuous and storm events for both quantity and quality aspects.
This unique model is used by the SMBT for 2 main objectives: (i) the water risk forecasting for both the quantity and quality aspects and (ii) the hydraulic development planning on the territory.
For the forecasting part, a library of many scenarios was created by the model based on various hydro-meteorological conditions. All the potential risks were considered in order to be able to manage in real time the flood, the bathing, the conchylicole activity, and the sewer network. Again, both the quantity and quality aspects were considered. Then based on the sensors measurements collected in real time on the territory as well as the hydro-meteorological forecasts, a platform is automatically selects and gives the predicted risk to expect on the area. The actors (municipalities, state, professional workers, partners…) can then decide which actions to take in order to avoid damages and loss.
For the hydraulic development part, the most sensitive areas of the territory can be identified with the model results in terms of both quantity and quality aspects. The SMBT can then organize its actions planning depending on the priority level.
The model is also regularly and successfully used as a powerful communication tool. Thanks to its user-friendly interface, the hydraulics works can be clearly presented and explained in a very didactic and open way, which facilitates the understanding for non hydraulics expert people. This aspect should not be neglected since the development acceptance by everybody is a guarantee for a harmonized and attractive context.

Remote Sensing and Field Monitoring

A Powerful Method of Measuring Sea Wave Spectra and Their Direction

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Keywords: Wave, Wave-height, Wave-direction, Sea state, Wind-force, Wind-direction, Directional wave spectrum, Datawell Directional Waverider buoy, North Sea

Besides the need of precise measurements of water levels of the sea, there is an increasing demand for assessing waves in height and direction for different purposes like sea-wave modelling and coastal engineering. The design of coastal structures such as piles, breakwaters, and offshore structures like wind farms must take account of the direction of the impacting waves. To date, records of wave directions are scarce. The reason for this might be the high costs of purchasing and operating such measuring devices. These are usually buoys, which require regular maintenance. Against this background, the German Federal Institute of Hydrology (BfG) developed a low-cost directional sea-wave monitoring system that is based on commercially available liquid-level radar sensors. These sensors have the advantage that they have no contact to the fluid, i.e. the corrosive sea water. The newly developed device was tested on two sites. One is the tide gauge 'Borkum Südstrand' that is located in the southern North Sea off the island of Borkum. The other one is the 'Research Platform FINO1' approximately 45 km north of the island of Borkum. The main focus of these tests is the comparison of the data measured by the radar-based system with those of a conventional Directional Wave Rider Buoy.

The general conditions at the testing sites are good for the tests. At the tide gauge 'Borkum Südstrand' waves propagate in different directions, strongly influenced by the morphological conditions like shallow waters of the Wadden Seas and the coast of the island of Borkum. Whereas on the open sea, at the site FINO1, the full physical conditions of the sea state, like heavy storms etc. play an important role.

To determine and measure the direction of waves, the device has to be able to assess the wave movements in two dimensions. Therefore, an array of several radar sensors is required. Radar sensors are widely used and well established in measuring water levels, e.g. in tanks and basins. They operate by emitting a chain of electromagnetic pulses at a frequency of 26 GHz twice per second and, in turn, detect the backscatter information from the water surface. As the travelling time of each pulse is proportional to the distance between water surface and sensor, the height of the water surface can be easily calculated. To obtain the directional information of the sea state, all four radar sensors in the array have to collect simultaneously the wave profiles at fixed points.

The Wave Rider Buoy works in a completely different way. Here, the wave height is calculated by the double integration of the measured vertical acceleration. By correlating the three-dimensional motion data, which are gained from gravity-stabilized vertical and horizontal accelerometers, the directional wave spectrum can be derived. Data of both devices were collected and analysed.

During the hurricane Xaver, extreme water levels and heavy sea hit the North Sea coast on 5 and 6 December 2013. The radar array at the testing site FINO1 measured wave heights in the order of 15.5 meters. Furthermore, it was possible to detect significant wave heights, the mean wave direction, and the spread of the sea state. For the first time the accuracy of the wave height distribution could be determined as well.

New Data Management System for Coastal Radar WERA to Support Decision Making

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Keywords: Data management system, Ocean radar, WERA, Decision-making

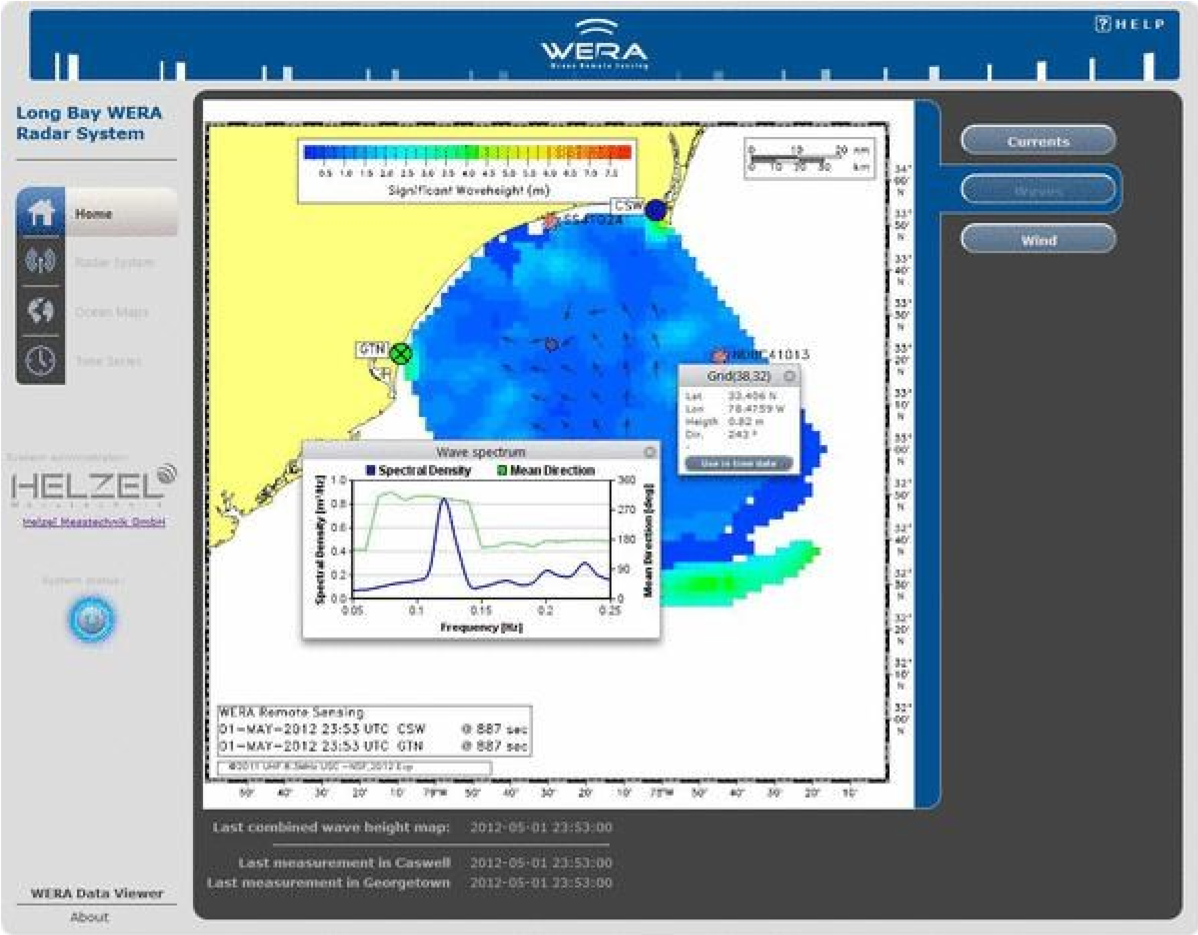
The HF-Coastal Radar "WERA" is a shore based remote sensing system to monitor ocean surface currents, waves and wind direction. This very reliable long range (up to >200 km) monitoring system provides reliable data maps of the coastal zone with high spatial and temporal resolution. These data can be used for decision makers to optimize coastal zone management and planning and in case of emergencies it can be used to support hazard management.

The new data management system provides easy and fast access to all archived current, wave and wind data. The data are stored in an archive and can be accessed as time series plots for individual grid cells or as animated maps for the entire measured area. For each grid cell all data are marked with quality flags which can be used to exclude suspicious data from the analysis. Various output formats are available to compare the ocean radar data with data acquired from other sensors or numerical models.

In addition to use the measured data for planning and real-time monitoring, a special forecasting mode can be used to improve predictions of ocean currents and waves in case of risk management. Due to the outstanding accuracy of the radar the acquired data can be assimilated into numerical oceanographic models. In case of accidents in a distance of up to 200 km off the coast the real-time ocean surface current data can help Search and Rescue (SAR) operators. Presently, SAR tools are based on hydro-dynamical and atmospheric models to provide hindcast and forecast situations. Even if these oceanic numerical models are efficient to produce instantaneous maps of currents, the accuracy of derived Lagrangian trajectories is not sufficient for search and rescue purposes.

Results of various experiments with drifters to simulate a drifting persons or containers show the significant improvement of the drift simulation, when using real-time current data provided by radar systems instead of using results from numerical models only. This improved quality of the drift prediction can be very useful for various applications.

The same tool can be used for backtracking a monitored oil spill and estimate the origin to identify the polluter. Furthermore the improved numerical models can be used to provide more reliable metocean forecasts (sea states and currents) to be used by ferry operators. Data and experimental results from the French coast demonstrate the efficiency of these instruments.



WERA
HELP
Long Bay WERA Radar System
Home
Currents
Wind
Significant Waveheight (m)
CSW
GTN
Grid(38,32)
Wave spectrum
Spectral Density
Mean Direction
Frequency [Hz]
WERA Remote Sensing
01-MAY-2012 23:53 UTC CSW @ 887 sec
01-MAY-2012 23:53 UTC GTN @ 887 sec
HELZEL
Helzel Messtechnik GmbH
Last combined wave height map: 2012-05-01 23:53:00
Last measurement in Caswell 2012-05-01 23:53:00
Last measurement in Georgetown 2012-05-01 23:53:00
WERA Data Viewer
About

Joint Observation of Shoaling Ocean Waves, Currents and Bathymetric Changes Using Coherent Microwave Radar

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Keywords: Coherent Marine Radar, Remote Sensing, Wave-Current-Bottom Interaction, Wave Breaking, Wave Shoaling, Wave Energy Dissipation, Morphodynamics

Introduction

In the surf zone of shallow water coastal areas waves, currents and the bottom are strongly coupled. Due to themorphodynamic activity these zones are inhomogeneous, and the data from In-Situ sensors, e.g. wave buoys and pressure sensors are not representative for the entire area of study. Ground-based remote sensing sensors cover both the spatial and temporal domain and therefore provide a more complete picture of coastal processes. During the last decade we have developed methods to deduce hydrographic parameters from incoherent and coherent radars. For further development as well as the validation of the methods we have setup a test site on the island of Sylt in the German bight. This site shows very active morphodynamics and is regularly protected by beach nourishments. Since 2013 two overlapping radar stations and several In-Situ sensors have been deployed at the coast to study the involved processes.

Coastal Processes

Figure 1 summarizes the hydrographic processes and their interaction in a morphodynamic feedback loop.

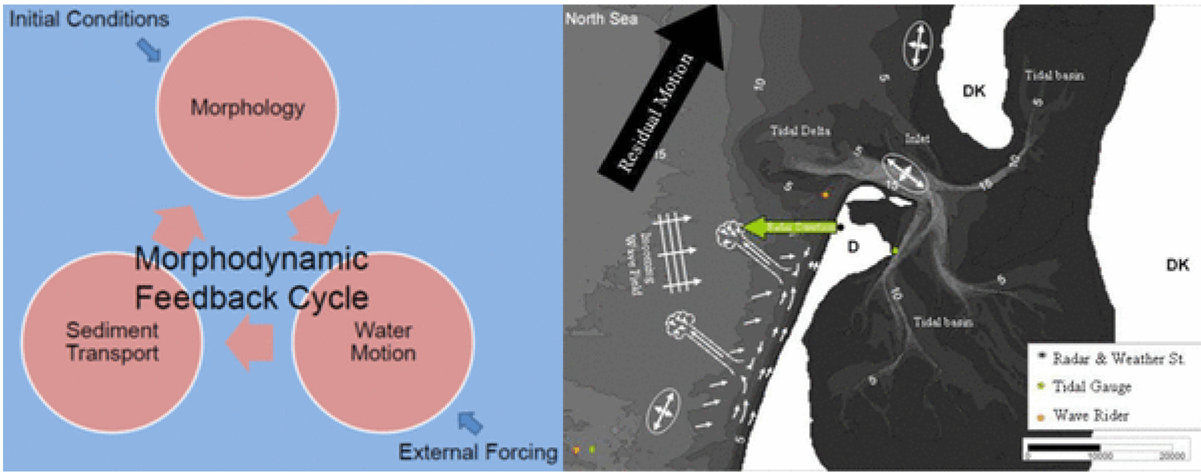

Figure 1. Left: Morphodynamic feedback cycle: The dynamics of waves and currents are guided by the bathymetry. Breaking and non-breaking waves as well as currents induce a bottom shear stress, resulting in sand transport, i.e. bathymetric changes. Right: Coastal processes: interaction of the tidal current with the bottom, wave refraction, shoaling and breaking due to the occurrences of the bottom slope and a sandbar parallel to the coastline. The rip currents are induced by the waves. Source: Flampouris 2010 (right).

Especially in the surf zone the incoming surface waves are strongly coupled with the tidal currents and varying bottom topography. The wave energy is dissipated mainly due to wave breaking in particular at the sand bar, which was generated by morphodynamic processes due to the currents and waves.

Hydrographic Processes inspected by Radar

A marine radar can image ocean surface waves in space and time and therefore retrieve various wave parameters e.g. wave spectra, wave period and wave height. It is well known that the phase speed of surface waves depends, in addition to the wave period and wavelength on the near-surface current and in shallow water areas on the water depth. We utilize this relation to retrieve in addition to the wave parameters the surface current and water depth (Senet et al. 2007, Fig. 2, left). Utilizing the coherent radar systems we can measure the speed of surface scatterers, which are strongly modulated by the surface currents, winds and waves. Using ship- based coherent radar systems with two antennas orientated perpendicular to each other the hydrodynamic interaction of the tidal current with the underwater sand dunes was studied (Cysewski et al. 2008, Kakoulaki 2009, Fig.1, right). Using our test site on Sylt we have studied breaking events, which we analyzed statistically by time averaging (Fig.3, left) and deterministically by following individual events (Fig.3, center and right).

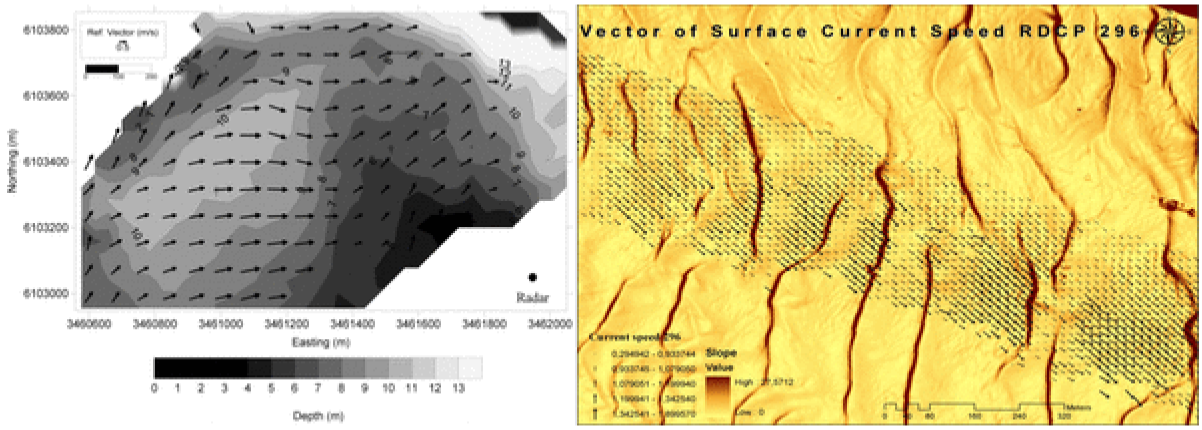

Figure 2. Left: Bathymetric and current map retrieved from a sequence of marine radar images acquired during a storm event. Right: Current map in the Lister deep from a ship-mounted radar. The currents are mapped on a slope image from a multibeam echo sounder. Source: Flampouris 2012 (left) and Kakoulaki 2009 (right).

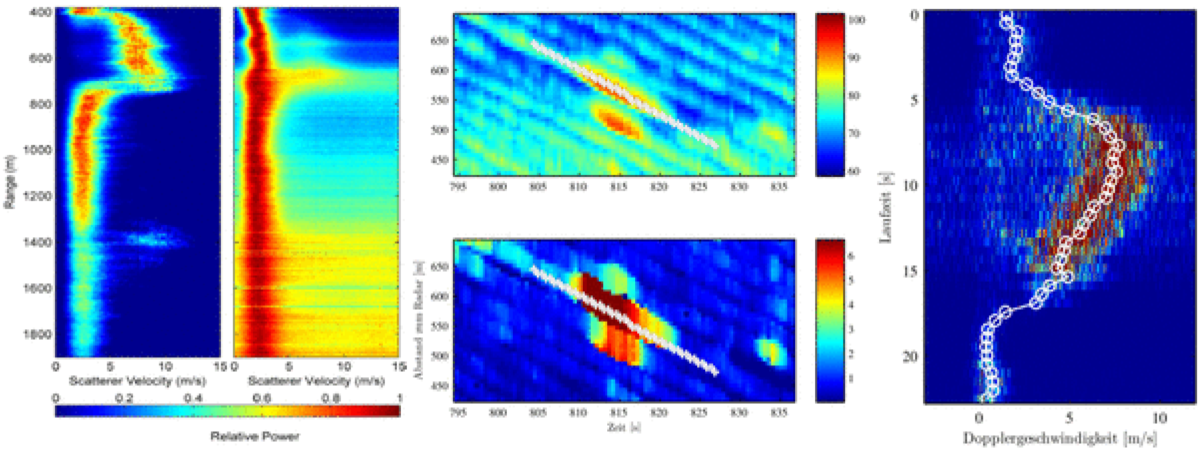

Figure 3. Wave breaking in the surf zone. Left: Range-Doppler velocity map. The Doppler velocity spectra are averaged over 5 minutes of measurement. During the breaking event the Doppler velocity jumps from the orbital to the phase velocity of surface waves. In the left part individual spectra are averaged, whereas in the right part the spectra are normalized before averaging. A breaking zone is detected at 500 and a second smaller one 1400 m close to the coastline. Center: Individual breaker event on a wave crest (white line) observed in the range-time map of intensity (top) and Doppler velocity (bottom). Right: Velocity-time map with the breaker event following the wave crest (center, white line). Source: [Flampouris2010] (left).

Summary and Outlook

Microwave radar remote sensing allows the survey of the water depth, near surface currents and the detection of breaking waves. Algorithms to estimate spatially resolved wave spectra and parameters, i.e. the significant wave height are under development.

References

Senet, C.M., Seemann, J., Flampouris, S. and Ziemer, F., Determination of Bathymetric and Current Maps by the Method DiSC Based on the Analysis of Nautical X-Band Radar Image Sequences of the Sea Surface (November 2007). Geoscience and Remote Sensing, IEEE Transactions on, 46(8): 2267-2279, 2007.

Cysewski, M., Ziemer, F. and Schymura, G., 2008. First Experiences and Application for Radar Doppler Current Profiler. In: H. Atkinson (Editor), Hydro8. The Hydrographic Society UK, Liverpool, 2008.

Kakoulaki, G., 2009. Study of the interraction between the current field and structures in the bathymetry in a tidal inlet, MSc Thesis, Christian Albrechts University, Kiel, 2009.

Flampouris, S., 2010, On the wave field propagating over an uneven sea bottom observed by ground based radar, PhD Thesis, University of Hamburg, 2010.

Surface Current Analysis from High Frequency Radar Measurement off the Coast of Yantai, China

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Keywords: HF radar, ADCP, Ocean surface current, Spectrum analysis

A high frequency (HF) radar system to measure surface currents and waves was installed at the coastline around 35km east of the city of Yantai, China. The data is to be used for calibration and validation of a coupled flow and wave model covering parts of the Shandong Peninsula. The HF-radar is a WERA system containing of two stations allowing for a 2D surface current observation of approximately 30 km off the coastline, as is shown in Figure 1. From July 23 to September 10, 2013, a bottom-mounted ADCP was deployed within the radar coverage area to record vertical current distribution, water levels and waves. The surface current data from the radar was validated by comparison with the ADCP data, which is shown in Figure 2. It can be seen that the differences between radar and ADCP are reasonable with significant correlation, indicating an adequate quality of the radar data for further analysis.

In the paper a detailed description of the method and filtering technique adopted will be presented. Spectral analysis of radar current and wind data showed that tide and wind are the dominating forces for surface currents in the area and there is also a peak near local inertial frequency (1.23 cpd). A band-pass filter was used to separate the inertial current from the radar data. The cross spectrum analysis of filtered currents and wind revealed, that for periods larger than two days there is a close correlation between local wind and surface current. Harmonic analysis was performed to get characteristic tidal currents. The semi-diurnal components are of similar importance as the diurnal components, whereas the M2 component dominates in water level. The analysis of the radar data helped to identify the relevant processes which determine the characteristic patterns of the surface currents within the area of interest.

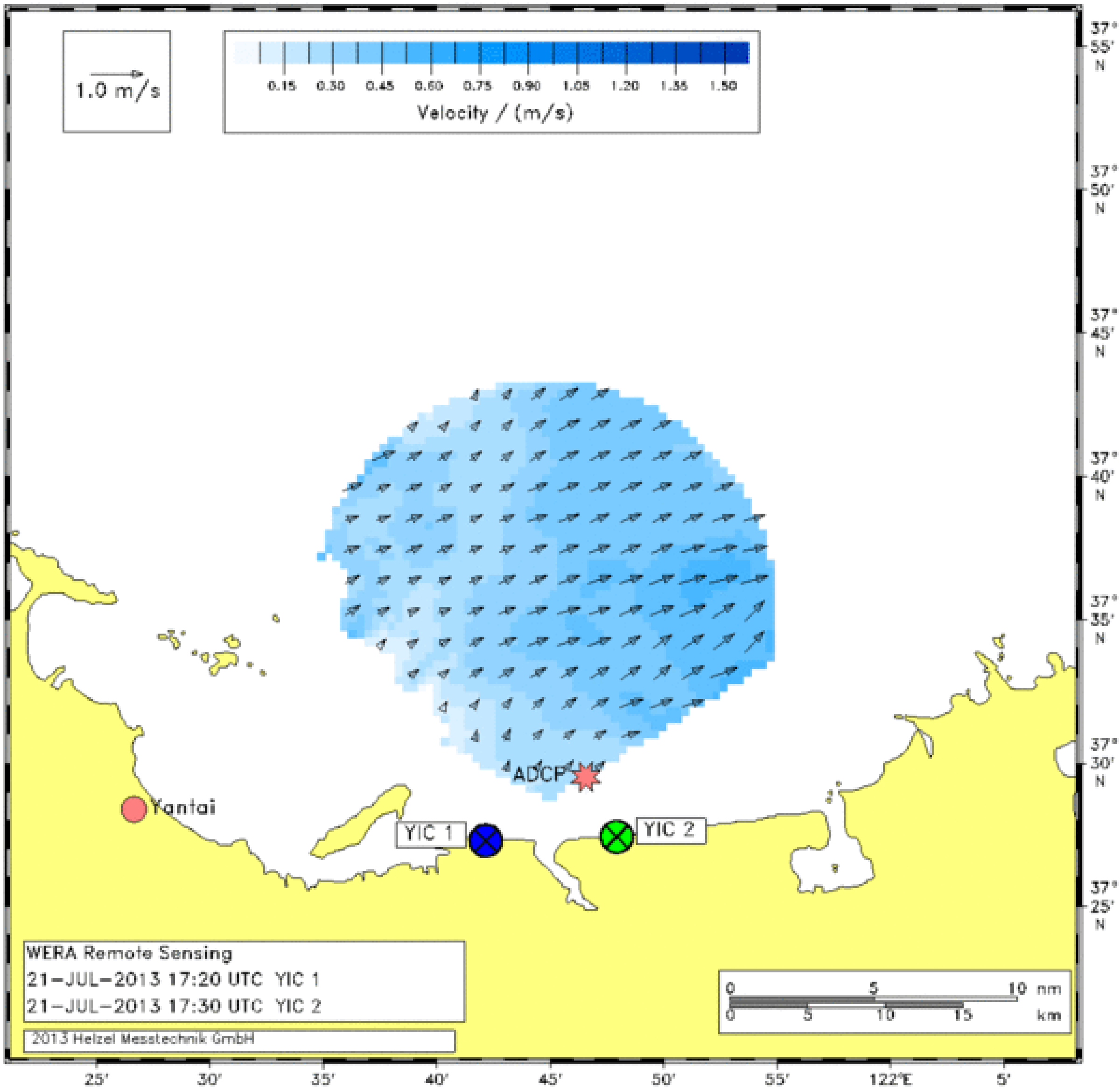

Figure 1. Area of radar-measured current.

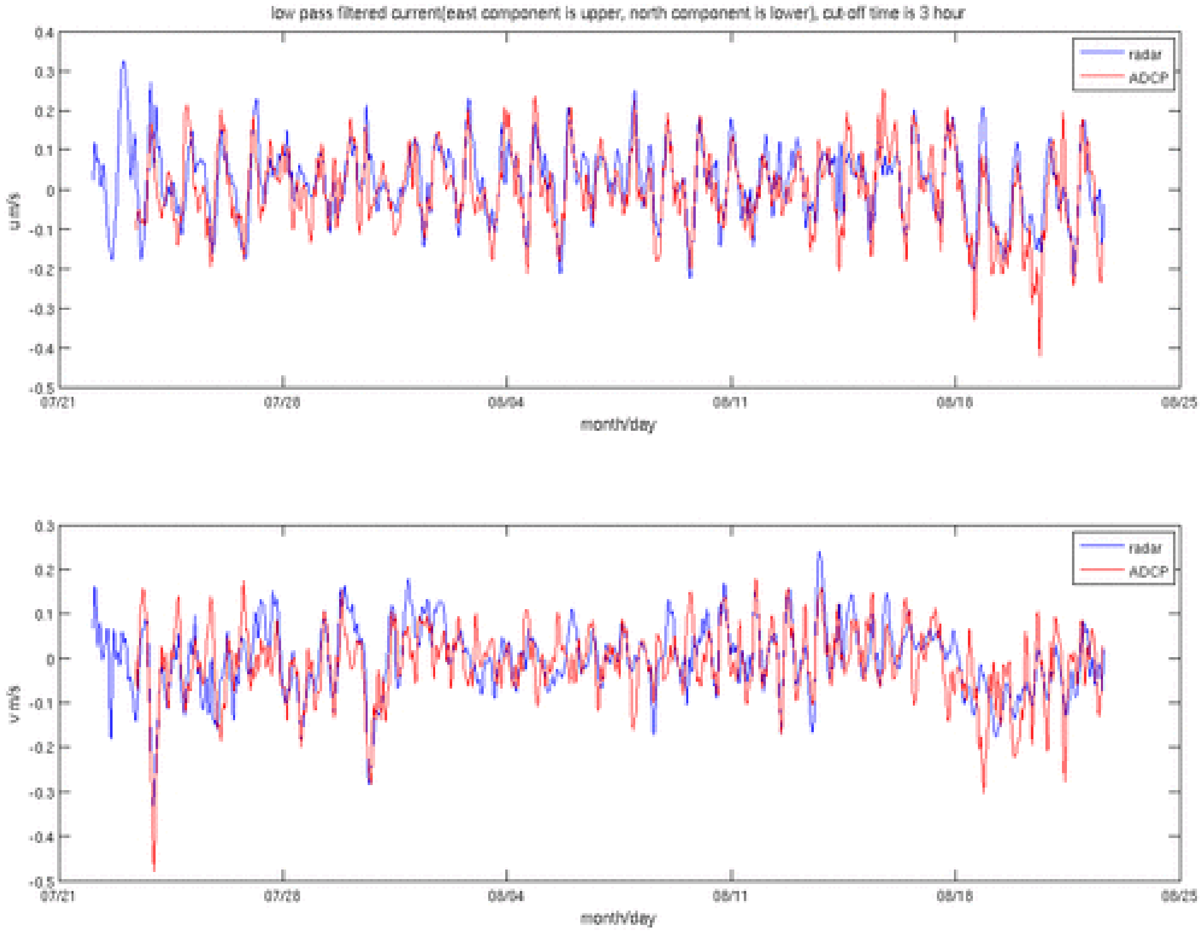

Figure 2. Comparison of surface current between radar and ADCP.

Information Management and Decision Support Systems

Dynamic Maritime Accident Probability Forecasting in the Strait of Istanbul

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Keywords: Maritime accident probability, Forecast, Strait of Istanbul, Dynamic, AIS

The Strait of Istanbul is one of the important waterways in the world with its traffic volume and challenging navigational conditions. Throughout the history of naval and maritime events, there have been catastrophic maritime accidents leading to major problems not only on the environment but also on the city life. Therefore, maritime accidents in the Strait of Istanbul generate nothing but a crucial issue in every respect.

Although recent precautionary policies and regulations; i.e. Traffic Separation Scheme (TSS) and Vessel Tracking System (VTS), have decreased the number of maritime accidents to a certain degree, they are not very effective yet. There are several reasons that can explain this inefficiency; but the heart of the matter might be that current studies that deal with the quantification of maritime accident probability in the Strait of Istanbul only benefit from the past data for the static predictions on near future environmental and traffic conditions. More clearly, these studies predict and creates accident probability map of the near future by considering solely past experiences, rather than current or expected circumstances. Unlike the majority of analyses in the literature, this study on the accident probability map of the Strait is conducted by using short-term expected environmental and navigational conditions. By means of long term AIS data, navigational conditions and hydrodynamic calculations, ship routes are predicted with their probabilities.

This paper has used AIS messages to attain the information on current vectors, the ship characteristics and position. For illustrating the former one, considering high values (up to 5-6 knot) of the current in the Strait, it might be said that its direction and magnitude constitute one of the most important environmental conditions that affect the ship motion in the region. Yet, there is no continuous data for a current map of the Strait. Class-A type AIS messages contain the information about boat speed and speed over ground together with heading and course over ground of the ship. By benefiting from vector calculation, current vectors have been found. Most predominant factor on current is the wind, therefore wind vectors have been recorded simultaneously. Due to wind forecast and past current data, current forecast has been obtained. The outputs of the model have been calibrated with the real time inputs from the ships. For explaining the latter issue; the ship characteristics and position, AIS messages again have provided the necessary information. According to further analysis, message reporting frequency is high enough to find the route of a ship. In terms of ship characteristics and environmental forces, determined routes have been explored. By means of AIS messages, the local traffic routes have been classified according to environmental conditions and time periods.

As one of the models that investigate maritime accidents, the accident probability model indicates that a ship may lose its navigational control due to a human error or an equipment failure. By applying this model into the case study, the probability of losing navigational control of a ship has been calculated. Furthermore, a ship's possible route for the period when it loses its navigational control has been discovered. By using obstacle density on these routes and collision diameter approach, impact probability has been calculated. In respect to these, combination of the losing navigational control and impact probability has provided the accident probability for the selected area.

As a result of this study, near future route probabilities in terms of ship characteristics have been found. According to ship routes, a near future accident probability map of the Strait has been created. The map demonstrates the accident probability of the Strait within a color chart. Consequently, hotspots can be easily recognized. And lastly, this map might be useful for captains of the transit ships and stakeholders who guide these ships.

Evaluation of the Best-Fit Probability Distribution for Rainfall Data in Austria Using L-Moments Method

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Keywords: L-Moments Method, Gumbel Method, Rainfall analysis, Best-Fit Probability Distribution, Goodness of fit test

The aim of this paper is to evaluate the Best-Fit probability distribution for rainfall-data in a small catchment area which is situated at the north part of Graz in Austria. In order to determine the probability of occurrence of any rainfall event, the frequency distribution, which can fit past characteristics on the magnitude and the probability of occurrence of such rainfalls, should be known. In this paper, in order to find the best-fit probability distribution model, some parameter estimation techniques such as L-moments and maximum likelihood models were used and for goodness of fit test, three methods were used as chi-square, Kolmogorov-Smirnov and the root mean square error (RMSE). In this paper, a comparison between four commonly used rainfall frequency distributions were carried out such as generalised extreme value (GEV), Gumbel, log-Pearson type 3 (LP3) and three-parameter log-normal (LN3). Finally, using the best-fit probability distribution, the IDF for this catchment area using a simple graphical method was determined.

Evacuation Alarm Using the Improved Magnitude Method to Damage Caused by Typhoon 9918

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Keywords: Forecasting, Evacuation, Alarim, Vulnerability, Magnitude, Damage length

Due to storm surges and wind waves, Typhoon 9918 caused enormous damage to maritime structures, and the significant storm surges due to this typhoon caused extensive flooding. The improved Magnitude (iM) Method (R. Hashimura, 2010) can be used to estimate the damage of maritime structures that will occur along the coast before a typhoon strikes. In this paper, the usefulness of a forecasting system for announcements of storm warnings and evacuations of coastal residents using the iM Method is discussed. The result shows that this forecasting system can be used for disaster prevention management to coastal residents.

The forecasting of damage length which occurs along the coastal areas is very important in the economic activities and security of fishermen, the operation of port facilities and the safety of port workers and local residents along the coastal region. The serious damage due to storm surges and wind waves caused the passage of Typhoon 9918 to occur in various areas in Kumamoto Prefecture. The significant storm surge caused especially severe flooding to coastal areas. In the northern part of the Yatsushiro west coast, 12 people were killed by the storm surges and wind waves. There was no forecasting system along the damage length that occurred by the typhoon passing through Kyushu Island. If an announcement of storm warning and evacuation had been provided for residents along the coastal area before the typhoon struck, these victims might have been spared. The forecasting method based on the magnitude of a typhoon center is described. The usefulness of a forecasting system for announcements of storm warnings and evacuations using an improved Magnitude Method for coastal residents is discussed.

Typhoon 9918, which maintained a maximum wind speed of almost 45 m/s near the center, struck the Kyushu Island in the western part of Japan. The anomalous storm surge was induced in the closed seas of the western region of the Kyushu Island by Typhoon 9918. The maximum anomaly is estimated to be about 3 m at the northern part of the Yatsushiro west coast. In total, 16 people were killed, 62,772 houses destroyed or damaged, and 1,883 houses were flooded.

The author proposed an improved Magnitude Method which is calculated based on 74 typhoons over 25 years from 1980 to 2004. This method is proposed for forecasting the damage length of maritime structures caused by an approaching typhoon on each coast along the coastal regions of Kumamoto Prefecture. All typhoons passed an area delineated by a latitude of 30° N and 35° N and a longitude of 127° E and 132° E in a 25-year period from 1980 to 2004. The number of typhoons passing through the delineated area is 74. The paths of typhoon are classified according to 13 types. The magnitude method is defined based on the maximum wind speed near the center and the size of the typhoon at any degrees of north latitude. The size of typhoon is defined as the radius of the area in which the wind speed is greater than 15 m/s. The maximum wind speed is classified into 10 ranks and the size is classified into 8 ranks. The magnitude is ranked from 1 to 17. The damage length is defined as an alongshore length of damaged structures caused by a typhoon. This magnitude method utilizes an index of vulnerability of a coast for a typhoon passing along a specified course, which was derived from the damage caused by 74 previous typhoons.

This paper has tried to estimate the damage length of maritime structures that will occur along the coast before a typhoon strikes based on the magnitude of a typhoon at a latitude of 30° N. The index of vulnerability of each coast depends on the sensitivity values of the coast. The damage length of maritime structures for each coast is estimated using the magnitude of a typhoon at a latitude of 30° N and the vulnerability of the coast to the typhoon.

The six numbers, 1 to 6, are termed as a “sensitivity value” for typhoon magnitude based on the damage length. The maximum sensitivity is shown as the vulnerability value for each typhoon course number on the individual coast. This number in a table indicates the vulnerability index for an

individual typhoon path on each coast. The length of damage induced by a coming typhoon for a coast can be estimated as follows: comparing the path of Typhoon 9918, shown in the Figure, with the 13 courses given in the Figure, the path of Typhoon 9918 is considered similar to the courses No. 3, 4, 5, 7 or 8. Based on the Table, the vulnerability index for the west coast of the Yatsushiro Sea is 6 for the typhoon in path No. 8. This coast is the most vulnerable for typhoon in path No. 8. If a typhoon with a maximum wind speed of 46.3 m/s and a radius 601 km at a latitude of 30° N takes the same course No. 8 with typhoon 9918, the magnitude value is 12. The smoothed damage length (Ls) is obtained from Equation for the vulnerability value 6 and the magnitude of 12. The smoothed damage length is obtained by substituting m into the line for Equation. The total damage length along the west coast of the Yatsushiro Sea over 25 years is obtained. Thus, the damage length for Typhoon 9918 is estimated.
Assuming that Typhoon 9918 comes from the south of Kyushu Island, it is equivalent to the prediction at 9 hours before a typhoon makes landfall as shown in the Figure. This time is equivalent to 9 p.m. of the 23rd. This means that the Kumamoto coast enters the storm area 4 hours before. In this case, except for what can be procured from convenience stores, disaster prevention measures against a coming typhoon are difficult for residents after 9 p.m. In fact, 12 people died in Matsuai town as a result of this situation. The storm tide reached the highest sea level, 3 m, at about 6 a.m. In other words, the disaster was caused by the attack of the typhoon in the morning before dawn. If the forecasting of damage was earlier, this method would become more valuable. Despite this affair, the forecasting method shows an effectiveness to evacuate and save human life from a storm disaster.
On the other hand, if the allowable range of the prediction error is magnified, it is possible to forecast the magnitude and the direction of the typhoon movement at a latitude of 30° N using the recent forecasting technology of JMA when a typhoon is located at around a latitude of 28° N. This latitude is equivalent to the prediction at 19 hours before a typhoon makes landfall. This time is equivalent to 11 a.m. of the 23rd. This means that the Kumamoto coast enters the storm area 14 hours before. After passing through at a latitude of 30° N, the forecasting accuracy is dependent on paying careful attention to the movement and change in the magnitude of a typhoon. In other words, it is possible to predict the risk to a coast 14 hours before Kumamoto Prefecture enters the strong wind area of 25 m/s. Thus, the forecasting of damage length before a typhoon approaches the coasts of Kumamoto Prefecture gives a sufficient evacuation time for disaster prevention measures for the coastal residents, for people who are involved in the fishery and for port administrative staff involved in the prevention of coastal hazards.
This method is intended for the prediction of damage of coastal structures due to typhoons. It is considered that the information is beneficial for those who conduct evacuations. An improved Magnitude (iM) Method may be used for the purpose of coastal management in disaster prevention works. Furthermore, it is useful for announcements of storm warnings and evacuations for residents along coastlines. By the attack of the typhoon 9918 and typhoon 8513, severely strong storm surges occurred in the Ariake and Yatsushiro Seas during high tide. A major disaster occurred among coastal residents and fishing parties concerned. When these two typhoons were approaching, there was no method for forecasting the damage level that would occur at each coast before the typhoon struck. From the weather forecasting of Typhoon 8513, which was given by JMA, residents considered that Typhoon 8513 would not attack with a strong wind. As a result, they had been off guard. There were 31 casualties due to this typhoon, many of them from the rollover of a fishing boat on the Ariake Sea.
The iM Method is performed using the media information of weather forecasting. The media information obtained from television is the data of the maximum wind speed and size of the typhoon and its path. By applying these meteorological data to the Figure, the data indicating the vulnerability as a risk of coast can be obtained. The need for countermeasures and evacuation is determined on the basis of this risk data. Therefore, it can be easily used among the general population. The establishment of a forecasting system of coastal damage caused by a typhoon passing through is very useful for the mitigation of disaster.

Reference

Hashimura, Ryusuke (2010): Forecasting of Dmage Length of Maritime Structures Caused by Typhoons Based on Improved Magnitude Method, Proceedings of the 9th International Conference on HydroScience and Engineering, IAHR, PP.1170~1177.

Development of Real Time Storm Surge Forecasting Using Artificial Neural Network

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Keywords: Storm surge, Neural network, Real time forecasting, Climate change

We developed a real time storm surge forecasting system using an artificial neural network (ANN) during typhoon events at Sakai Minato and Hamada, Japan. In this system, the ANN forecasts a time series of surge heights at times of t + 1h, t + 2h, t + 3h, t + 4h, t + 5h, t + 12h and t + 24h to provide the information to decision makers and officials for decision making of evacuation warning or execution.
In order to develop the real time forecasting ANN at Sakai Minato and Hamada, a feedforward neural network was trained using data sets consisting of parameters gathered from historical typhoons and projected typhoons in the conditions of the present (1978-2008) and future (2075-2099) climates. The data sets combine the parameters of the surge height at Sakai Minato and Hamada, the sea level pressure and its depression rate at several meteorological stations. Figure 1 shows a schematic diagram representing the real time storm surge system.
First, the historical parameters were obtained from the observations and a series of numerical simulations for the historical storm surges (1950-2010). The weather research and forecast (WRF) and the coupled surge, wave and tide model (SuWAT) were used. Second, the projected typhoon's wind and pressure fields were obtained from output data of MRI-AGM model (the projects of KAKUSHIN (2007~2012) and SOUSEI by the Ministry of Education, Culture, Sports, Science and Technology, Japan). Then, these output data are downscaled and directly forced to simulate the storm surges in SuWAT in the domain of Fig.2 which shows the projected typhoon tracks in the present and future climate. The parameters of the surge height, the seal level pressure and the depression rate of the sea level pressure from numerical simulations and the available observations are grouped by the following method introduced by Kim et al. (2013).
Using the developed forecasting ANN, we conducted a series of forecasting experiments for Typhoon Megi (2004) surges at Sakai Minato at times of t+1h, t+2h, t+3h, t+4h, t+5h, t+12h and t+24h. Figure 3 shows comparisons of the forecasted and observed surges at Sakai Minato. The detailed results and discussions will be presented at a conference.

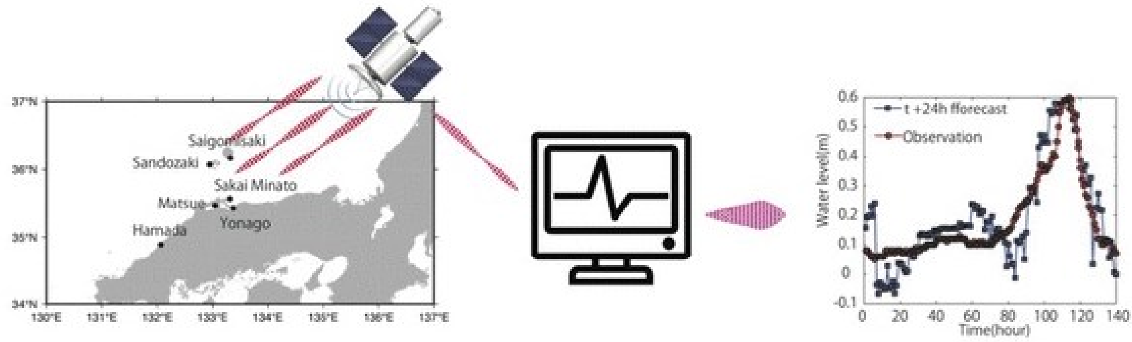
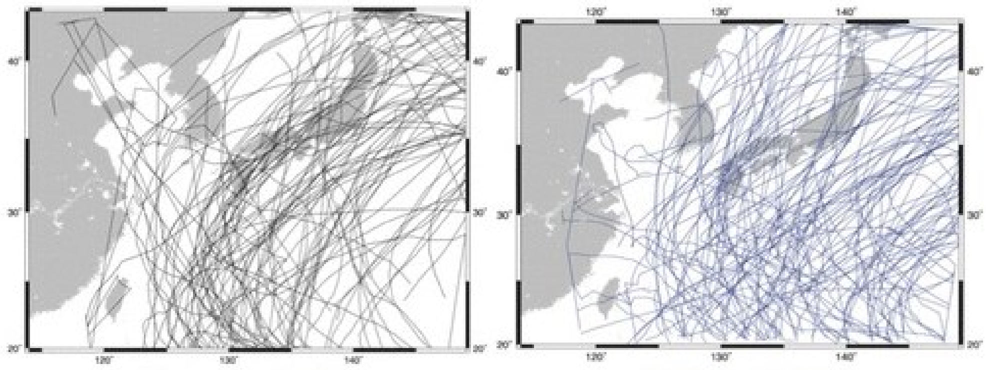


Fig. 1 Schematic diagram for the framework of the real time storm surge forecasting system



(a) present climate (b) future climate

Fig. 2 Projected typhoon tracks in the computational domains.

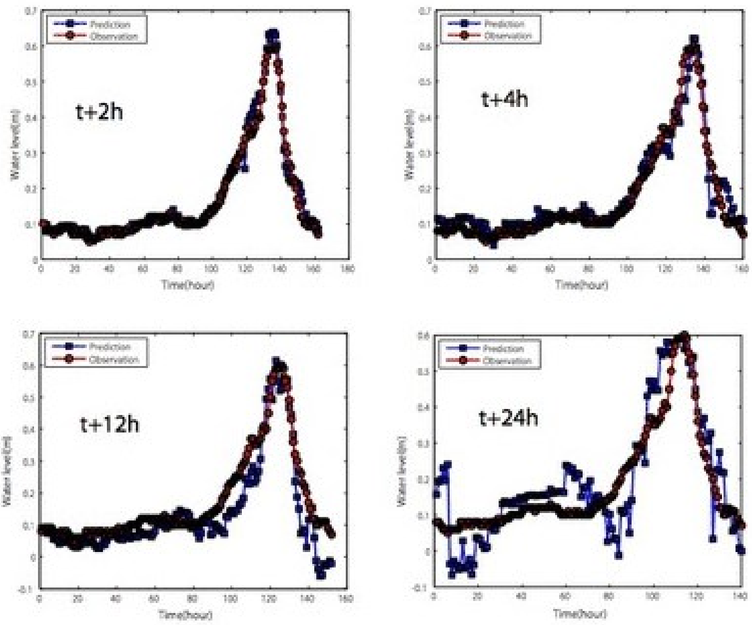


Fig. 3 Comparisons of the projected and observed surges at Sakai Minato during Typhoon Megi (2004).

Reference

S. Y., Kim, S., Shiozaki and Y., Matsumi, (2013) Sensitivity study of real time storm surge forecast system to meteorological and hydrodynamic fields along the Sanin Coast, Japan, *Proc. Of 7th Int. Conf. on Asian and Pacific Coasts,* 555-560

Mini-Symposium: CFD in the nearfield of structures

Hybrid Modelling of a Filling and Emptying System of a Navigation Lock

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Keywords: OpenFOAM®, CFD, Hydraulic structures, Lock, Valve

The navigation lock "Iffezheim" near the German city Baden-Baden at the river Rhine is one of Europe's largest inland navigation locks. Every year about 30 million tons of cargo is transported through the lock. It consists of two chambers with a length of 270 m and a width of 24 m. The lift height is up to 10 m. The filling and emptying of the lock is operated through two longitudinal culverts at both sides of the chambers. These culverts are connected to the chambers by 960 filling nozzles ("Multiport System"). The flow is controlled with two roller wagon valves at every culvert, one at the upstream inlet and another one at the downstream outlet. With this configuration it is possible to perform a filling or emptying process within 10 minutes. In front of and behind each roller gate is a vertical shaft, which allows blocking the culvert with bulkheads for service purposes. The upper edges of these shafts are at ground level. As upper coverage of the shafts 8 ton steel plates are used. In case of an emergency stop while filling or emptying a chamber, the roller wagon valves close as fast as possible so that the water level in the chamber stops rising or falling. As a result of this fast closing water hammering occurs, which sometimes lifts the covering steel plates from the service shafts. The Federal Waterway Engineering and Research Institute (BAW) has been commissioned to investigate this issue and to develop solution proposals.

For investigating this problem, a numerical model of the lock chamber and the filling system had to be created to understand the major hydraulic processes in case of an emergency stop. Essentially, a navigation lock can be simplified as a reservoir with pipes connected to it. For modelling and simulation of systems like that, the software Flowmaster® is often used. Flowmaster® is a commercial 1D Computational Fluid Dynamics (CFD) solution for modelling and analysis of complex internal flow systems. It allows simulating system-wide fluid flow rates and pressure levels for the lock. Many typical hydraulic components are available in the supplied libraries. These have to be parameterized with diameters, roughnesses or local losses. Water hammer problems are dependent on the flow rates and the closing velocity of the roller gates. On the one hand small scale phenomena like flow detachment at corners are not of interest for the investigation, so that a 1D simulation of the chamber and the filling and emptying system would be the most efficient choice. On the other hand the parameterization of the individual parts of the 1D model has a large influence on the similarity of the model with reality. Thus, a hybrid 1D-3D approach has been chosen. To find the necessary parameters, like the energy losses at the valves or the filling nozzles, multiple small scale 3D models of these individual parts of the lock were created. For these small scale simulations, the open source CFD toolbox OpenFOAM was used. OpenFOAM is a widely known CFD toolbox for solving fluid mechanical problems. For the head loss investigations, the one phase transient solver pimpleFoam was used. The calculations were performed on the computational clusters of the Federal Waterway Engineering and Research Institute. The pressure upstream and downstream of each component to be parameterized was recorded in the simulations. To calculate the energy loss coefficient ζ from the 3D results as a parameter for the 1D model, the Bernoulli equation was used.

The parameters derived with the 3D model were then used to set-up a 1D network model of the lock and investigations with emergency stops at different times during the filling and emptying process of the chamber were performed. Water hammering, which was high enough to lift the covering steel plates of the service shaft could be reproduced with the numerical model. Considering the intensity of the water hammer as a function of the time at which the emergency stop occurs, you can see, that the forces lifting the steel plate depend on the one hand on the gradient of the flow rate and on the other hand on the velocity, with which the gate closes. It is impossible to modify the gradient of flow rate without changing the filling time of the chamber. Due to the requirement of avoiding unacceptable water level rising or falling in case of emergency stop, the gates should close as fast as possible, which triggers the water hammering problems. Considering these two restrictions, a way to close the gates as fast as possible with as little impact on the filling time as possible which avoids water hammering had to be developed. After several attempts with different closing velocities, a solution was figured out which is presented in the full paper.

During the investigation the BAW was asked to evaluate the maximum vertical forces acting on the roller wagon valves. The deadweight forces and the forces due to the flow around the gates have to be big enough, so that the gates can be closed without any additional external force. Opening the valves is performed by moving them up in a shaft with a hydraulic cylinder. If the valves are partially opened there are two small gaps at the upstream and at the downstream side of the valves labelled as e_1 and e_2 [Figure 1] and flow above the gates occurs. The flow detachment in front of and behind the valves and in the gaps has large influence on the forces. Therefore a small scale 3D model with a very high resolution in the regions of flow detachment was created to determine the vertical forces for different opening positions. The calculations were performed with the two phase transient solver interFoam. Numerical investigations with twenty different valve opening positions were carried out. The calculations were performed on the high performance computers of the BAW. Considering the results of the CFD calculations, the vertical forces acting on the gates depend on the gate opening and in particular on the width of the two gaps e_1 and e_2.

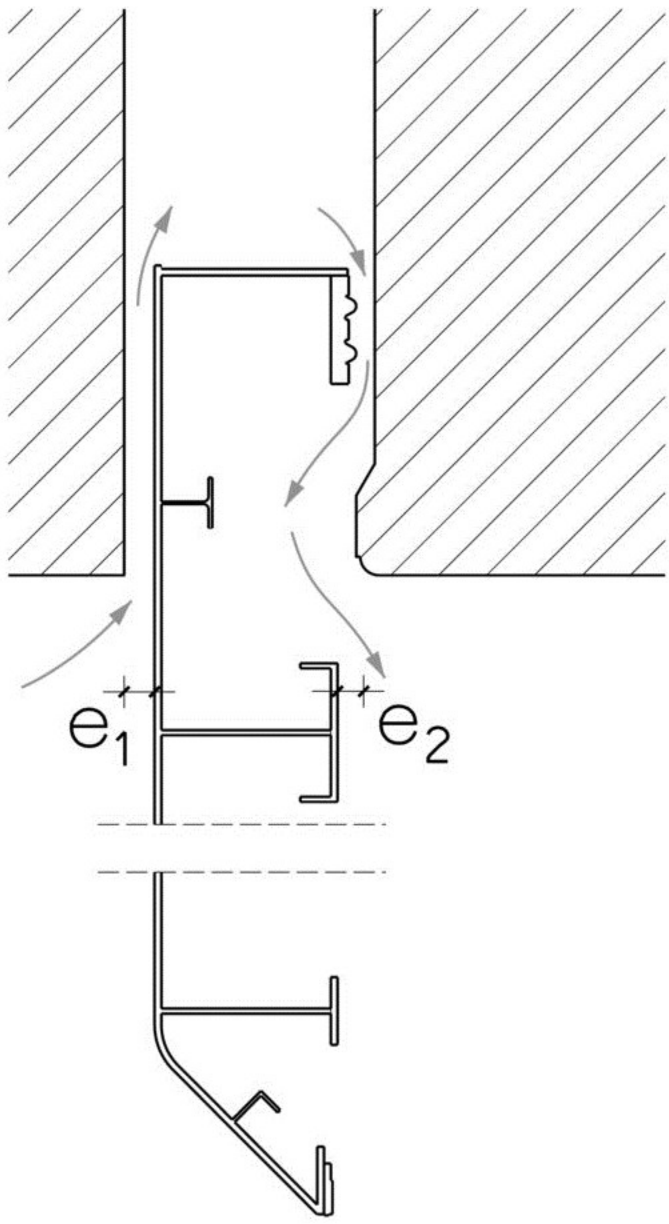

Figure 1. Gate with the upstream and downstream gaps.

With increasing gate opening the gap e_2 increases and the flow above the gate intensifies, which leads to decreasing pressure above the gate and smaller downward forces. In a second step the sensitivity of the forces to the gap widths was investigated. This investigation showed, that the forces are strongly dependent on the actual sizes of the gaps.
In the paper and the presentation the engineering problems and the investigation strategy for the navigation lock "Iffezheim" will be presented. This includes the procedure for the 1D/3D hybrid modelling of the filling and emptying system with OpenFOAM and Flowmaster®. It will give an overview over a chosen practice-orientated approach for solving these problems and the results will be discussed. In addition to the water hammering problem, the procedure for determining the vertical forces acting on the roller wagon valves and developed remedies will be presented.

The Use and Validation of OpenFOAM on Flows in and Around Navigation Locks

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Keywords: CFD, OpenFOAM®, Navigation locks, Hydraulic structures, Density current

The use of CFD in the hydraulic design of navigation locks is still not well established. Although it is being used more often, engineers still rely primarily on relatively simple computational models and scale model tests. Simple computational models are a good way to test multiple conceptual designs because they are fast to calculate and relatively easy to setup. However, many details cannot be accounted for in such simple models and to test a final design a scale model test is preferred. The disadvantage of scale model tests is that they are expensive, time consuming (to build and operate) and usually limited to a single configuration. CFD should position itself in between these methods. The conceptual design can be made using simple computational models and more detailed parts of the design like the culverts or levelling openings in the gate can be investigated using CFD. From this follows a design that can be tested in a scale model. Results of the scale model can be used to validate and improve both the simple computational model as well as the CFD model. This will make it possible to investigate multiple designs before the scale model is built. An example of the use of CFD, and OpenFOAM in particular, on flow in and around navigation locks is the calculation of longitudinal forces (often referred to as hawser forces) on a ship due to density currents in the lock chamber.
Large density differences around a sea lock give rise to so called density currents. These are gravity induced currents where the salter, and thus heavier, water flows beneath the fresh water and the fresh water flows over the salt water. When the lock gates open such a density current flows into the lock chamber and upon reaching the moored vessel causes a mostly longitudinal force. In the case of large sea locks that accommodate large vessels these forces can be quite significant as shown in [1]. At the moment a new large sea-lock is planned in the Netherlands at IJmuiden (Port of Amsterdam). At the lock complex of IJmuiden there can occur a relatively large density difference between the outer and inner approach harbours. Using a simple computational model for the simulation of density currents is possible, but this models should preferably be tuned using results from a scale model [2]. It is also possible to investigate the problem using a scale model as shown in [1, 3], but this is costly and time consuming. However, this problem can also be investigated using a CFD approach.
In [4] a method was presented to calculate the longitudinal forces due to density currents using OpenFOAM. The numerical method was validated using results from scale models tests and showed to perform well for the case of a ship moored in the lock chamber. It showed almost perfect agreement with the scale model test. This numerical method is further validated using prototype measurements at the Volkerak recreational lock near Willemstad, the Netherlands. This also made it possible to finally validate the model for the case of an initially salt lock chamber instead of an initially fresh lock chamber. The results are shown in Figure 1 and Figure 2 which show a good agreement between measurements and calculation.
The results show that it is feasible to use CFD for the determination of flow in and around navigation locks. It gives a more reliable, no tuning necessary, result than a simple computational model, but is not as costly or time consuming as scale model test. It is also relatively easy to apply this method to different ship geometries or to locks of different dimensions or with different density differences.

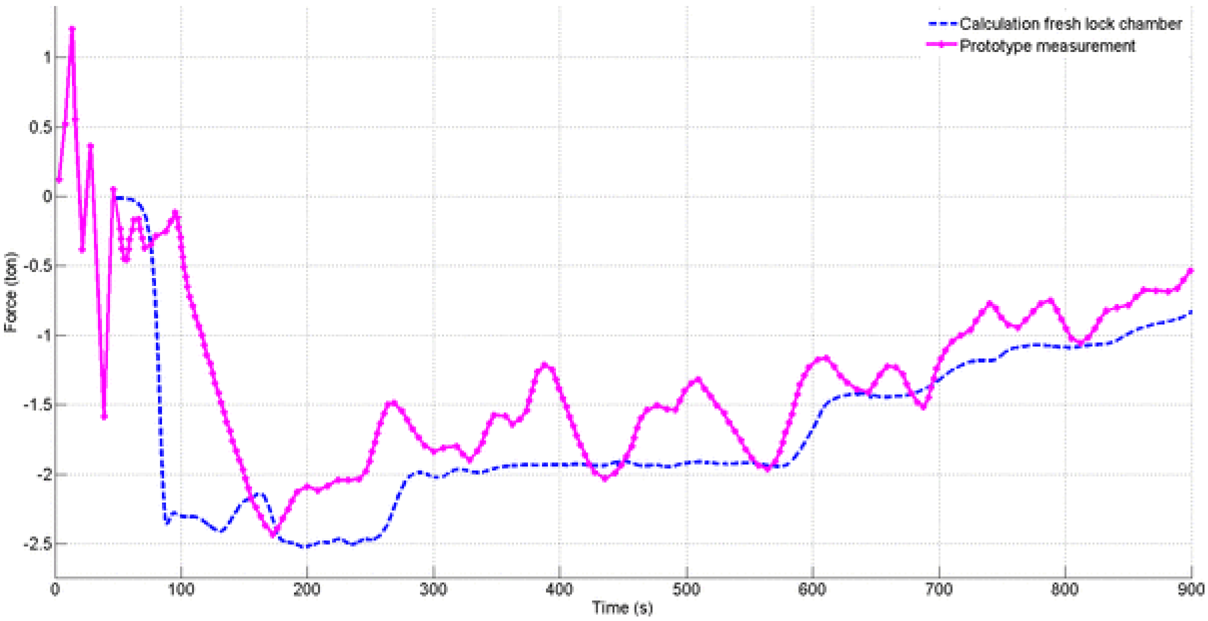

Figure 1. Comparison between calculation and measurement results for an initially fresh lock chamber and salt approach harbor.

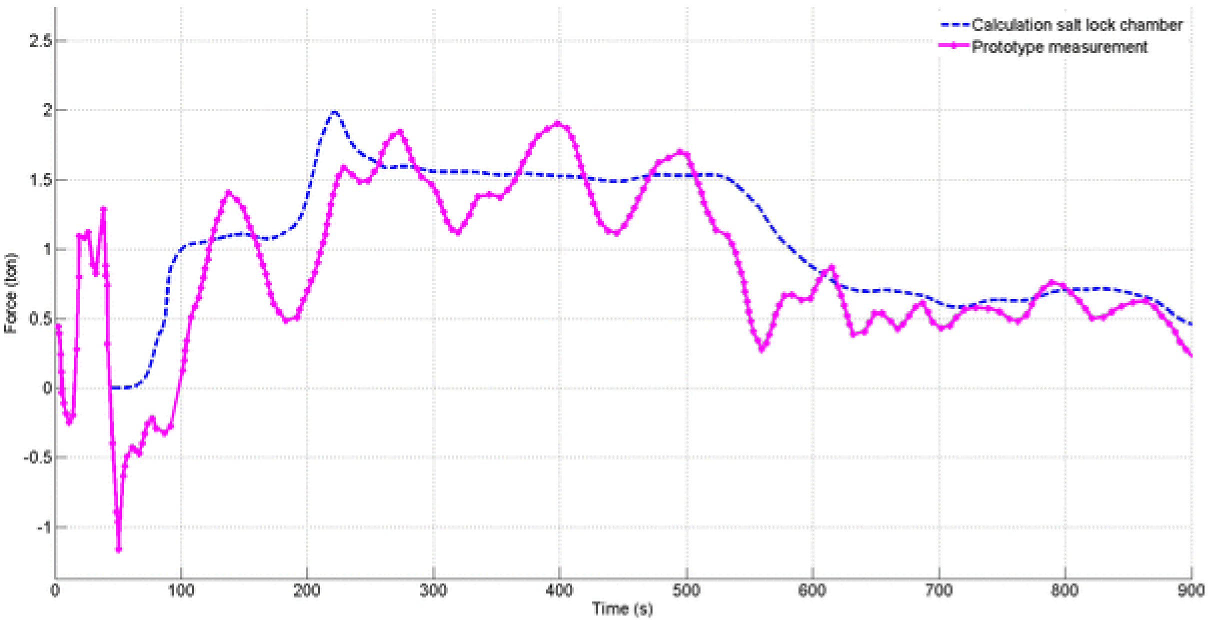

Figure 2. Comparison between calculation and measurement results for an initially salt lock chamber and fresh approach harbour.

References

Vantorre, M., G. Delefortrie, and F. Mostaert, Behaviour of ships approaching and leaving locks: Open model test data for validation purposes. Version 2_0. 2012, Flanders Hydraulics Research and Ghent University – Division of Maritime Technology: Antwerp, Belgium.

Vrijburcht, A., Forces on Ships in a Navigation Lock Induced by Stratified Flows. 1991, Delft University of Technology.

Delefortrie, G., et al., Oriënterende sluisinvaarproeven voor de nieuwe sluis te IJmuiden. 2013, Waterbouwkundig Laboratorium: Antwerpen, België.

Loor, A.d., et al., The use and validation of OpenFOAM to determine the lateral and longitudinal forces exerted on a vessel in the lock and in the lock approach, in Third International Conference on Ship Manoeuvring in Shallow and Confined Water. 2013: Ghent, Belgium.

Simulation of Flood Scenarios with Combined 2D/3D Numerical Models

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Keywords: Hybrid modeling, Flood, weir, OpenFOAM®

Germany's navigable rivers are regulated by approximately 340 weirs ensuring a sufficient water depth to enable waterborne transport. Like any other technical system movable gates are subject to failure and need to be maintained from time to time. For defining flooded areas in case of a failure or revision of a weir in combination with a simultaneously appearing 100-year flood, water level calculations have to be done. The calculated water levels in context of these investigations are compared to existing water levels of a 100-year flood. Thus the increase of the flooding situation caused by failure of a weir body can be judged. The Federal Waterways Engineering and Research Institute was assigned to estimate the hazard potential at the Main river.

In such a case, the flow regime consists of two- and three-dimensional flow effects. In close vicinity to the barrage the phenomena are characterised by a three-dimensional velocity field, where water circulates around solid structures and overflows the weir body. In contrast to these three-dimensional small-scale effects, the flow in the far field of the barrage and over the wetlands can be approximated as two-dimensional. In order to simulate the variety of effects correctly with an appropriate effort of time 2D- and 3D-models were built, creating a hybrid model.

Depending on the upstream water level, the total discharge of the Main river will split up into one over the wetlands and another through the weir. The tailwater level highly depends on this distribution and the point of backflow into the Main river. Furthermore the tailwater level affects the backwater at the weir and in consequence the upstream distribution of the discharge. Neither the two- nor three-dimensional model can reproduce all the correlations in a sufficiently correct way. This explains why a hybrid model is necessary for these kinds of scenarios.

The 2D model was set up with Hydro-AS_2D and stretches over several kilometres of the river valley. Its aim is to compute the flow rates through and around the weir as well as the tailwater level. The results serve as boundary condition for the 3D model, which was set up with OpenFOAM and is limited to the close proximity of the weir. As 2D models lack a sufficiently correct reproduction of vertically accelerated flows, the aim of the three-dimensional multiphase model is to estimate the backwater effect of the weir. The measured tailwater level of the 3D model can be different from the prescribed boundary condition due to the distance between measure points and boundary. The correlation of flow through the weir, tailwater level and backwater is unknown at the beginning of the investigation. Accordingly, temporary results of the 2D model must serve as hydraulic boundary condition. On the other hand, correlations found by the 3D model are integrated into the 2D model.

Comparing the estimated backwater values of the two models a statement can be made whether the hydraulic capacity of the weir in the 2D model is accurate. Accordingly the overflow coefficient integrated into the weir needs to be adapted to the flow conditions of the 3D model. After the adaption of the 2D model another simulation run is performed.

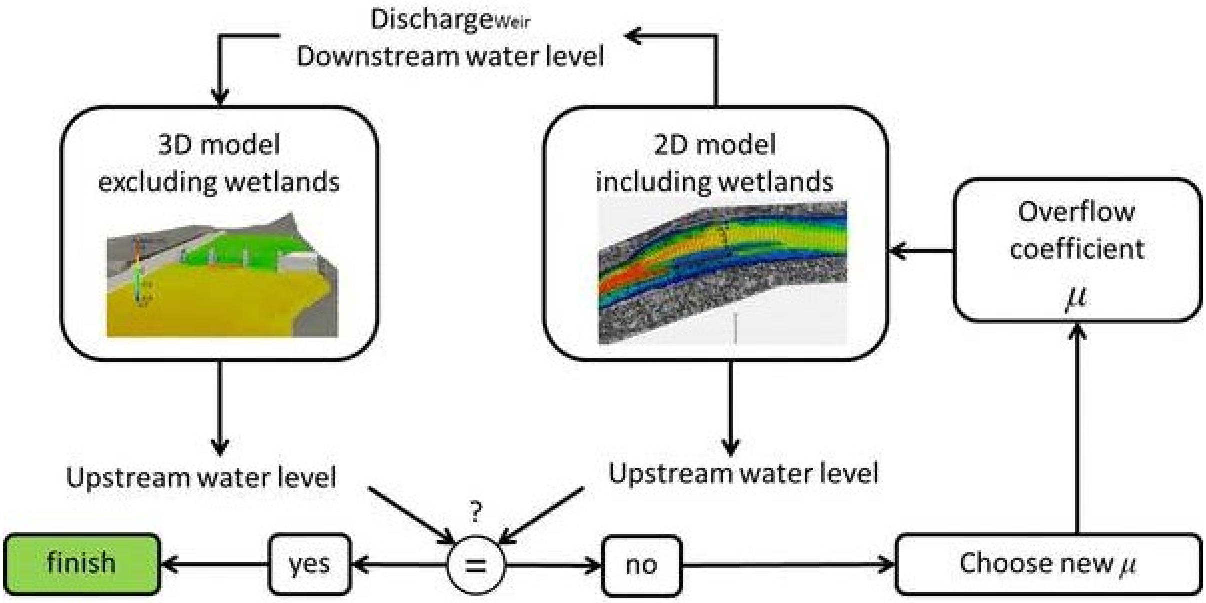

Figure 1. Iteration procedure to consolidate the results of the 2D and 3D model.

The correlation of flow over the wetlands and discharge through the weir changes with all resulting consequences due to the adaption. The newly estimated values for flow through the weir, tailwater level and backwater are controlled by another simulation of the 3D model. Several steps of iteration are needed to consolidate the results of the two models. Investigating both cases, failure and revision of a weir, detailed information about the water levels was obtained. Comparing those with existing water levels of a 100-year flood the effects of failure can be recognized.
Since the necessary amount of iteration steps and occurring range of boundary conditions are unknown at the beginning of the investigation an approach is needed to limit the number of simulation runs of the 3D model. Avoiding a time-consuming iteration, an efficient methodology will be explained. The approach of joining the two- and three-dimensional model in order to create a hybrid model will be shown.

Generation of a 3D Mesh Using snappyHexMesh Featuring Anisotropic Refinement and Near-wall Layers

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Keywords: Mesh, Anisotropic, SnappyHexMesh, OpenFOAM®

A workflow for 3D mesh generation in waterways engineering is delineated in this article. 3D waterways engineering problems typically include scales ranging from the order of decimeters to hundreds of meters, curved structure geometries, and a free surface, making it necessary to apply multiple levels and types of local refinement in several regions. This includes near-wall layers, if the flow in wall vicinity is of special interest. The tool used here is snappyHexMesh, the standard meshing tool of the free, open source CFD software package OpenFOAM®. As comprehensive and detailed manuals for waterways engineering problems are lacking, the work with snappyHexMesh can be described as demanding for beginners. To lessen this drawback, some experiences and thoughts regarding the workflow are shared in the following.
As a real-life example for the workflow process, meshing of a hydro power dam tailwater is chosen. The geometry's outer dimensions are about 133 m x 105 m x 12 m, including three turbine draft tubes and a weir segment. Highly resolved data gathered using a multibeam echo sounder is used to model the bottom boundary in 3D. Purpose of the final CFD model (not covered here) is to investigate the flow field within the highly turbulent tailrace right next to the power station up to about 25 m distance downstream, supporting the projection of a fishway with multiple entrances in this area.
Starting with geometry generation and completing with quality control, the workflow is split into seven stages explained separately, including best-practice guidelines based on personal experience. The stages are:

- CAD generation and export: Boundaries are defined and conventions regarding the axis orientation and positioning are made. Advantages of local over global coordinates are expounded.
- blockMesh: The basic hexahedral mesh is set up. It is exposed how boundaries undefined by geometrical restrictions, such as the atmosphere and in-stream boundaries, can be shifted easily. Some thoughts are given regarding the choice of the basic edge length.
- castellatedMesh: The basic mesh is cut along the boundaries, needless parts are discarded, and isotropic refinements are conducted (Fig. 1a). One of the most important parameters, the so-called "re-solveFeatureAngle", and its background, are explained in detail. A simple workaround to graphically determine block limits with ParaView is shown. Some ways of fighting a common problem referred to as "creeping", i.e. expanding of the mesh into regions not belonging to the model, are listed.

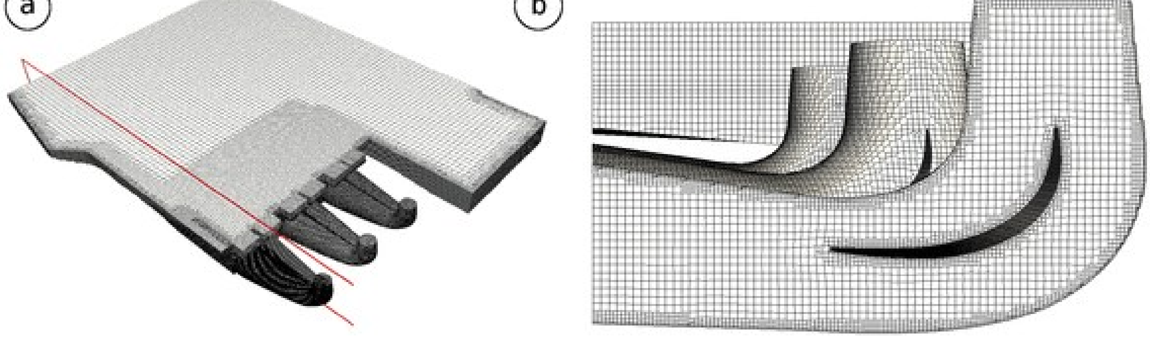

Figure 1. (a) Castellated mesh stage of the example hydro power dam tailwater. Flow direction is from bottom right towards top left. Three draft tubes are visible in the foreground. A section through the left draft tube is labeled and shown in (b) after layer insertion (stage six of the meshing process).

- refineMesh: Optional anisotropic refinements of certain mesh regions can be achieved by iteratively calling the tool refineMesh, which is not part of snappyHexMesh itself. The importance of homogenous vertical mesh resolution in vicinity of the water surface when applying the volume-of-fluid method is both emphasized and justified. Ways to ease the work with refineMesh are presented, such as defining and integrating multiple areas or controlling the tool's iterative execution via a shell script.
- snap: Hexahedral cells at the boundaries are deformed to fit the geometrical restrictions, including feature edges.
- addLayers: Near-wall layers are inserted after displacing the existing cells (Fig. 1b). Special attention is laid on this step, as its entailed disadvantages may overcome its advantages, depending strongly on the purpose and setup of the simulation. Numerous parameters can be set within the respective sub-dictionary. Based on experience, adapted values for the most important parameters are given. Altering of the built-in sub-dictionary meshQualityControls for the purpose of parameter-adjusting is mentioned, and a brief comparison with the layer generation process of the commercial CFD software Star-CCM+ is made.
- checkMesh: This tool is typically run subsequently and, in case the mesh fails some checks, indicates the problems in its output. Some guidance is given to interpret the output and to decide if and where changes need to be applied to the mesh.

At all stages, decisions made in the model example in general are discussed. Common mistakes and dead-ends are mentioned to prevent users falling for them. Pros and cons of anisotropic refinement and layer insertion are given more room, as, at one hand, they tend to be time-consuming due to a combination of complex interactions and poor available documentation and, on the other hand, are not necessarily needed for every kind of 3D waterways engineering simulation problem.

Numerical Simulation of Turbulent Free Surface Flow around a Circular Cylinder

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Keywords: Turbulent flow, Free surface, Cylinder, Numerical simulation

The flow past a wall-mounted cylindrical obstacle is dominated by the horseshoe vortex and the lee-wake vortical structure. Due to the presence of the adverse pressure gradient induced by the obstacle, the approaching turbulent boundary layer undergoes a three-dimensional separation leading to the formation of a complex horseshoe vortex system around the obstacle. Flow past a surface-piercing cylindrical structure further exhibits a substantial amount of free-surface variation along the obstacle surface at high Froude number. The free-surface variations and the corresponding pressure gradient result in a remarkable downward flow with a strong velocity component in the radial direction. Graf and Yulistiyanto (1998) had been experimentally investigated the interactions of turbulent vortical structures with the free-surface as well as the cylinder and bottom wall at the Reynolds number of 1.47×10^5, based on the free-stream velocity U and the cylinder diameter D and at the Froude number of 0.5. Rouland et al. (2005) carried out numerical simulation of the flow of Graf and Yulistiyanto using unsteady Reynolds-averaged Navier-Stokes (URANS) approach along with a rigid-lid (free slip), free surface assumption. At the given high Froude number, they failed to capture the distinct flow structures around the cylinder observed in the experiment, and reported that the resolving of free surface variation around the cylinder is essential to reasonably reproduce even the mean flow topology.

In this study, we present numerical simulation results obtained by applying the OpenFOAM open source CFD tool to the turbulent free surface flow of a wall-mounted, surface piercing cylinder that was experimentally investigated by Graf and Yulistiyanto (1998). We investigate the performance of the URANS computations employing widely used two-equation turbulence models, such as the standard k-ε and the k-ω SST models, to reproduce free-surface variation and flow behavior in the vicinity of the cylinder at the Fr of 0.5. The scale-adaptive simulation (SAS) approach based on the k-ω shear stress transport (SST) model of (Menter and Egorov 2010) is also evaluated by applying it to the flow. The SAS model behaves in many flows similarly to the detached-eddy simulation (DES), but with less explicit impact of the grid spacing on the model formulation (Egorov et al. 2010). The sensitivity of numerical solutions to the wall boundary conditions is conducted by employing two different computational meshes for wall-function and wall-integration calculations. A two-phase volume of fluid (VOF) technique is employed to simulate the variation of free-surface. The governing equations are solved numerically by means of the finite volume method implemented in the open source CFD toolkit. Overall fully second-order-accurate setup both in time and in space is used for the simulations. The convective term is discretized by a bounded central difference scheme, called by Gamma scheme. The 68 D long computational domain takes the whole experimental channel width of 9.1 D into account to eliminate the blockage effect on the flow.

Our numerical results demonstrate that the resolving of the free-surface variation is an essential prerequisite to accurately capture the mean flow fields including the distinct counterclockwise circulation at the downstream side of the cylinder that can't be reproduced by numerical simulation with rigid-lid boundary conditions at the Fr of 0.5. URANS computations employing wall functions can reasonably predict the time-averaged velocity vector fields, but significantly underestimate the turbulent kinetic energy distribution associated with the horseshoe vortex and the lee-wake vortices. It is attributable to that the URANS computations yield the quasi-steady-state flow fields in the vicinity of the obstacle regardless of the wall treatment. The URANS computations with wall integration of the viscous layer improve of the numerical prediction of the turbulence statistics.

The SAS appears to well reproduce the rich dynamics of the large-scale instability of the lee-wake vortices and the horseshoe vortex system with intense unsteadiness. The comparison of computed turbulent kinetic energy and time-averaged mean velocity field with the experimental measurements of Graf and Yulistiyanto (1998) confirms that the SAS can reasonably well capture both the mean flow features and the turbulence statistics of the flow around the cylindrical obstacle with affordable computational resources.

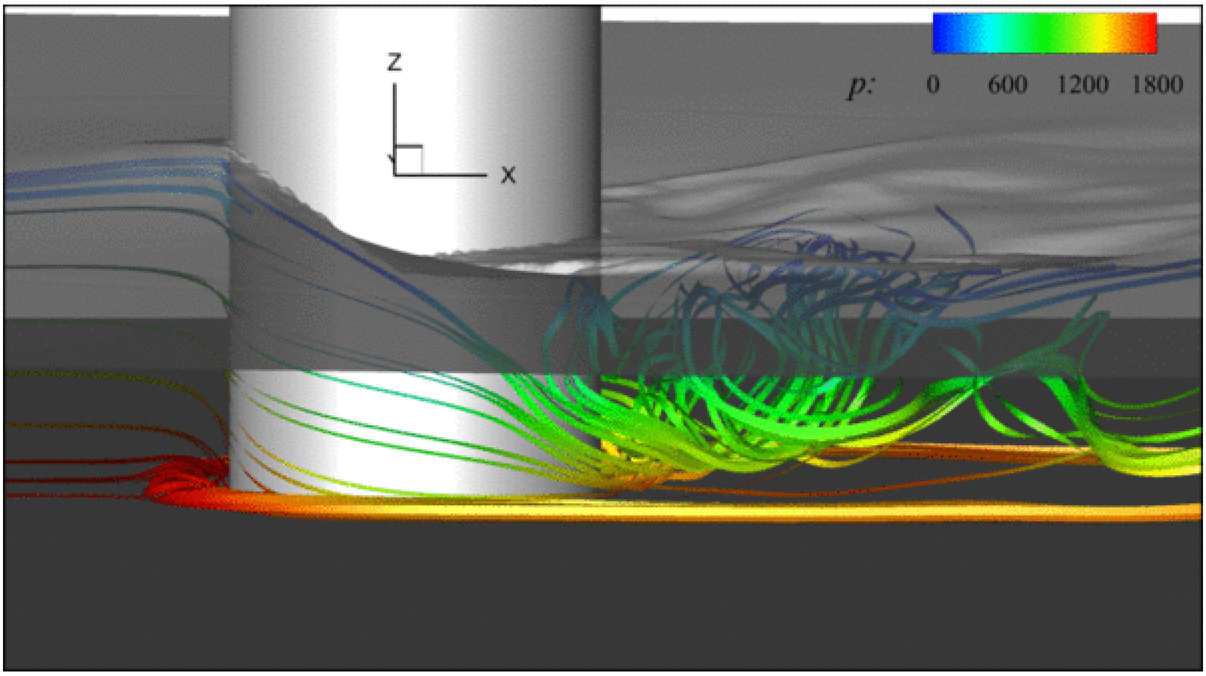

Figure 1. Snapshot of instantaneous flow field around the cylinder computed by the SAS approach. Free-surface variation is visualized by the iso-surface of the volume fraction and the horseshoe and lee-wake vortices are identified by streamlines colored by pressure.

References

Egorov, Y., Menter, F. R., Lechner, R. & Cokljat, D. 2010. The scale-adaptive simulation method for unsteady turbulent flow predictions. Part 2L application to complex flows. Flow, Turbulence & Combustion. 85:139-165.

Graf, W. H. and Yulistiyanto, B. 1998. Experiments on flow around a cylinder; the velocity and vorticity fields. Journal of Hydraulic Research, 36:4, 637-654.

Menter, F. R., & Egorov, Y. 2010. The scale-adaptive simulation method for unsteady turbulent flow predictions. Part 1: theory and model description." Flow, Turbulence & Combustion, 85(1): 113-138.

Rouland, A., Sumer, B. M., Fredsøe, J. and Michelsen, J., 2005. Journal of Fluid Mechanics, 534, 351-401.

Hybrid Modelling of Flow Processes in Underground Pump Storage Reservoirs

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Keywords: Pump storage reservoirs, Hybrid Modelling

Introduction

Pump storage reservoirs are of high importance for the German energy turnaround and the transition from the fossil fuel and nuclear energy age to volatile renewable energy sources. Renewable energies such as wind energy, solar energy and hydropower energy show high temporal and spatial fluctuations while the demand depends on human activities. The resulting difference between energy demand and energy supply requires new energy storage capacities in different time intervals from sub second to seasonal ranges.

Traditional pump storage reservoirs are often critically evaluated due to conflicts with nature conservation and population. Therefore, research is required for innovative and new pump storage reservoirs avoiding the aforementioned conflicts. Underground pump storage reservoirs are regarded as one promising alternative due to the possibility of subsequent use of old mines (coal, ore or salt).

The hydraulic processes in these underground pump storage reservoirs are an important prerequisite apart from mining, technical, economic, approval and operational aspects. Consequently, the hydraulic processes in underground pump storage reservoirs are investigated in detail on the basis of an hybrid modelling approach using OpenFoam and a small scale physical model.

Model Set-Up and Test Programme

First, a physical model of an underground storage reservoir (UPSR) was set-up in an approximate scale 1:100 to investigate the filling, emptying and flow processes and to identify relevant processes (Fig. 1).

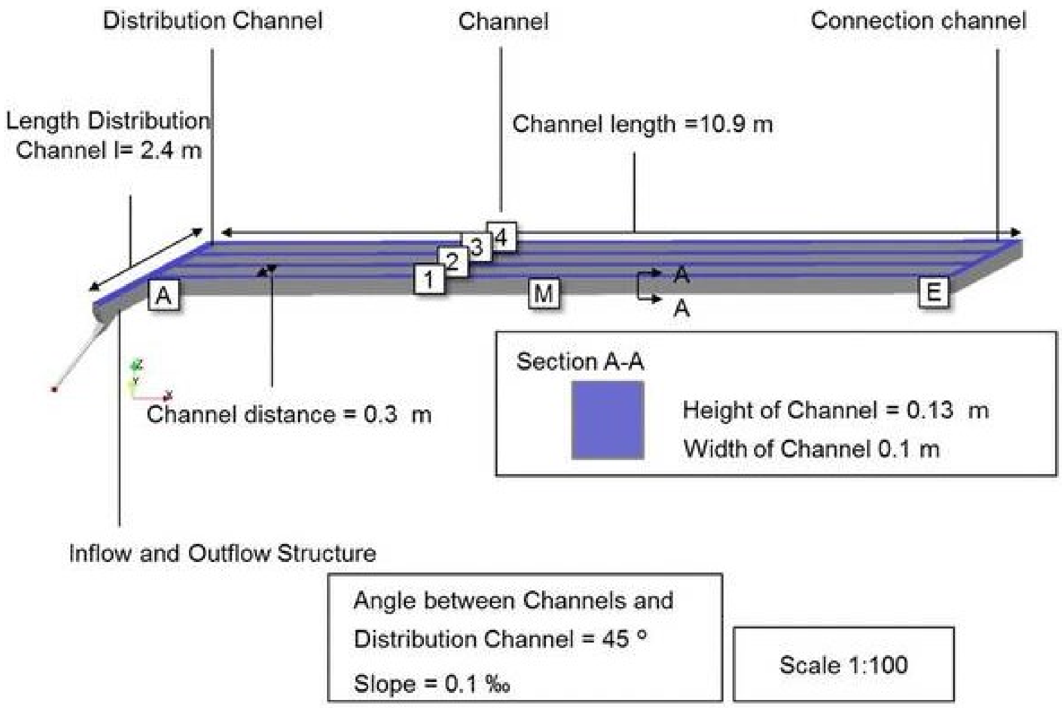

Figure 1. Model set-up.

In a second step, the hydraulic processes in the underground pump storage reservoir were simulated by using 2D and 3D numerical models (OpenFoam, Flow3D, Telemac 2D). The numerical models were calibrated by the physical model and different model geometries (e.g. number of channels, length of channels) were investigated to find an optimum geometry. The test programme was identical in the physical and numerical model simulations to simulate the underground pump storage reservoir as a unit in the German energy network, Therefore, typical filling and emptying processes were given as in- and outflow boundary conditions.

Results
The experimental and numerical data were analysed to get more information on the following aspects:

- Global and local flow processes in an UPSR (Fig. 2)
- Optimum geometry of an UPSR
- Flow and pressure impacts on surrounding ground
- Suitability of 2D and 3D numerical models to assess flow processes in UPSR
- Energy storage in UPSRDetailed results will be given in the final paper.

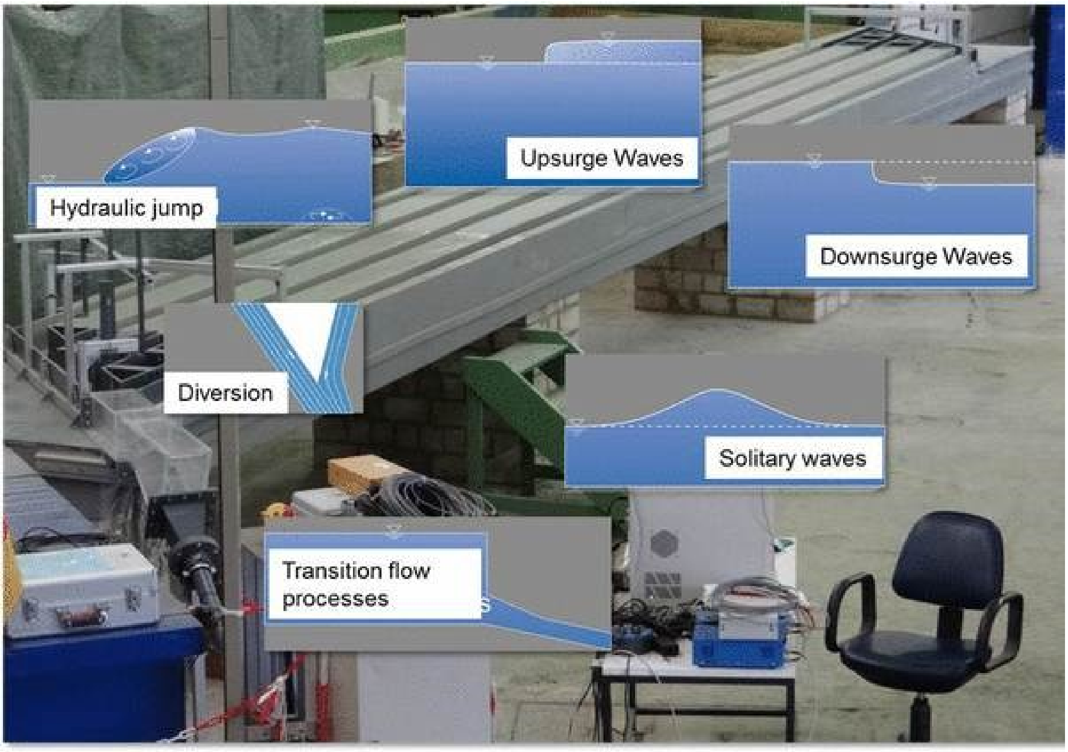

Figure 2. Local and global flow processes in an underground pump storage reservoir (UPSR).

An hybrid modelling approach was found to be the most suitable way to investigate the aforementioned processes due to complexity of the turbulent and two phase processes on hand and the need to investigate different geometries on the other side.

References
Pummer, Elena; Lorke, Stefanie; Nelihsen, Winand; Schüttrumpf, Holger: Experimental and numerical investi-gations regarding the hydraulic performance of underground pump storage reservoirs. - In: The wise find pleasure in water: Meandering through water science and engineering: Proceedings of the 35th IAHR World Congress: September 8-13, 2013, Chengdu, China / Organized by China Institute of Water Resources and Hydropower Research. - [Chengdu, China] : [IAHR], 2013, S./Art.: 1-7.

The Multiphase Capabilities of the CFD Toolbox OpenFOAM for Hydraulic Engineering Applications

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Keywords: CFD, OpenFOAM®, interFoam, Multiphase, Hydraulic engineering

The widely known CFD-toolbox OpenFOAM is a well-designed C++ library that allows the numerical simulation of various engineering applications. Through its object-orientated structure and the open code concept it is very flexible and can be adjusted to very specific problems. However, only little documentation and the lack of a graphical user interface make the usage in the beginning more difficult than most commercial software. However, once the concept of setting up cases is understood, the handling of the OpenFOAM is not more costly than other CFD tools. This contribution is aiming to show the functionalities and capabilities of the toolbox for hydraulic engineering applications, including a short description of the meshing process, the numerics of the solver as well as a short overview of the applicability and the limitations of the mostly used multiphase solver interFoam.

Due to its generic formulation, the complete toolbox is designed for enabling simulations with arbitrarily structured meshes. This feature is especially of great advantage, when complex structures are to be investigated. With the included meshing tool snappyHexMesh, large unstructured meshes can be created. Since some parts of the numerical solution procedure are very sensitive for bad cells in the mesh, effort must be put into the meshing process. Therefore, some background knowledge about the general concept of the solution procedure is of advantage when pre-processing the simulations.

In research the tool is already widely applied, but with a bit of training the tool can also be used for daily business in hydraulic engineering. In particular, OpenFOAM offers several solvers that can be used for the simulation of flow inside or close to hydraulic structures. Considering applications where the free surface is of relevance, the interFoam solver is suitable. The interFoam solver is capable of modelling the flow of two immiscible fluids inside a predefined three-dimensional region. For capturing the interface between the two fluids, the Volume-of-Fluid approach is applied, where in addition to the mass- and momentum conservation equation the volume fraction equation is solved. This additional equation accounts for the transport of the volume fraction with a simple advection equation. Since the numerical solution of an advection equation always tends to introduce numerical diffusion, a special numerical technique has to be adopted to counteract this effect. In the interFoam solver an artificial compression term is introduced to avoid smearing of the free-surface between the phases. The used approach is suitable for hydraulic engineering applications where a long stretched interface is of interest. Small bubbles or droplets can only be modelled, when the grid size is much smaller than the dispersed particles.

For simplicity the interFoam solver assumes, that the two phases are incompressible. This assumption leads to the fact, that special solution algorithms for the pressure-velocity coupling must be applied. Due to the code structure it is difficult to understand the complete solution procedure of the solver at first sight. In this contribution the solution procedure will be described and analysed.

For taking into account the occurring turbulence within the flow, several turbulence models are available which must be chosen according to the investigated problem.

The code structure of OpenFOAM in combination with the embedded Message-pasing-Interface allows massive parallel computing, where the parallelization is theoretically only limited by the available resources not by the number of licenses available. In reality however, it must be considered, that the scalability of the simulations is not only dependent on the number of used computation units but is also dependent on the time for the information exchange between the units, e. g. at some point the communication between the units exceeds the actual computation time. An optimal compromise between computation time and communication time must be found by extensive testing for each hardware cluster. Rough guiding figures are given in this contribution.

Most information described in the paper stem from years of experience with OpenFOAM at the Federal waterways Engineering and Research Institute, where the tool is used to investigate complex questions concerning waterway structures like locks, weirs, fish passages or the interaction between ship and waterway. The experience shows, that the above/here described interFoam solver is a suitable tool for the investigation of waterlevels, velocities, pressures etc. The quality of the results is mainly dependent on the grid quality and the chosen discretization schemes. Unlike most commercial CFD software OpenFoam is very sensitive concerning the grid quality since it hardly contains numerical tricks for stabilizing the simulation. Therefore, a bad quality mesh can lead to an unintended abortion of the simulation. Schemes, that are more stable can overcome this problem, but mostly result in an inaccurate solution. One of the most difficult tasks for the engineer is therefore to find an suitable compromise between a fast and stable calculation and accurate results.
As usual the definition of the domain extent, the definition of the boundary condition as well as the adjustment of all other settings is crucial for getting plausible results. In opposite to commercial tools, the user must get used to handling with text files instead of a graphical user interface. However, once the concept of setting up cases is understood, the handling of the OpenFOAM is not more costly than other CFD tools and the open code concept even allows the introduction of new boundary conditions as well as the adaption of the code.

Analysis of Wake Effects Induced by Wind Assisted Propulsion Systems on Vessels

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Keywords: Flettner rotor, Magnus effect, Wake effect, CFD, OpenFOAM®

The open source CFD code OpenFOAM has been adapted accurately to a wide range of fluid dynamic problems regarding waterways and ships. In the area of ship propulsion "green shipping" is a significant keyword. The "Windhybridcoaster" project provides the opportunity for testing the single phase solvers of OpenFOAM regarding maritime modeling strategies.

Until now, the modeling of rotating components on the basis of moving meshes is not really established in the engineering practice. But the electrically driven Flettner Rotor is an ideal case due to the fact that the moving structure is axially symmetric. A tangential velocity boundary condition is located at the cylinder surface and the grid is adapted with a high-resolution boundary layer.

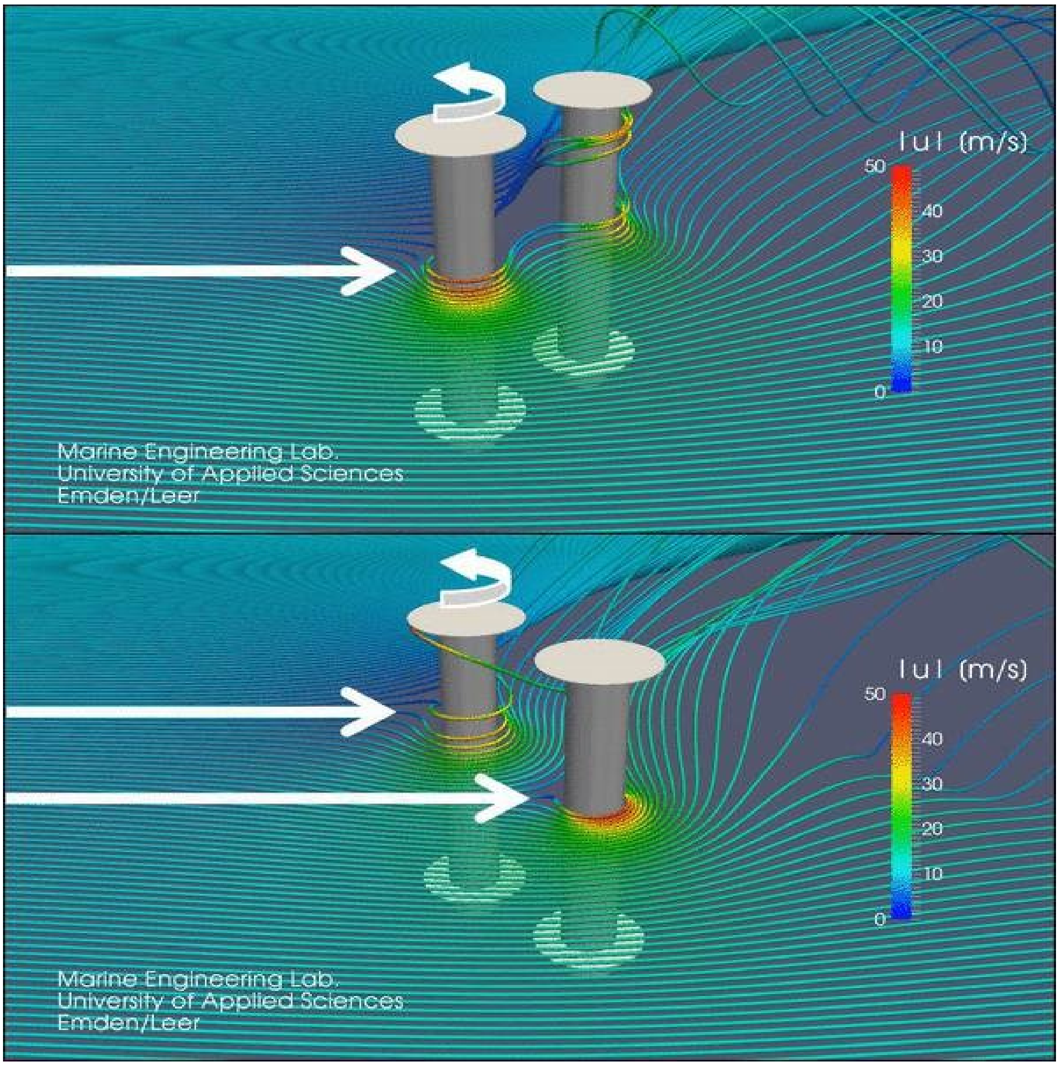

Figure 1. A favourable location of the downwind rotor is influencing the degree of efficiency.

A typical benchmark in the field of flettner rotors is the enhancement of the Magnus effect caused by end plates on top of the rotating cylinders. OpenFOAM provides the expected results. The end plates have the same effect as the typical winglets at the tip of wings. In case of end plates an increasing speed ratio (quotient of the tangential velocity over the wind speed) results in a significantly heightened lift coefficient. Extremely increasing values as determined in early experimental set-ups are not reproduced by the numerical model. It is assumed that short measured experimental facilities force the air into a Magnus effect. The necessary spatial extension of the modeling volume for the prevention of a high level Magnus effect caused by boundary effects was investigated.

The steady state solver simpleFOAM and the transient solver pimpleFOAM are in the scope of interest of this investigation. The Magnus effect on a cylinder converges to a quasi steady state. The impact of the choice of a steady state or a transient numerical solver will be discussed.

Aerodynamic interaction between two or more rotors has a significant influence on the sail performance. The wake effect close to typical onshore wind energy converters is still a controversial issue. This problem is resolved with increasing distances of the converters within the onshore wind farms.

The strongly restricted deck area of vessels impedes arbitrary rotor interspaces. Different rotor geometries, rotor locations and vessel courses result in a multitude of test cases. The capability of OpenFOAM in handling several hundreds of these test cases will be shown. The numerical investigation enables the determination of diagrams to forecast the degree of efficiency of different rotor combinations on the deck of a vessel. For the very first time the wake effect close to two Flettner rotors can be quantified systematically. The combination of the vessel‘s course relative to the wind direction and the sense of rotation is decisive for the degree of efficiency of the lee side rotor. In a constellation of two Flettner rotors the upwind rotor itself provides a lift coefficient close to the value of one single rotor on a vessel. The rotation of the upwind rotor is deflecting its wake into the incoming flow of the downwind rotor (see Figure 1 above). The process results in a significantly decreasing lift coefficient of the downwind rotor. A favourable location of the downwind rotor outside of the deflected wake is reducing this effect remarkably (see Figure 1 below).

The Validation of the Open Source CFD Toolbox OpenFOAM Regarding Wave Induced Forces on Offshore Tripod Support Structures

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Keywords: Wave loading, Offshore, Foundation, Tripod, OpenFOAM®

Germany is in the process of changing its energy sector completely to renewable technologies. A number of full load hours within the range of 4500 hours and a number of operating hours exceeding 8000 hours attaches prime importance to the offshore windenergy. Hydraulic engineering activities are focused on the grounding structures of the offshore windenergy converters. The so-called Tripod was already widely used in the oil & gas industry, where experiences could be mobilised for its new purpose as a suitable wind turbine support structure for water depths of more than 25m. Maximum wave heights of approximately 18 m in the German Bight result in wave breaking at the surface of the structure and a highly complex three dimensional flow around the structure. This paper deals with the capability of the 3D Navier-Stokes solver OpenFOAM in the field of offshore wind energy support structures.
In a first step simple methods for the wave generation and wave damping based on OpenFOAM standard tools were analyzed. Several inlet boundary conditions for the velocity field are implemented in OpenFOAM by default. These boundary conditions were used for a simple wave generation based on time series of the volume flux. A so-called numerical beach realizes wave damping at the opposite boundary by means of a grid stretched in x-direction. The procedure was compared with the OpenFOAM toolbox waves2Foam introduced by Jacobsen, Fuhrman and Fredsoe [1]. The library provides a large number of wave theories and algorithms for handling waves associated with the interFOAM solver.

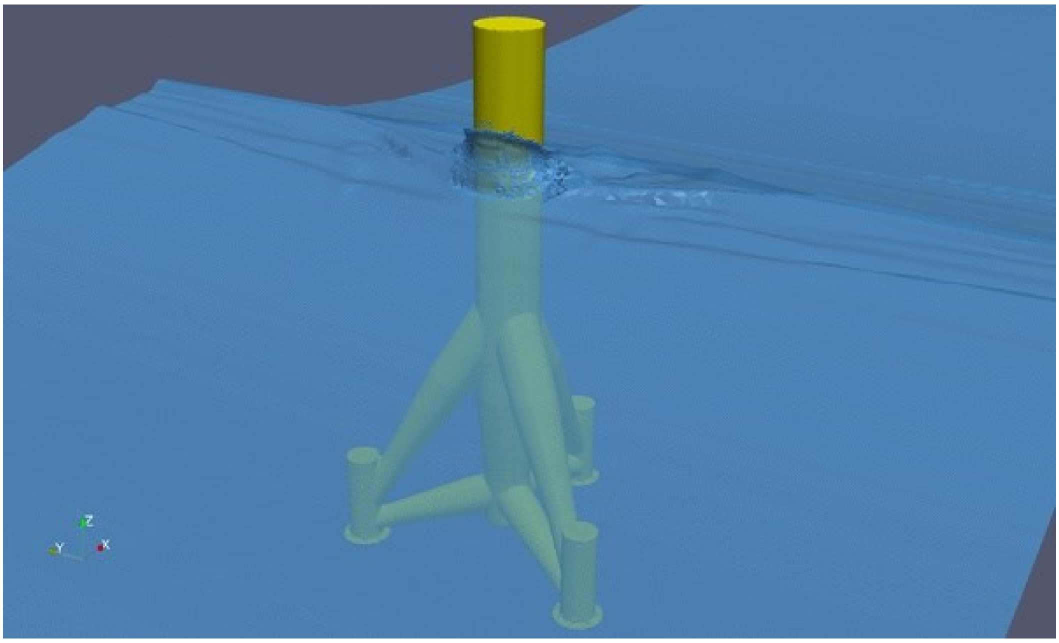

Figure 1. Vertical wave run-up in front of a tripod support structure.

During the validation process the wave load on structures was in the focus of interest. For verification purposes, tests with a cylinder in a rectangular channel were simulated. The numerical results were compared to rough manual calculations based on the Morison equation and to the results of the

software WaveLoads 2.0. This tool was introduced by Nguyen and Mittendorf [2] at Hanover University. Based on typical parameters describing regular waves or sea state the tool calculates wave loading on hydrodynamically transparent combinations of inclined tubes on the basis of the Morison equation.
After a successful validation on the basis of a cylinder in a rectangular channel, simulations for a realistic tripod geometry were performed and a broad range of modeling parameters requiring special supervision was discussed. Wave breaking and run-up (Figure 1) in front of an original tripod geometry was investigated and the capability of the VOF-method regarding these processes was evaluated.

References
[1] Jacobsen, N. G., Fuhrman, D. R., Fredsoe, J.: A Wave Generation Toolbox for the Open-Source CFD Library OpenFoam. pp 1073-1088, Int. J. Numerl. Meth. Fluids, No. 9, Vol. 70, 2012, DOI 10.1002/fld.2726.
[2] Mittendorf, K., Nguyen, B.: WaveLoads - A computer program to calculate wave loading on vertical and inclined tubes. User Manual, Institute of Fluid Mechanics and Environmental Physics in Civil Engineering, Hanover University, 2002.

Mini-Symposium: Impacts of Climate Change

Sea Level Rise Impacts and Adaptation Measures for Sandakan, Sabah

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Keywords: Malaysia, Impact, Inundation, Adaptation, Wave, Current

Sea level rise can give various impacts such as inundation in the low-lying areas, increase the erosion and extreme events such as storm surge, wave overtopping, salt intrusion and damage to existing coastal infrastructure, hence affects the socio-economy and the livelihood of the coastal communities. The projected sea level rise along the Sandakan coast for the year 2020, 2040 and 2060 is 0.1 m, 0.25 m and 0.5 m, respectively. This study was carried out to assess the impacts of sea level rise to Sandakan coast for 2020, 2040 and 2060; and to recommend some relevant adaptation measures to reduce the impact. Hydrodynamic models show no significant change in Sandakan Town with simulations of 2020 and 2040 projected SLR when compared to the existing condition due to its high level platform. However, model simulations for 2060 show that the wave heights may be increased by 0.18 m compared to the existing 2.6 m, although the wave heights in Teluk Sandakan will not change much. The maximum current velocities will be increased by 0.15 m/s in 2060, compared to the existing condition of 0.3 - 0.5 m/s. Overall, more impacts of sea level rise can be observed at Pulau Duyong due to its low-lying area. There will be a reduction in land area; about 958 hectares out of the existing 1,800 hectares of mangrove forests and coastal vegetations will be lost due to inundation and erosion, generated by the 0.5 m projected sea level rise in 2060. Construction of railings, low walls and rock bunds are recommended as an adaptation measures to ensure the safety of the people living along the Sandakan coast. There is also a need to raise the bund and platform levels for jetties and slipways at the Marine Police Complex to avoid inundation. The total cost for all the adaptation measures is estimated to be about RM18.25 Million.

Influence of Internal Climate Variability on Estuarine Sediment Dynamics

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Keywords: Internal climate variability; Freshwater discharge; Sediment transport; Estuary

Climate variability influences the sediment yield in German North Sea estuaries such as the Elbe river. The maintenance of the navigable water depths in the estuaries is strongly influenced by fresh water discharge and requires dredging and disposal of large amounts of sediments. For instance, a persistent low fresh water discharge causes increased sedimentation rates due to the intensification of tidal pumping and therefore larger amounts of dredged material. Climate variability is expected to influence the hydrology and sediment yield.

A clear task for the further improvement of sediment and dredged material management is to evaluate the basic influences between the hydrological regime and a low fresh water discharge. Especially long-lasting (several weeks) low discharge values highly affect the transport of suspended sediment stream upwards the estuary.

The lowest runoff in Europe usually occur during late summer and causes then in the tidal Elbe river a maximum sedimentation. During spring, the mean runoff reaches the maximum in the annual cycle and enhances the natural output of fine sediment from the estuary towards the German Bight, thus it supports the dredging and sediment management in safeguarding the required output rate.

Therefore, we focus on two questions: (1) How often does occur a persistent low discharge conditions and in which season? (2) How are these persistent runoff conditions related to internal modes of climate variability?

For this study we investigate the daily Elbe discharge at the station Neu-Darchau for the years 1902-2013. We perform a hierarchical cluster analyses to group the discharge of the single water years into typical discharge modes. These clusters show distinct interannual to multidecadal variability. Subsequently, we analyse these clusters to evaluate the relationship with synoptic weather patterns to foster a climate dynamical interpretation.

In this context we analyse the correspondence of our clusters to large-scale climatic conditions such as sea surface temperatures, sea ice as well as the general atmospheric circulation patterns based on Hadley Centre's sea level pressure (HadSLP2) and sea ice datasets (HadISST1), which cover the period of our fresh water discharge time series. The influence of these parameters on runoff of European rivers have already been demonstrated by several studies for interannual to multidecadal changes (Ionita et al. 2011 and 2008, Rimbu et al. 2005) as well as for extreme events such as flash floods (Petrow and Merz, 2009).

Climate dynamical interpretations are especially important for an enhanced understanding of estuarine sediment dynamics. This accounts for past, present and future situations, when it is suggested that global warming will especially effect high northern latitude winter temperatures. This would lead to a northerly shift if the sea ice edge and thus subsequently to an increase of blocking highs over Siberia and Scandinavia which transports cold and dry air masses towards Europe (Deser et al., 2010; Screen et al., 2010). This scenario would lead to anomalous low Elbe river discharge and thus to an increase of upstream transported fine sediment in the Elbe estuary due to an increased effect of tidal pumping. This mechanism is also consistent with the results from the KLIWAS ensemble project (Imbery et al., 2013) which demonstrates a decrease of winter discharge during winter (Nilson et al., 2014).

In addition it is also the summerly fresh water discharge known to be effected by large scale climatic patterns. Winter sea surface temperatures have a strong impact in determining the control of hydrological droughts e.g. the variability of moisture conditions over Europe in the upcoming summer (Ionita et al., 2012). It has, however, to be emphasized that the influence of large-scale climate patterns on hydrological regimes and thus estuarine sediment dynamics during summer are much more difficult to detect in comparison to winter.

References

Allan, R.J. and Ansell, T.J.: A new globally complete monthly historical mean sea level pressure data set (HadSLP2): 1850-2004, Journal of Climate 19.22 (2006).
Deser, C., Tomas, R., Alexander, M. & Lawrence, D. The seasonal atmospheric response to projected Arctic sea ice loss in the late twenty-first century. J. Clim. 23, 333–351 (2010).
Imbery, F., et al.: Processing and analysing an ensemble of climate projections for the joint research project KLIWAS, Adv. Sci. Res., 10, 91-98, doi:10.5194/asr-10-91-2013 (2013).
Ionita, M. et al.: Prediction of Spring Elbe Discharge Based on Stable Teleconnections with Winter Global Temperature and Precipitation." Journal of Climate 21.23 (2008).
Ionita, M. et al.: Decadal variability of the Elbe River streamflow. International Journal of Climatology 31.1 (2011).
Ionita, Monica, et al.: Interannual to decadal summer drought variability over Europe and its relationship to global sea surface temperature. Climate dynamics 38.1-2 (2012): 363-377.
Nilson, E., et al.: Auswirkungen des Klimawandels auf das Abflussgeschehen und die Binnenschifffahrt in Deutschland. KLIWAS-Schriftenreihe 02/2014: DOI: 10.5675/Kliwas_43/2014_4.01 (2014).
Petrow, T., & Merz, B.: Trends in flood magnitude, frequency and seasonality in Germany in the period 1951–2002. Journal of Hydrology, 371(1), 129-141 (2009).
Rayner, N.A., et al.: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century J. Geophys. Res.Vol. 108, No. D14, 4407 10.1029/2002JD00267 (2003).
Rimbu, Norel, et al. Seasonal prediction of Danube flow variability based on stable teleconnection with sea surface temperature. Geophysical research letters 32.21 (2005).
Screen, J. and Simmonds, I.: The central role of diminishing sea ice in recent Arctic temperature amplification. Nature 464.7293, 1334-1337 (2010).

Sensitivity of Sediment Contamination in the Estuaries Elbe, Weser and Ems to Climate Change

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Keywords: Climate change, North Sea estuaries, Sediment transport, Contaminants

As a result of the projected climate-induced changes of temperature and precipitation (IPCC, 2007), an increase is to be expected of the frequency and intensity of extreme events such as floods, storm surges or of extended periods of low river discharge. These, in turn, may affect the sediments and their quality in the North Sea estuaries of the rivers Elbe, Weser and Ems. In addition, a sea level rise is predicted to occur along with global warming. Due to the increases in intensity and occurrence of floodflows, additional inputs of contaminated sediments from the inland reaches of the rivers to the estuaries are expected. Vice versa, in case of more frequent low-flow situations, or with rising sea levels, rather uncontaminated sediments of marine origin will migrate upstream into the estuaries and reduce the contaminant concentrations in particulate matter there, i.e. in sediments depositing on the riverbeds and in suspended particulate matter (SPM).

The contamination of particulate matter plays an important role for the ecological quality of water bodies and has accordingly to be taken into account also in the sediment management of navigable waters. The potential influences of climate change on the levels of contamination and the transport of contaminated particulate matter in the North Sea estuaries of the rivers Elbe, Weser, and Ems were investigated within the scope of the project “Impacts of climate change on the transport behaviour of contaminated sediments and the maintenance of coastal waterways”. This project was part of the national research programme KLIWAS “Impacts of climate change on waterways and navigation” aiming at identifying the need of adapted dredged-material management practices in coastal waterways.

The three estuaries under consideration have some characteristics in common: Regarding particle-bound contaminants that have their main sources along the inland courses of the rivers or in the upper parts of the estuaries, monitoring revealed a decrease of concentrations from the inner estuaries towards the river mouths (Kowalewska et al., 2011). This decrease is attributed to the fact that towards the sea the highly contaminated fluvial sediments carried by the rivers into the estuaries are becoming more and more mixed with growing volumes of sediments of marine origin that are only slightly contaminated. Particularly in the mixing zone of marine and fluvial particulate matter, considerable intra-year variations of the concentrations of many contaminants were observed. With increasing river-discharge, the concentrations of contaminants increase too, and in times of low freshwater discharges contaminant concentrations are low as well.

Despite these few similar characteristics, the estuaries under consideration also have some different features which may lead to differences in their sensitivity to climate change. The main differences are the lengths of the estuaries, the river-discharges, the reach of upstream transport of marine, rather uncontaminated sediments, the inputs of fluvial SPM into the estuaries via the tidal weirs, and the contaminant patterns and concentrations. In the Ems estuary, for example, sediments with low and uniform contaminant concentrations were detected in the whole estuary, i.e. marine sediments dominate over freshwater sediments up to the tidal weir at Herbrum. In contrast, the marine influence in the Elbe estuary could be observed up to Bunthaus (Elbe-km 609, located just 17 % of the estuary length away from the tidal limit [at 0 %]) and in the Weser estuary up to the sampling site Farge (Weser-km 26.3, at 36 % of the estuary length).

For analysing the impact of climate-change induced increased inputs of freshwater SPM on the contamination of particulate matter in the three estuaries, the ratio between marine and fluvial sediments at a given location x in the estuary is essential. For these calculations, it was assumed that contaminant sources within the estuaries are negligible, and a mixing model was applied.

The percentages of marine and fluvial material at a location x in the estuary can be derived from concentrations known from sediment monitoring. For the Elbe estuary, statistical analyses provided robust mixing ratios at several monitoring sites.
In the Elbe estuary, the analysis used projections of SPM loads at the gauging station Hitzacker (Elbe-km 522.9) for the near future (2021-2050) and for the far future (2071-2100). These projections were provided by the KLIWAS project “Climate Projections for Sediment Budgets and Risks due to Cohesive Sediments“ (Hillebrand, 2013). They are based on the emission scenario A1B of the IPCC report 2007 (IPCC, 2007) and on projections of river discharges provided within the KLIWAS model chains (Lingemann et al., 2012). Corresponding projections on the rivers Ems and Weser are not available, so that the approach used on the Elbe was transferred to the estuaries of these rivers.
With increasing sediment loads that enter the estuaries, the contaminant concentrations in the estuaries are increasing, too. The strongest effects were estimated for the Elbe estuary: the percentages of changes in contaminant concentrations in particulate matter ranged between -10 % and +15 % in the near future and from -25 % to +35 % in the far future. In the Elbe estuary, even the highest concentrations projected exceed the natural variability only slightly, and the projected changes in the sediment contamination in the estuaries of the Weser and Ems remain within the range of natural variability. In the case of rising sea levels and the resulting enhancement of the upstream transport of rather uncontaminated marine sediments, the contaminant concentrations will decrease in the Elbe and Weser estuaries, while no relevant change is expected in the contamination levels in the Ems estuary.
In summary, the projected climate-induced changes in estuarine contaminant concentrations are near or within the range of natural variability. It was concluded that climate change has a minor impact on sediment contamination in the estuaries in comparison with anthropogenic activities like, for example construction works, so that adaptions of dredged-material management practices in coastal waterways to climate-change impacts on sediment contamination need not be recommended.

References

Hillebrand, G. (2013): Climate Projections for Sediment Budgets and Risks due to Cohesive Sediments, private communication.
IPCC (2007): Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.
Kowalewska G, Belzunce-Segarra M J, Schubert B, Heininger P, Heise S (2011): The Role of Sediments in Coastal Monitoring. In: Quevauviller, P, Roose P, Verreet G (eds.), Chemical Marine Monitoring – Policy Framework and Analytical Trends, Chapter 12, S 377-395, John Wiley & Sons, Ltd.
Lingemann, I., Nilson, E., Carambia, M., Krahe, P. (2012): Änderungen des Wasserhaushalts der Elbe im 21. Jahrhundert. In: Bundesanstalt für Gewässerkunde (Hrsg.): Die Zukunft des Wasserhaushaltes im Elbeeinzugsgebiet. Kolloquium am 29.-30. November 2012 in Dresden;
Veranstaltungen 6/2013, Koblenz, Mai 2013, 236 S., deutsch/tschechisch;
DOI: 10.5675/BfG_Veranst_2013.6; URL: http://doi.bafg.de/BfG/2013/Veranst6_2013.pdf

Assessment of Coastal Vulnerability for Present and Future Climate Conditions in Coastal Areas of the Aegean Sea

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Keywords: Vulnerability, Flooding, Coastal, Climate change

The impact of storms in coastal areas induces morphodynamic responses such as beach and dune erosion, overwash and inundation on low-lying areas. Climate change influences the coastal zones and amplifies the vulnerability to such phenomena. Thus, we need to predict how and in which manner this change will affect them.

Vulnerability to flooding for two coastal areas of the Aegean Sea (Chania at Northern Crete Island and Thrace at Northern Greece) is assessed taking into account climate change effects. Two approaches are applied for the present (1951-1999) and future conditions (2000-2049, 2050-2099).

A Flood Vulnerability Index (FVI) is estimated based on run-up and storm surge computations for both present and future climate. Run-up is calculated from an empirical formula (Stockdon et al. 2006), based on area morphology and wave climate, derived from a Digital Elevation Model of the areas of study and a third-generation spectral wave model SWAN (Booij et al. 1999), respectively. For the complete description of the morphology of the areas, an adequate number of cross-shore profiles is created at each site. SWAN model is forced by wind data from the ICTP RegCM3 model (Dickinson et al. 1989), according to emission scenario A1B SRES of IPCC. On the other hand, storm surge is calculated from the MeCSM hydrodynamic model (Krestenitis et al., 2011) forced by wind and pressure data from the ICTP RegCM3 model for the same emission scenario.

The first approach, proposed by Mendoza and Jimenez (2009), uses cluster analysis to classify all storms and then evaluates total water level ($Ru + \xi$) for each class in order to estimate the corresponding FVI. The second one, proposed by Bosom and Jimenez (2011), is a probabilistic approach which evaluates Ru for the maximum annual storm, uses extreme value analysis for extracting the total water level which corresponds to return periods of 50, 100 and 500 years and then estimates FVI for each area.

The results highlight that the area of Chania is very prone to flooding. Both methodologies indicate very high vulnerability for the majority of the selected beach profiles describing the area. For the area of Thrace the first methodology indicates that 45% of the cross-shore profiles for present and 55% for future wave climate show very high vulnerability to flooding. The second one implies that for extreme waves and storm surge with a return period of 50 years or more, the area is prone to flooding for both the present and future conditions.

References

Booij, N., Ris, R. C., and L.H. Holthuijsen. (1999). A Third-Generation Wave Model for Coastal Regions. 1. Model Description and Validation, J. Geophys. Res., 104, 7649-7666.

Bosom E. and Jiménez J. A. (2011) Probabilistic coastal vulnerability assessment to storms at regional scale – application to Catalan beaches (NW Mediterranean). Nat. Hazards Earth Syst. Sci., 11, 475-484, 2011.

Dickinson R., Errico R., Giorgi F. and Bates G. (1989). A Regional Climate Model for the western United States. Climate Change 15: 383-422.

Krestenitis YN, Androulidakis YS, Kontos YN, Georgakopoulos G (2011) Coastal inundation in the north-eastern Mediterra-nean coastal zone due to storm surge events Journal of Coastal Conservation 15:353–368.

Mendoza, E.T. and Jiménez, J.A (2009). Regional geomorphic vulnerability analysis to storms for Catalan beaches. P. I. Civil Eng-Mar. En., 162, 3, 127–135.

Stockdon, H. F., Holman, R.A., Howd, P.A., and Sallenger, A.H.,(2006) Empirical parameterization of setup, swash, and run-up, Coastal Engineering 53, 573-588.

Ensemble Stream Flow Projections for Waterways in Central Europe – Current Status and Further Steps

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Keywords: Ensemble discharge waterway, Europe, Rhine, Danube, Elbe

During the recent years, major concerted studies have revealed a wealth of information on future regional climate change (e.g. project EU-ENSEMBLES, Van der Linden & Mitchell, 2009) and related hydrological impacts in Central Europe (e.g. KLIWAS, Nilson et al., 2014). Constrained by greenhouse gas emission scenarios, the results show major changes but also major uncertainties. These uncertainties result in a span of possible future conditions rather than single values. This is sometimes a challenge for stakeholders who have to decide on specific adaptation needs.

This contribution takes examples from the KLIWAS research programme to show how an ensemble of stream flow projections has been generated for the waterways Rhine (cf. Figure 1), Elbe, and Danube. Furthermore, it explains how a set of scenarios has been derived which now serve as a basis to develop adaptation strategies (e.g. ICPR, 2011) and to support decision processes, e.g. in the inland navigation sector. Finally, ongoing work and knowledge gaps are presented for selected case studies.

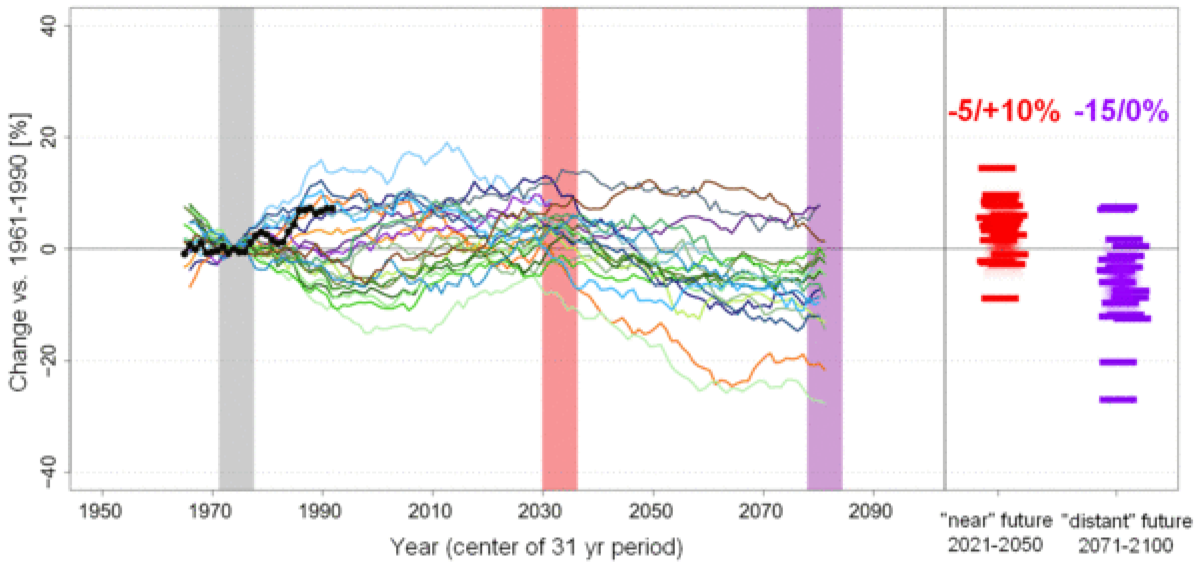

Figure 1. Low flow changes in the Middle Rhine since 1961-1990.

Lowest average flow over 7 days per water balance year (Apr-Mar) at gauging station Kaub. Coloured lines represent 31 yr running means based on an ensemble of 21 discharge projections (SRES A1B). The black line is based on observations. Red and purple bars represent two evaluation time spans (2021-2050 and 2071-2100), the grey bay marks the reference period (1961-1990). Source: Nilson et al. (2014).

References

ICPR (2011): Study of Scenarios for the Discharge Regime of the Rhine. State: April 2011. ICPR report 174. http://www.iksr.org/fileadmin/user_upload/Dokumente_en/Reports/188_e.pdf

Nilson, E., Krahe, P., Lingemann, I., Horsten, T., Klein, B., Carambia, M., Larina, M. (2014, in prep.): Auswirkungen des Klimawandels auf das Abflussgeschehen und die Binnenschifffahrt in Deutschland. KLIWAS-Schriftenreihe 02/2014: DOI: 10.5675/Kliwas_43/2014_4.01.

Van der Linden, P. & Mitchell, J.F.B (2009). ENSEMBLES - Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project. Met Office Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK. 160 S.
http://ensembles-eu.metoffice.com /docs/Ensembles_final_report_Nov09.pdf

Influence of Sea Level Rise on Tidal Hydrodynamics in a Fluvial Estuary, a Marine Estuary and a Mixed Estuary: Comparison of Past, Present, and Future Conditions

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Keywords: Sea level rise, Tidal hydrodynamics, Morphological changes, Numerical model

Sea level rise (SLR) threatens coastal environments with loss of land, inundation of coastal wetlands, and increased flooding during storm events. Planning for changes under SLR requires crucial information for managers to make informed decisions for human and natural communities. Evaluating changes in tidal hydrodynamics under future scenarios is a key aspect for understanding the effects of SLR on coastal systems; tidal hydrodynamics influence inundation, circulation patterns, sediment transport processes, erosion of beach and estuarine shorelines and productivity of marshes and other biological species.

This interdisciplinary study evaluates the dynamic effects of SLR and morphologic scenarios on tidal hydrodynamics along the northern Gulf of Mexico coast and within three diverse National Estuarine Research Reserve (NERR) systems, namely Apalachicola, FL, Grand Bay, MS, and Weeks Bay, AL. Each NERR has various hydrodynamic influences and is compared and contrasted from historical, present, and future conditions. This research seeks to answer the following: will SLR amplify the past effects in each estuary, or will it initiate new changes in the tidal hydrodynamics? Is one estuary more vulnerable to SLR than the others; if so what factors influence the vulnerability of an estuary to SLR (e.g., morphology, tidal range, erosion, exposure, sedimentation, circulation)?

Apalachicola is a fluvial estuary that receives freshwater discharge from the Apalachicola River through a wide delta system and is sheltered from the Gulf of Mexico with a series of barrier islands. Grand Bay is a marine dominant environment located within the Mississippi Sound. The estuary is one of the few remaining extensive coastal marsh environments in Mississippi and is undergoing rapid erosion due to the lack of a sediment source and the migration of the offshore barrier islands which allows stronger wave and tidal forces from the Gulf of Mexico to attack the marsh shorelines. Weeks Bay is a mixed estuary system that is located within the Mobile Bay estuary and is influenced with tides as well as freshwater discharge from the Fish and Magnolia Rivers. Each NERR provides habitats and nurseries for many ecologically and economically significant species. Due to the variable hydrodynamic influences, it is likely that each basin will have different dynamic responses to SLR, with various effects to the coastal wetlands and organisms within them.

A large-scale hydrodynamic model forced with astronomic tides and river inflow is used to simulate past (circa 1848, 1917, and 1960), present (circa 2005), and future (circa 2050 and 2100) conditions. To observe the response of the coastal system under past conditions, each scenario is simulated with unique sea levels, morphology and shorelines that represent the conditions at those times. Past sea levels are determined based on linear mean sea level trends at nearby tidal gauges, and the current digital elevation model (DEM) is updated to represent past landscapes by removing features such as roadway beds and dredged shipping channels, altering depths using historic bathymetric, recreating shorelines using historic shoreline data, and lowering marsh elevations using historic marsh accretion rates. Future sea levels are determined using SLR scenarios from Parris et al. (2012), and the DEM is updated from present conditions to reflect projected marsh elevations using a hydro-marsh model, as well as projected shorelines through use of historic shoreline change rates and a unique local data set. Past, present and future simulations illustrate the hydrodynamic response of the system to a changing landscape and permit examination of changes in variables such as tidal constituents, tidal range, mean high water, mean low water, circulation patterns and inundation areas. This provides a better understanding of each estuary's current state and gives insight to how SLR and coastal landscape changes may affect future tidal hydrodynamics, shoreline erosion and marsh productivity.

Results from this study have synergistic effects with a variety of interdisciplinary coastal studies. Establishing scenarios for future conditions (morphology and sea level) enables storm surge assessments of SLR within the study domain, which can aid in infrastructure planning, flood control, and land acquisition to mitigate storm damage. Results can also be used in biological assessments of SLR including marsh, oyster, and submerged aquatic vegetation (SAV) productivity. In addition, findings can be used in management decision making and adaption planning. Understanding changes to marsh inundation patterns will aid in establishing priority of land acquisition to allow for the migration of marsh habitats given potential impacts of SLR. Identification of vulnerable shorelines will give better insight to shoreline stabilization and nourishment projects to reduce shoreline erosion. Areas vulnerable to increased inundation may be prohibited from future development or modification and designated as protected habitats. Ultimately, this will allow coastal managers and policy makers to make more informed decisions that address specific needs and vulnerabilities of each particular estuary.

References

Parris, A., Bromirski, P., Burkett, V., Cayan, D., Culver, M., Hall, J., Horton, R., Knuuti, K., Moss, R., Obeysekera, J., Sallenger, A. and Weiss, J. (2012). "Global Sea Level Rise Scenarios for the United States National Climate Assessment". NOAA Tech Memo OAR CPO-1: 37.

Storm Surges in German North Sea Estuaries and Climate Change – Investigating Impacts and Developing Adaptation Strategies

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Keywords: Storm surge scenario, Climate change, Sensitivity study, Hydrodynamic numerical model, Wind, Sea-level rise, River run off

As climate will change in this century and beyond, the German Ministry of Transport (BMVI) is interested in the effect of climate change on the waterways in the German North Sea estuaries and therefore initiated the research project KLIWAS (www.kliwas.de). In order to find a strategy for adaption to climate change it is important to understand today's situation and analyse the future situation under the influence of climate change. This concept will be presented by looking into storm surges in the German Bight. A sensitivity study is used to identify areas along the estuaries of Elbe, Jade-Weser and Ems, which are vulnerable in case of storm surges and climate change.

Climate change is expected to cause a global sea-level rise as well as a local sea-level rise in the North Sea, an increase in winter precipitation over Europe that can induce higher river run off in the storm surge season, and an increase in wind speed. These possible consequences of climate change can influence the height of storm surges in the estuaries along the German Bight.

The height of a storm surge in an estuary is determined by the water level at the estuaries boundary to the North Sea, the river run off into the estuary and the wind field over the estuary. A sensitivity study on storm surges is used to investigate scenarios that are highlighting central elements of a possible future.

The scenarios are built based upon high historical storm surges, e.g. the storm surge of January 3rd, 1976 in the Elbe und Weser estuary and the storm surge of November 1st, 2006 in the Ems estuary. The sensitivity study investigates the influence of

- sea-level changes in the North Sea,
- increase of river run off into the estuary and
- increase of the local wind speed over the estuary

on the highest water level along the estuaries during storm surge. The parameters mentioned are varied according to the knowledge about expected changes in a future climate (KLIWAS, 2011).

The sensitivity is studied using hydrodynamical numerical models of the estuaries (UnTRIM, V. Casulli and P. Zanolli (1998) and BAW (2004)). The wind fields are provided by the German Meteorological Agency (DWD).

As a result of the sensitivity study an influence of sea-level rise on high water level, low water level and the highest water level during storm surge can be found. Sea level rise is also influencing high water time. The highest water level during storm surge is reached earlier. Water levels higher as e.g. NHN + 3.00 m are occurring longer. An increase of river run off or wind over the estuary is influencing the same parameters. Areas of the estuaries can be found where water levels are influenced due to a change in the parameters sea-level rise, river run off or local wind. So the local impact of climate change on the water levels along an estuary during climate change can be identified.

In a second step the efficacy of several adaptation measures is investigated. As an alternative to increasing the dike height along the whole estuary, narrowing the mouth of the estuary and storm surge barriers in the mouth of the estuary are investigated. Again a sensitivity study varying the parameters that might change in a future climate, such as sea-level rise or increase of river run off, is used to test the efficacy of the adaptation measures.

It shows, that to narrow the mouth of an estuary can reduce but not compensate the effect of sea-level rise on the highest water levels during storm surge whereas a storm surge barrier protects an estuary against storm surges even in combination with sea-level rise. But both adaptation measures cause restrictions for ships using the waterways in the estuaries.
The results of the sensitivity studies help to identify vulnerabilities of e. g. shore protection in each estuary due to climate change. Several adaptation measures can be developed and tested. The advantages and disadvantages can be investigated. The results give a chance to develop an adaptation route for the waterways in the estuaries of Elbe, Jade - Weser and Ems in order to mitigate problems caused by climate change.

References
BAW (2004). Validation document - Mathematical Model UnTRIM. Bericht der Bundesanstalt für Wasserbau - Dienststelle Hamburg. (see BAWiki: www.baw.de)
Casulli, V. and R.A. Walters (2000). An unstructured three dimensional model based on the shallow water equations. International Journal for Numerical Methods in Fluids, 32: 331-348.
KLIWAS (2011). Conference Proceedings KLIWAS - Impacts of Climate Change on Waterways and Navigation in Germany, Second Status Conference – Federal Ministry of Transport, Building and Urban Development, Berlin – 25 and 26 October 2011. ISBN 978-3-940247-05-6.

Impact of Sea Level Change on Inner Coastal Waters of the Baltic Sea

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Keywords: Sea level rise, Inner coastal waters, Western Baltic, Sea level variability, Climate impact

A rise of the mean sea level (MSL) is expected at the German Baltic Sea Coast due to several processes. One is the well documented lowering of the land surface caused by eustatic effects after the last glaciation. A second one is the effect of climate changes due to anthropogenic influences, e.g. burning of fossil fuel, which leads to a global warming and expansion of the oceanand ice melting .
Change of the MSL influences the volume and area of coastal waters and therefor has practical consequences to the people living at the Baltic Coast and their infrastructure. Adaptation of coastal defence structures and port infrastructure to a higher MSL is necessary. Drainage strategy of low lying areas has to be adapted also. Adaptation strategies have to be optimized to fit into the public budgets.
Within the research project KLIWAS which was initiated by the German Ministry of Transport (BMVI) we concentrated on the influence of a rising MSL to the short term dynamics in inner coastal waters. A modelling framework for the Baltic Coast was developed toward a state, which is capable to deal with processes of the small fjords and inner waters of Schleswig-Holstein and Mecklenburg-West Pomerania. This framework contains several model grids and forcing data sets (Seiß 2012).
The inner coastal waters of the Baltic Sea are shallow and have narrow connection channels towards the Baltic Sea. The range of short term variability of the sea level can be considerably smaller than at the open coastline. This fact is caused by the ratio between the cross sectional area of the mouth and the water volume of the inner waters. The shallow channels have a hydraulic resistance, which depends on the actual water level (cross sectional area).
The inner coastal waters are characterized by a rather long term exchange of properties with the open sea due to their large volume compared with the cross sectional area of the mouth and due to the typically small current velocities. MSL changes will influence the capacity of the waters to dilute salinity and other substances and their exchange with the sea.
A case study of the sensitivity due to rise of MSL was done for the Schlei estuary. Two simulations were done:

- First simulation ACT states on present time MSL
- Second simulation MSL+80 states on = MSL + 0.8 meters

The simulations were done with the Version 2007 model of UnTRIM (Casulli, Lang 2004).
If the range of variability of the water level is compared by difference, there is an increase of the range of variability recognized in the whole area of the Schlei (Fig. 1). The hydraulic resistance of the approach channel drops down with higher MSL. This fact leads to stronger in- and outflow of water during events of high and low water level.

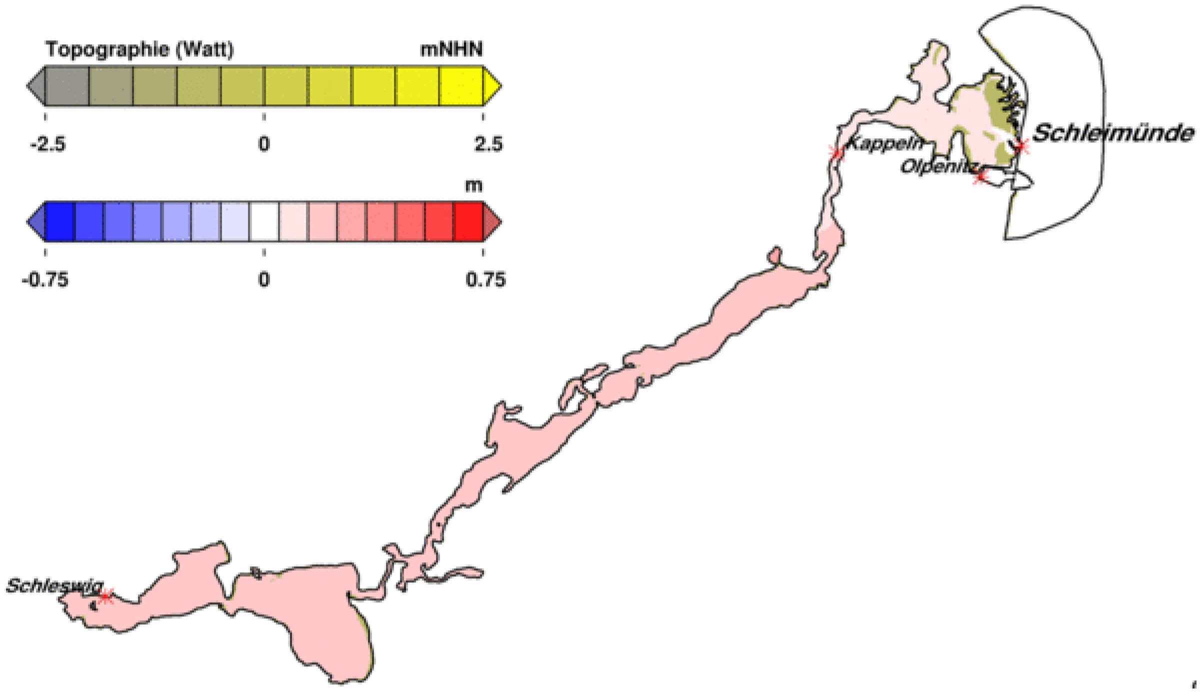

Figure 1. Change of water level variability range inside the Schlei estuary for the scenario "MSL+80".

Tracer simulation for above scenarios have been performed. At one location near Schleswig a tracer source has been installed. The both simulations were started with zero tracer concentration. After the end of simulation the state of tracer concentration of both runs was compared.
The results show a stronger dilution of the tracers due to the higher volume in the MSL+80 scenario.
The study leads to the conclusion, that some adaptation could be necessary to adapt infrastructure not only to the MSL but also to the stronger variability of the water level in the far future.
A positive aspect can be recognized also from the MSL rise here: the stronger dilution of tracers in the MSL+80 scenario mitigates the anthropogenic pollution of the inner waters due to agriculture and waste water.

References

Casulli, Vincenzo; Lang, Günther (2004): Mathematical Model UnTRIM Validation Document. Technical Report. Version June 2004 (1.0). Bundesanstalt für Wasserbau. Hamburg. Available online at http://www.baw.de/downloads/wasserbau/mathematische_verfahren/pdf/Simulationsverfahren_Kueste_validation_document-untrim-2004.pdf.
Seiß, Guntram (2012): Das Ostseemodell der Bundesanstalt für Wasserbau. Technische Dokumentation. Bundesanstalt für Wasserbau Dienststelle Hamburg.

Impact of Sea Level Rise on Estuarine Hydrodynamics

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Keywords: Sea level rise, Inner coastal waters, Western Baltic, Sea level variability, Climate impact

The three estuaries of Elbe, Jade-Weser and Ems, located in the German Bight (North Sea), are used as waterways and present important economic factors for whole regions. Due to future climate change hydrodynamic conditions in the estuaries will change. For the development of adaptation strategies we need to know how climate change will affect the hydrodynamic conditions in the estuaries. Additionally, the estuaries form important ecosystems providing unique conditions for wildlife.

The interaction between marine influences (e.g., tides, influx of salt water) and the inflow of fresh water characterises hydrodynamic conditions in the estuary. The tidal dynamics in the interior of the estuaries play an important role. The shape of the tidal signal entering the estuary at the seaward boundary is almost symmetric. That means flood current duration and ebb current duration are similar. As a result of different nonlinear processes, the tidal curve is continuously deformed while propagating in upstream direction. Typically, flood current duration shortens while ebb current duration extends.

Mean sea level in the North Sea is rising because of climate change. A sea level rise generally increases water levels within the estuary. Due to the greater water depths tidal dynamics change and the deformation of the tidal curve is influenced. The objective of this work is to investigate how sea level rise changes tidal dynamics in the interior of the estuaries.

Using 3D-hydrodynamic numerical models we simulate estuarine hydrodynamic conditions. We carry out different model simulations with and without sea level rise. The analyses show that in most parts of the estuaries high water levels rise more than low water levels. Thus tidal range is larger in the model simulations that include sea level rise. As a result of sea level rise the shape of the tidal curve is changed. In many parts of the estuaries flood current velocities increase more strongly than ebb current velocities. Due to the larger ratio of flood current velocity to ebb current velocity more sediment is transported in upstream direction.

Modelling the Impact of Climate Change on Phytoplankton Dynamics and the Oxygen Budget of the Elbe River and Estuary (Germany)

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Keywords: Water quality modelling, Elbe Estuary, Climate change, Oxygen, Phytoplankton

Our results show that in the Elbe river and estuary system climate change could affect phytoplankton dynamics and the oxygen budget by altering external forces like river discharge and water temperature. A model-based approach is chosen to describe and quantify the impacts by using a 1-d hydraulic model (HYDRAX) coupled with a water quality model (QSim). The model QSim represents the main processes determining the oxygen and nutrient budget as well as the algal and zooplankton growth in an aquatic system. The coupled models are applied to the Elbe river (585 km) and the connected mesotidal estuary (142 km). This approach is realized as part of the research program KLIWAS of the German Ministry of Transport. This multi-model approach has generated a range of feasible climate change scenarios for the whole Elbe river, its estuary, and the coastal regions.
A long-term run (1998-2010) of the water quality of the Elbe river and estuary is used as a reference status. The results demonstrate that the model is able to represent the intra-annual and inter-annual variability of phytoplankton dynamics and the oxygen contents. The simulations proof the major importance of river discharge on both state variables. A decreased river flow increases the water residence time and supports thereby the algal growth. The riverine produced algal biomass leads to a higher input of living algae and related detritus from the river into the estuary. There the living algae die off due to light limitation in the deep section of the Elbe estuary. During their decay the algae respire more oxygen than they produce. In addition oxygen is consumed by heterotrophic bacteria utilizing the degradation products of the algal biomass. Both processes have a significant impact on the oxygen deficit during summer in the Elbe Estuary. An increase in temperature has to be considered in more detail. If the water temperature is lower than the optimum temperature for algal growth, the biological processes are stimulated, i.e. a higher algal biomass is transported into the Elbe estuary causing more severe oxygen deficits. However, if the temperature is higher than the optimum temperature for algal growth, it has a reversed effect.
At least the impact of climate change on the phytoplankton dynamics and the oxygen for near (years 2021-2050) and far future (years 2071-2100) scenarios is estimated by a model-based sensitivity analysis and evaluated by comparison with the reference status.

Mini-Symposium: Data management in hydro-engineering

RichWPS Orchestration Environment for Geo Services

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Keywords: RichWPS, Spatial Data Infrastructure (SDI), Orchestration, Web Service, Web Processing Service (WPS), Workflow

Distributed applications are state of the art in most every discipline even public administrations. In the geo information sector the European Union as a driving force promotes its members to implement the INSPIRE directive to form a spatial data infrastructure (SDI) for environmental reporting and data provision (INSPIRE, 2007). Also national authorities tend to set up SDI for public information like the Marine Data Infrastructure Germany (LeMe, 2010).
SDIs conform to INSPIRE have to apply various standardized services like the ones from Open Geospatial Consortium (OGC). Best known at the moment are download services for feature and coverage data (e.g. WFS, WCS) or view services (WMS). Web processing is rather new to this domain even if the Web Processing Service (WPS) was provided in 2007 by the OGC (OGC, 2007). Compared to local processing it is harder to use. WPS uses a rather generic API consisting of the three operations GetCapabilities, DescribeProcess and Execute allowing experts to access hosted processes.
The SDI is a specialization of the well-known service oriented architecture (SOA). Every SOA uses distributed services. The main idea is to offer functionality once and use it many times. This means existing services have to be included to build up more complex business workflows. Web service orchestration is one major key to success (Josuttis, 2007). Based on this the University of Applied Sciences Osnabrück in corporation with Disy Informationssysteme is developing an orchestration environment for WPS, that helps domain experts without in-depth knowledge in informatics to design new WPS processes by composing existing ones and provide them to others.
The environment that shall be developed is called RichWPS. It is evaluated by two test scenarios provided by our partners Federal Waterways Engineering and Research Institute (BAW) and Schleswig-Holstein's Government-Owned Company for Coastal Protection, National Parks and Ocean Protection (LKN). For this the tasks of the scenarios are divided into smaller reusable units of work that are deployed as separated WPS processes on various servers. Basic WPS processes developed long time ago by the GIS community and can be included as well.
RichWPS can be subdivided into: SemanticProxy, ModelBuilder and RichWPS-Server. The SemanticProxy serves metainformation for available WPS processes and also download services in the accessible network; the ModelBuilder offers a graphical user interface to compose a workflow model in a diagram editor and to forward the model using a textual domain specific language (DSL) to the server side orchestration engine; this is part of the RichWPS-Server and includes an interpreter to run the composed WPS process.
So we use a graphical DSL to allow the user to model the workflow in an easy way and transform this model into a textual DSL that is machine readable. The textual DSL is called RichWPS Orchestration Language (ROLA) and shall be used for persistence, transmission and execution. Both languages take the WPS specific properties into account. The graphical notation is based on a kind of process flow diagram and represents a WPS process as a box with input and output ports that can be interconnected by lines. Arrows mark the flow of control and/or resources. Output ports can be connected to one or more input ports forming a composition, but not necessarily a chain. Inputs of the overall process connect to the inner processes and output ports of the inner processes connect to the output ports of the overall process.
The textual language is created by using Xtext to lay a grammatical solidified foundation. It is not a static description of the model but a sequence of commands as we know it from most every programming language. After a workflow description has been described by the ModelBuilder, it is part of the RichWPS server to receive, store, publish and execute the workflow on demand.

The RichWPS server component is based on the WPS server implementation of 52°North. Looking forward to the upcoming WPS 2.0 specification and the project goals, it is one of the most suitable server implementations to work with. A formerly developed transactional interface by (Schaeffer, 2007), which extends the server to publish and unpublish WPS processes, has been reactivated to work with the latest server version. The WPS-T interface is already prepared to receive and persist ROLA scripts, their ProcessDescription and a set of static data inside a specialization of a so-called “DeploymentProfile”. Deployed WPS processes get registered in a dynamic process repository, are visible inside the GetCapabilities response and can be accessed in an appropriate DescribeProcess request.

A ROLA interpreter, which is currently under development, will be able to execute deployed ROLA scripts using the Execute request of the WPS 1.0.0 interface. Therefore it reads and executes a script by executing the defined processes, performing assignments of input and output variables and if applicable by using sets of static data. A first approach includes the execution of local processes; a second one also includes the ability to orchestrate external WPS processes on any server.

Besides the described transactional interface, the server will be extended with a debug and profiling interface. In this way, the process of creating workflows with the ModelBuilder can be supported with information about the success of a test run and e. g. the consumed time and resources. These functionalities both make use of a Hot Deployment of orchestration models.

As afore-noted two scenarios will be used for testing. Next to the BAW use case, another one was defined by the LKN. The LKN uses a procedure for assessment of the state of the Wadden Sea by comparing seaweed and algal occurrences. This procedure has already been implemented as a WPS process and is ready for execution with the 52°North WPS server. It will be decomposed in several smaller processes and reassembled to a workflow using RichWPS. For this, every single processes is reusable and in the same way. Also existing workflows can be altered by simple substitution of individual processes in the composition. Single workflow steps in this scenario that can be realized as reusable processes are: extraction of relevant data, data integrity checks, selection of relevant topologies, selection of relevant reporting areas, geometrical standard operations, characteristics calculation and report generation.

For more flexibility it is planned to extend the environment with support for conditional executions, new data sources and metadata.

References

[INSPIRE, 2007] Infrastructure for Spatial Information in the European Community: INSPIRE Network Services Architecture, date 17.12.2007. Accessible online: http://inspire.ec.europa.eu/reports/ImplementingRules/network/D3.5_INSPIRE_NS_Architecture_v2.0.pdf, 2007.

[Josuttis, 2007] Josuttis, N.: SOA in Practice, O’Reilly Media, Inc. p. 96 ff., ISBN: 0-596-52955-4, 2007.

[LeMe, 2010] Lehfeld, R.; Melles, J.: MDI-DE – Marine Dateninfrastruktur Deutschland. Abstract, 3. Hamburger Symposium „Geoinformationen für die Küstenzone“. Accessible online: http://www.gis-kueste.de/2010/sbt/abstracts_Lehfeldt_Melles.pdf, 2010.

[OGC, 2007] Open Geospatial Consortium: OpenGIS Web Processing Service Version 1.0.0, Accessible online: http://www.opengeospatial.org/standards/wps, 2007.

[Schäffer, 2007] Schäffer, B.: Integrated Web Geoprocessing Workflow Composition and Deployment. Diploma thesis, Institut für Geoinformatik, Westfälische Wilhelms-Universität Münster, Germany, 2007.

Data Service for German Marine Research Data

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Keywords: Data access, OGC, WFS, MaNIDA

It is the aim of a data infrastructure to give access to data. For most existing data portals the main goal is the ability to search for data and to describe data using the metadata. The COSYNA[1] data portal[2] uses a different approach having the access to data as the main scope. Access means searching for data, describing data, visualizing data and the possibility to download data.
In this talk a next step is presented. The direct and integrated access to data from different providers is introduced. Data are expressed in a 5 dimensional space consisting of the 5 dimensions time, latitude, longitude, water depth and observed properties. The work was done within the Marine Network for Integrated Data Access (MaNIDA). The first outcome is realized as a web service accessing salinity and temperature data of different repositories.
The related databases are COSYNA-DB located at Helmholtz-Zentrum Geesthacht, the data base "Deutsches Ozeanographisches Datenzentrum (DOD) located at BSH in Hamburg and PANGAEA located at AWI/MARUM[3] in Bremen. From the MaNIDA-Portal the databases could be queried using an interface based on an OGC compliant Web Feature Service (WFS) or a database connection. The accessible data covers the basic oceanographic parameters salinity and temperature of water. The parameters are labeled with the Climate and Forecast (CF) standard nomenclature.
The user could filter the queried data by the parameter name, time and geographical area. The result can be downloaded in one single file. Data from different repositories are merged together and comprise spatial information as well as quality flags, the institution of the data provider and links to respective metadata. This is done for every single data point.
The filter is applied using the OGC Filter Encoding. The Filter Encoding describes a XML scheme which can be used in reference with geospatial web services (e.g. Mapserver, Geoserver).
If the experiences with this new approach were positive it is planned to add all in-situ measured parameters to give direct access to a big part of German marine research data.

References

[1] Coastal Observing System for Northern and Arctic Seas.
[2] http://codm.hzg.de/codm.
[3] Zentrum für Marine Umweltwissenschaften, Universität Bremen.

Management of Marine Data in Germany

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Keywords: Marine data infrastructure, Web service, Metadata, INSPIRE, MSFD

Introduction
Governmental Agencies collecting environmental data are subject to many reporting commitments. Especially in Europe there is a multitude of reporting duties to comply to. For example, in 2007, the INSPIRE-Directive entered into force to establish an infrastructure for spatial information in Europe with common implementing rules for a number of specific topics such as metadata, data specifications, network services, data and service sharing as well as monitoring and reporting. But also other directives and international conventions require data and metadata: MSFD (Marine Strategy Framework Directive, 2008), OSPAR and HELCOM (Regional Conventions to protect the environment of the North East Atlantic, 1992, and the Baltic Sea, 2000) are only the most prominent. The federal structure of Germany leads to 11 different agencies or institutes which are thematically or geographically responsible for the marine environment, marine conservation and coastal engineering.

Elements of data infrastructures
During the development of the "Marine Data Infrastructure in Germany (MDI-DE) one of the goals was to use INSPIRE regulations, guidelines and specifications wherever possible. In this way, the distributed data concerning both the German coastal and the German exclusive economic zone are processed according to the requirements for data provision by EU member states. A large number of marine monitoring and surveying data has to be provided according to technical interoperability, i.e. data access via OCG web services (WMS, WFS, WPS), data documentation via ISO metadata (ISO 19115:data and ISO 19119:services) as well as the paradigm of seamless data, i.e. data harmonization.
During the work on MDI-DE between 2010 and 2013, established German coastal metadata systems and marine information systems merged into a novel web portal for marine data composed of the following infrastructure elements:

- a multidisciplinary network for integrating the major coastal data sources,
- an open number of distributed Web servers located at Federal and State public authorities and research centers,
- a new Web portal for Ocean and Coast, MDI-DE,
- a comprehensive national Ocean and Coastal Information System as catalog services CS-V providing data mining web services for data visualization and for data download,
- a coastal thesaurus for controlled vocabulary making use of semantic technologies,
- a coastal gazetteer for documenting geographic names of features than can change shape, location and names over time, and
- a coordinated working environment relying on metadata and Web services.

The obvious benefits of this joint effort, i.e.:

- comprehensive provision of distributed marine data,
- improvement of workflows with data from heterogeneous coastal sources to produce data products to support political and economic decisions as well as for reporting and presentation in different target systemshave been recognized and as of 2014, MDI-DE is in operational mode with joint financing from Federal and State agencies.

Sustainable Application

The participating agencies or institutes are thematically or geographically responsible for the marine environment, marine conservation and coastal engineering. Their spatial data are made available by OGC compliant Web services and documented with metadata according to the ISO standard thus fulfilling the INSPIRE interoperability requirement The Web portal www.mdi-de.org serves as central entry point for data and information from the German coastal zone and the adjacent marine waters. This facilitates intersectoral views of resources by providing technological solutions of networking and distributed data management.

In order to present the data from different sources and topics in a homogenous manner it has to be merged and arrangements must be made on the structure and content to harmonize it. These agreements are strictly based on European guidelines and international standards. Not only names and formats have to be defined, but also code lists, units and reference systems. For a unified visualization of the different datasets, signatures and class boundaries must be defined and applied to the distributed data.

While interoperability of data essentially is a technical issue, harmonization of data is a much more complex and time-consuming process that, when carried out carefully, results in widely recognized guidelines for presenting data. This people-intensive procedure is necessary for every parameter to be provided by a Web portal that feeds on distributed sources. In particular, the qualitative descriptors for determining good environmental status specified in Annex 1 of the Marine Strategy Framework Directive pose a great challenge nationally and internationally.

To achieve seamless integration, each node within the network needs to be equipped with a few basic components: services to provide the data and metadata and a database to feed the two. For the provision of spatial data, the Open Geospatial Consortium (OGC) has developed a number of open and international standards. The most appropriate in this context are the Web Map Service (WMS) to generate and visualize digital maps in the Web and the Web Feature Service (WFS) to download the data in an interoperable form such as GML. For both several software packages in the Open Source and commercial sector are available which can easily be used. The underlying database needs to support these services. This can be achieved by either installing a spatial database dedicated for this purpose or adding a data view to an existing database to adapt existing structures to the needs of the services. After thus ensuring the data distribution, the last piece of the puzzle is the corresponding metadata that again is available through a specialized database or a data view and provided in the Web by any metadata management tool that offers a standardized Catalogue Service for the Web (CS-W) interface.

Our guideline on “Linking an additional infrastructure node to the MDI-DE network” in combination with our guideline on “Metadata” outlines the technological principles we follow and presents the individual implementations at our partner institutions.

Figure. Web portal Marin Data infrastructure Germany – MDI-DE.

The MDI-DE Web portal provides both a keyword search for geospatial data mining and several theme based entry points with data and information on particular subjects.

Uncover Greater [or “Hidden”] Value in Maritime Data

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Keywords: ENC, Esri, Maritime Chart Server, WMS, S-57, Web Service

Timely and accurate dissemination of Electronic Navigational Charts (ENCs) is critical for Safety of Navigation. New and emerging technologies have allowed this rich maritime data to be made available as a Web Mapping Service (WMS). As a WMS, the data content within an ENC can used for other visualization and decision making purposes, unlocking the true value of the data. NOAA has made its entire ENC portfolio available online via the NOAA ENC Online viewer by implementing Esri’s ArcGIS technology. This paper discusses NOAA’s objectives in making ENC data available as a reliable web service to support non-navigational and operational user environments, and how users can take advantage of this capability.
The Maritime Chart Server is a Server Object Extension (SOE) built on top of ArcGIS for Server technology. This extension gives you the ability to publish S-57 services that display S-57 products such as AML, ENC, and IENC based on the S-52 presentation library. The Maritime Chart Server technology enables the rapid display and query of vector nautical charts as an OGC Web Map Service (WMS) 1.3.0. It enables hundreds of users within an organization to access these WMS data via an on premise or public-facing website. A range of capabilities that are configurable by the end user include a sample application that enables users to interact with the data provided by the Maritime Chart Server technology. These capabilities also include search, location calculation, performing measurements of distance and area, layer control and feature identification and attribute display.

Figure 1. MCS Esri 2.

Standardized Web Processing of Hydro-Engineering Operations

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Keywords: Web processing, RichWPS, OGC Services, Service Composition, Hydro-Engineering Operations, Spatial Data Infrastructures, Metadata

Spatial Data Infrastructures (SDIs) have been established for visualizing and allocating spatial data in distributed networks for a few years now. Starting with basic geodatasets, SDIs increasingly provide data from other domains. Ocean-specific data is made available in initiatives such as SeaDataNet on the European level or in the Marine Data Infrastructure Germany. These infrastructures are fostered by European directives such as the Marine Strategy Framework Directive, demanding the delivery of status reports and data via technologies defined by INSPIRE (Infrastructure for Spatial Information in the European Community).
Web processing is considered to be the next evolutionary step in SDIs (Brauner et al. 2009). The integration of processing services in a distributed service-oriented infrastructure extends the possible uses of available geodata. The Open Geospatial Consortium (OGC) defined, next to visualization and download services such as Web Mapping Service (WMS) and Web Feature Service (WFS), the Web Processing Service (WPS) (Schut 2007). The WPS provides an interface with the basic operations getCapabilities, describeProcess and Execute to manipulate geodata with server-located processes. Within the GIS community, several processes for geospatial data such as buffering and intersecting features or coordinate transformations have been developed (Schäffer et al. 2012). By orchestrating existing web processing services into stand-alone services, so-called workflow implementations, more sophisticated processes can be offered in SDIs.
The generic interface of the WPS enables its usage for applications outside the scope of fundamental GIS processes. Numerical simulations are one of the most demanding computing tasks requiring, amongst others, solutions for high resource requirements. The WPS could serve as a general interface to provide repetitive parts of the overall simulation process in distributed infrastructures (Foerster et al. 2010; Goodall et al. 2011). Performing individual analysis tasks with simulation data using a WPS in an OGC web service environment already shows the advantages of distributed computing and the paradigm of Software as a Service, notably the low resource requirements for the user.
We set up a case study to compare simulation results from numerical models with measured data at the same position, a common task in simulation analysis. Four individual processes have been developed and are provided as part of a WPS by the Federal Waterways Engineering and Research Institute (BAW): "Read NetCDF data file", "Harmonize data sets", "Compute difference of two time series" and "Compute single side amplitude spectrum". The files with modelled and measured data sets are read in by the first process. The data sets often come in different time steps, it is therefore important to make them comparable. Temporally, they are harmonized in equidistant time steps by a spline interpolation in the second process. The next process computes the actual difference between the two time series. Finally, a single sided amplitude spectrum of the harmonized input time series with a fast Fourier transformation is produced. Based on these treatments, a qualitative assessment of the modeled data is now possible.
Developing such complex applications within a WPS is still an ambitious task, requiring programming skills and knowledge of software libraries. The effort for an integration in existing software frameworks and data infrastructures is high. To extend the options for dealing with composite WPS applications further tools are required. The RichWPS compositional environment developed by University of Applied Sciences Osnabrück and Disy information systems provides a user friendly toolset for defining composite workflows out of distributed existing WPS processes. These workflows

can be deployed on an adapted WPS server and thereby made available as common WPS processes. The toolset is able to orchestrate processing steps defined in the scenario and do the subsequent calls.
A directory service called SemanticProxy provides a search interface for processes and services available for modelling of process chains. Users can include them into work sequences by using the ModelBuilder, a centralized application of the environment. The ModelBuilder is equipped with a diagramming user interface and connects to the adapted WPS server. For transfer and execution, the static model is transformed into a sequential form represented through the specifically developed RichWPS Orchestration Language (ROLA).
For our case study, we deploy the above named processes. In the ModelBuilder, the processes can be chosen and connected without the need of programming skills and deployed on the RichWPS server. To show the usability of the developed and deployed analysis processes, a testing environment has been set up as part of the case study at BAW. The interactive user interface enables the user-friendly choice of two sample data sets of modeled and measured water levels, the comparison and visualization of the results in different plots and the description of the involved elements. This hides the complexity of the processes modelled in the RichWPS ModelBuilder from the user and enables the choice of various input data sources like OGC WFS services in the future.

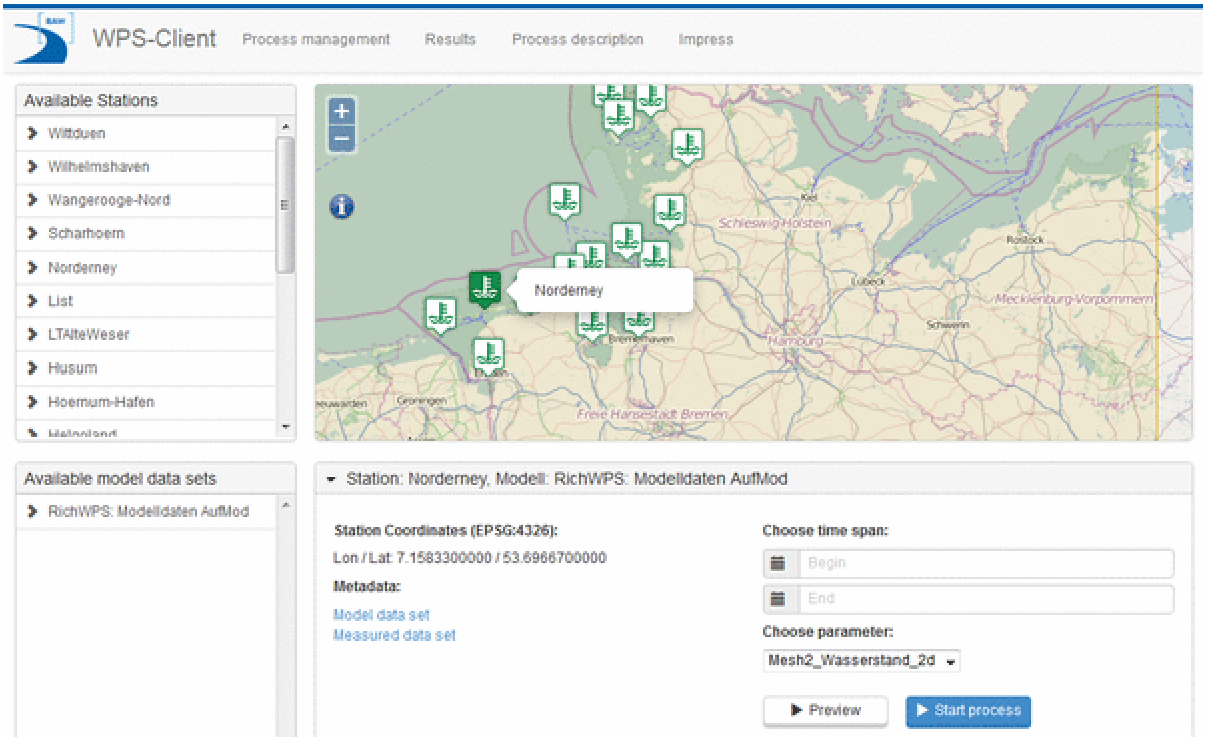

Figure 1. The interactive user interface for comparing measured data (stations) and model data.

The final outcome of the WPS service chain should include information on the input data sets and the processing steps performed to reach the result. Input data metadata can be extracted when reading NetCDF files, which include standardized descriptions in NetCDF Metadata Language (NcML) (Nativi et al. 2005). To describe the process chain a custom web service was developed specifically for the case study, which generates a description of the used process chain modeled in SensorML (Botts and Robin 2007), an XML-encoding. SensorML already provides a schema for the description of process chains. The metadata of a result dataset therefore includes, besides the actual result, links to the origin of the input datasets and a description of the process chain. To include the case study results and its metadata seamlessly in SDIs, we aim to develop ISO-compliant metadata sets in the future. While single data sets can be transformed from the NcML metadata, ISO-compliant metadata for generic WPS Process compositions are yet to be developed.
The case study of comparing simulation results from numerical models with measured data shows the possibilities of analysis tools in distributed networks. The RichWPS compositional environment offers an essential benefit for the development of complex tasks in the interoperable environment of OGC web services.

References

Botts, M. and Robin, A. (eds.): OpenGIS ® Sensor Model Language (SensorML) Implementation Specification. Open Geospatial Consortium (OGC 07-000), 2007.
Brauner, J.; Foerster, T.; Schäffer, B. and Baranski, B.: Towards a Research Agenda for Geoprocessing Services. In: M. Sester, L. Bernard and V. Paelke (eds.): Advances in GIScience. Proceedings of the 12th AGILE Conference, Berlin: Springer (Lecture notes in geoinformation and cartography), 2009.
Foerster, T.; Schäffer, B.; Baranski, B. and Brauner, J.: Geospatial Web Services for Distributed Processing. In: P. Zhao and L. Di (eds.): Geospatial Web Services, IGI Global, 245–286. DOI: 10.4018/978-1-60960-192-8.ch011, 2010.
Goodall, J. L.; Robinson, B. F. and Castronova, A. M.: Modeling water resource systems using a service-oriented computing paradigm. In: Environmental Modelling & Software, Vol. 26, 5, 573–582. DOI: 10.1016/j.envsoft.2010.11.013, 2011.
Nativi, S.; Caron, J.; Davis, E. and Domenico, B.: Design and implementation of netCDF markup language (NcML) and its GML-based extension (NcML-GML). In: Computers & Geosciences, Vol. 31, 9, 1104–1118. DOI: 10.1016/j.cageo.2004.12.006, 2005.
Schäffer, B.; Müller, M. and Kadner, D.: Bringing the Process to the Data - Introducing the WPS AppStore for Geoprocessing Functionality. Presentation. Prague, The Czech Republic, 21.05.2012.
Schut, P. (ed.): OpenGIS ® Web Processing Service. Open Geospatial Consortium (OGC 05-007r7), 2007.

Mini-Symposium: Modeling Methodology for Agricultural Research

Watershed Runoff and Sediment Transport Impacts from Management Decisions Using Integrated AnnAGNPS and CCHE1D Models

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Keywords: Runoff, Erosion, Sediment Load, RUSLE, Gully Erosion, PEG, AnnAGNPS

The development of watershed conservation management plans involves many decisions that affect various aspects of a watershed system, with consequences that are difficult to measure. Evaluations of conservation practices are often performed as individual practices with their impacts determined locally without consideration whether combinations of practices would provide a greater impact throughout a watershed system on reducing sediment loads. Often, conservation practices developed for sheet and rill erosion are also expected to treat ephemeral gully erosion. An example is when no-till practices are implemented expecting complete erosion control, but gullies form in the field producing significant amounts of eroded sediment. Recent studies indicate that ephemeral gully erosion on cropland in the U.S. can average around 40% of the sediment delivered to the edge of the field and developing the most appropriate plan to address this is a critical issue. Channel erosion sources have been shown to produce over 80% of the total sediment load within a watershed. Targeted implementation of integrated conservation practices devised to address the entire system, rather than isolated sources, can provide the most efficient use of conservation resources. A combination of conservation tillage, grassed waterways, riparian buffers, and instream measures may provide greater impact on reducing sediment with less impact on agricultural productivity. Integrating these and other conservation practices for sheet and rill, gully, and channel erosion would provide a better overall watershed management plan that improves agricultural production while improving water quality.

Watershed modeling technology has been developed to aid in evaluating conservation practices implemented as part of a management plan, but often lacks the capability to identify how a source, such as sheet and rill erosion, ephemeral gully erosion, edge-of-field erosion, or channel erosion, is specifically controlled by a practice or integrated practices. Various watershed technological capabilities incorporated into an integrated modeling system can be helpful in understanding how a source is controlled from one or more practices. Integrated technologies can be used to evaluate optimal combinations of integrated practices at multiple scales that would have the least impact on agricultural productivity, resulting in the greatest economic benefits, while having the most impact on improving watershed water quality. Although, without improved research studies, subjective observations will continue to be used to satisfy quality criteria in lieu of scientifically defensible, quantitative methods to estimate the impact of an integrated conservation practice approach to addressing all sources of erosion. The U.S. Department of Agriculture's Annualized Agricultural Non-Point Source pollutant loading model, AnnAGNPS, has been developed to determine the effects of conservation management plans and provide sediment tracking from all sources within the watershed, including sheet and rill, ephemeral gully, and channel erosion. Since the AnnAGNPS channel erosion components have no geotechnical or channel evolution capabilities, the National Center for Computational Hydroscience and Engineering CCHE1D hydrodynamic model has been linked together using topographic analysis tools and common databases to evaluate the effectiveness of in-channel remedial and control structures on watershed sediment loads. CCHE1D provides integrated technology with AnnAGNPS for simulations of one-dimensional unsteady flows and sediment transport in dendritic channel networks.

The 167 hectare mixed-landuse subwatershed of the Goodwin Creek Experimental Watershed located in North-Central Mississippi is part of the USDA-ARS Benchmark CEAP-Watershed Assessment Study project and was used to analyze the integrated capabilities of AnnAGNPS and CCHE1D for evaluating various conservation management plans that implement various integrated conservation practices for sheet and rill, gully and channel erosion control. Within this watershed, rainfall, runoff and sediment data were collected on a continuous basis from 1982 to the present. In 1982, the cultivated landuse was nearly 50% of the subwatershed, where by 1989 was reduced to no cultivated land areas. This provides an excellent location to study the impact of agricultural practices on sediment load. The watershed has detailed information describing elevation, soil and landuse conditions for each year of the study. Comparisons between simulated and observed data provide not only validation of the model, but also the basis for evaluating the effects of alternative conservation practices.

This study describes the current state and research needs for modeling integrated conservation practices and management planning. Additionally, this study provides an evaluation of the capability of the AnnAGNPS and CCHE1D models to simulate runoff and sediment loads from multi-landuse watersheds, including an assessment of the effects of placement and integrated combinations of various conservation practices on watershed water and sediment loads. Developing enhanced technology and research to assess conservation management plans is critical for planning and implementing conservation practices specifically designed for erosion control. Improved integration of national databases describing watershed characteristics and flow are needed to provide timely information to decision makers. Expanding capabilities of computer and Internet systems using remote sensing data acquisition opportunities will continue to provide an interesting challenge to developing effective watershed planning technology. Models need to continue to incorporate the latest watershed research at the surface and subsurface scales critical for evaluating new and existing management practice impacts related to improving the health of ecosystems as water quantity and use issues become an expanding national and worldwide problem.

Impacts of Agricultural Activities on Water Quality in Oxbow Lakes in the Mississippi Delta

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Keywords: Water quality, Agricultural activities, Numerical model, Oxbow lake, Mississippi Delta

The United States has more than 330 million acres of agricultural land that produce an abundant supply of food and other products. However, agricultural activities can degrade water quality if no appropriate management is implemented. The most recent National Water Quality Inventory reported that agricultural nonpoint source (NPS) pollution is an important factor influencing quality of surface waters, as well as a contributor to groundwater contamination. To address NPS pollution problems and reduce discharging pollutants into surface waters in agricultural areas, best management practices (BMPs) have been installed in many watersheds.

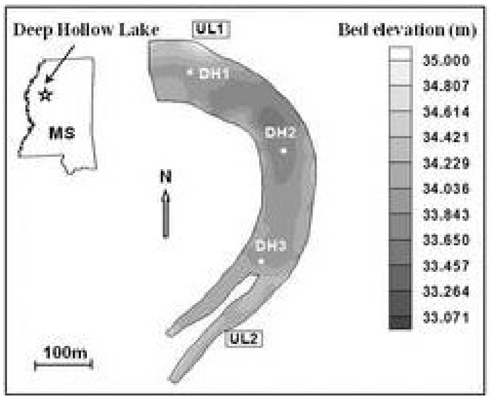
The Mississippi Delta is one of the most intensively farmed agricultural areas of the United States. However, highly erodible soils and agricultural activities have resulted in a large amount of NPS sediment-associated pollution discharged into the water bodies, which can greatly influence water quality and aquatic biota. To evaluate the efficiency of BMPs in reducing chemical runoff, several lakes in this area, including Beasley Lake, Deep Hollow Lake, and Thighman Lake have been selected for assessments under various ARS Projects, such as the "Mississippi Delta Management System Evaluation Area (MDMSEA)" and "Conservation Effects Assessment Project (CEAP)" (Locke 2004, Locke et al. 2008). All of these watersheds fall within the Lower Mississippi River Basin, a Long-term Agroecosystem Research (LTAR) area.

In these watersheds, BMPs were established to reduce the NPS pollutant discharge into the lakes. In order to assess the effectiveness of BMPs, the water quality in the watersheds and lake has been monitored. Weekly or biweekly samples of suspended sediment, nutrients, chlorophyll, bacteria, and other selected water quality variables in those lakes were collected and analyzed by the USDA-ARS National Sedimentation Laboratory (NSL). Field measurements show that the concentrations of nitrate and ammonia in the lakes were very low, while the concentration of phosphorus was relatively high (Knight et al. 2013). Suspended sediment concentrations were relatively high, exceeded the published levels known to adversely impact fish growth and health. The water quality of the lakes was sensitive to suspended sediment concentrations because photosynthetic activity was limited by elevated turbidity levels following runoff events. Therefore, when the watershed water quality is concerned, one has to consider factors such as agriculture activities and sediment yield from farmlands.

Numerical modeling is an effective and efficient approach for studying water quality constituents in surface water bodies. A three-dimensional water quality model was developed based on CCHE3D hydrodynamic model (Jia et al. 2005), and applied to predict the distributions of nutrient, phytoplankton, dissolved oxygen, etc., in natural lakes affected by agricultural management. The model considers processes in the water column, the bed sediment layer, and the exchange between those layers. Three major sediment-associated water quality processes were simulated, including the effect of sediment on light penetration, the adsorption-desorption of nutrients by sediment and the release of nutrients from bed sediment (Chao et al. 2010).

Deep Hollow Lake, one of ARS study lakes located in Mississippi Delta, was applied to demonstrate the capabilities of the developed water quality model. This lake receives runoff from a two square kilometer watershed which was heavily cultivated. Wind was an important driving force for the water movement within the lake (Fig.1). The flow fields in the lake were first simulated using CCHE3D hydrodynamic model, and the obtained flow data was then used by the water quality model for simulating the concentrations of nutrients and chlorophyll. The simulated results were generally in good agreement with field observations (Fig.2). The water quality model was also applied to conduct

analyses of the sensitivity of chlorophyll concentration to the suspended sediment concentration and nutrient loadings in the lake. It was found that the lake primary productivity is mainly limited by the suspended sediment concentration, while it is somewhat less sensitive to concentrations of nitrogen and phosphorus. In order to provide more useful information to evaluate the BMPs installed in Mississippi Delta watersheds, this model will be applied to simulate water quality constituents in other Delta lakes, such as Beasley Lake.
Since water quality constituents in those oxbow lakes are influenced by agricultural practices, the model presented here is designed to assess their impacts. The accuracy and efficiency of a water quality model are highly dependent on simulated physical-chemical processes, boundary conditions and computational technologies. To significantly improve water quality modeling, it is necessary to conduct additional researches to further understand the aquatic physical-chemical process, to improve model inputs on watershed information and agri-management, and to update computing methods for integrated watershed-surface water modeling system. The improved water quality model will be able to provide more accurate information to assess the impacts of agricultural activities on water quality in water bodies. Assessments may support the decisions for selection of agricultural conservation measures, adoption of planning and management policy, and operations to protect the quality of water, ecology and environment in areas adjacent to shallow lakes in agricultural watersheds.



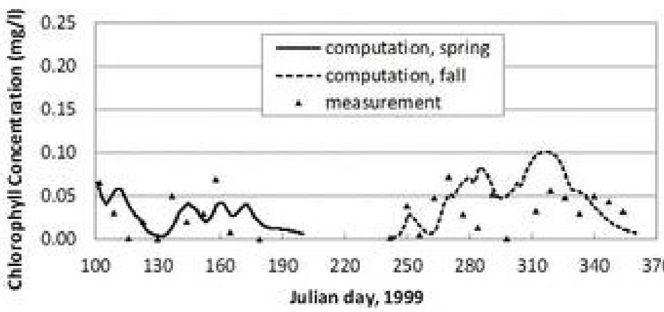


Figure 1. The study area of Deep Hollow Lake; Figure 2. The Concentration of chlorophyll at Station DH1.

References

Chao, X., Jia, Y., Shields, F. D. Jr., Wang, S.S.Y. and Charles M. Cooper (2010), Three-Dimensional Numerical Modeling of Water Quality and Sediment-Associated Processes with Application to a Mississippi Delta Lake, Journal of Environmental Management, 91,1456-1466.
Knight, S.S., M.A. Locke, S. Smith, Jr. 2013. Effects of agricultural conservation practices on oxbow lake watersheds in the Mississippi River alluvial plain. Soil Water Res. 8(3):113-123.
Jia, Y., Scott, S., Xu, Y., Huang, S. and Wang, S.S.Y.(2005), "Three-Dimensional numerical simulation and analysis of flows around a submerged weir in a channel bendway." J. Hydraul Engrg., 131(8), 682–693.
Locke, M.A. 2004. Mississippi Delta Management Systems Evaluation Area: Overview of water quality issues on a watershed scale. In Water quality assessments in the Mississippi Delta: Regional solutions, national scope. M.T. Nett, M.A. Locke, and D.A. Pennington, eds., ACS Symposium Ser. 877, pp. 1-15.
Locke, M.A., S.S. Knight, S. Smith, Jr., R.F. Cullum, R.M. Zablotowicz, Y. Yuan, and R.L. Bingner. 2008. Environmental quality research in Beasley Lake Watershed, 1995-2007: Succession from conventional to conservation practices. J. Soil Water Cons. 63(6):430-442.

Modeling Agricultural Sheet, Rill, and Ephemeral Gully Erosion

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Keywords: Runoff, Erosion, Sediment Yield, RUSLE2, RUSLER, EphGEE, PEG, AnnAGNPS

Ephemeral gully erosion can be a serious contributor to soil degradation in agricultural fields, but this form of erosion is not routinely included in predictions made with current conservation planning technology. To address this deficiency, the Revised Universal Soil Loss Equation, version 2 (RUSLE2) has been modified to predict a gully-forming runoff event sequence suitable for linkage with a new processed-based channel model, the Ephemeral Gully Erosion Estimator (EphGEE). At the watershed scale, the Annualized Agricultural Non-Point Source pollutant loading computer model (AnnAGNPS) that uses RUSLE technology to estimate sheet and rill erosion and is enhanced to estimate tillage induced ephemeral gully erosion. All of these models will be accessed through GIS tools that are under development. At the field scale, a GIS tool, RUSLE2-Raster, determines the locations of concentrated flow areas that end RUSLE2 hillslopes, organizes and controls the execution of the RUSLE2 computational engine using standard RUSLE2 databases, and links hillslope runoff and sediment yield to EphGEE. At the watershed scale, an Agricultural Integrated Modeling System (AIMS) facilitates the preparation of AGNPS input files from topographic, soil, climate, and management information; defines watershed streams and sub-area polygons; executes AnnAGNPS; and links AnnAGNPS outputs to the CCHE-1D channel network model.

RUSLE2 was traditionally applied to one-dimensional, user-selected representative hillslope flow paths to estimate sheet-and-rill erosion and sediment delivery to hillslope-ending channel flow paths. Where high-resolution digital elevation models are available, terrain analysis methods can be used to determine surface drainage patterns, to define a raster network of potential gully channels, and to subdivide the study area into catchments draining into channel cells. To support the application of RUSLE2 in complex 2-D landscapes with flow convergence, RUSLE2 was modified to estimate local slope length based on the ratio of runoff leaving a cell to that of runoff generated within that cell rather than being calculated based on linear distance from the top of the hillslope. This approach is more powerful than determining slope length from contributing area alone since it also accounts for spatial variability in runoff generation related to soil type and management effects. Using the new RUSLE2 representative runoff event sequence, event hillslope runoff and sediment loads serve as distributed inputs to each channel cell for channel flow and erosion/deposition computations by EphGEE.

In EphGEE, initial channel cross sections are assumed to have a triangular shape after tillage. For each storm, steady water surface profiles are computed along each gully channel, based on channel geometry, hydraulic roughness, and flow discharge. The model determines erosion and deposition rates based on local available shear stress, sediment transport conditions, and soil erodibility parameters. Gullies are assumed to evolve with rectangular cross sections. When sediment load exceeds local transport capacity, sediment deposition aggrades rectangular or trapezoidal channel sections.

Within the AnnAGNPS watershed model, potential ephemeral gully locations and erosion are calculated with different procedures. After the watershed digital elevation model (DEM) is discritized into stream channels reaches and upland polygons, the potential locations of ephemeral gullies nickpoints within each upland polygon are determined using a compound topographic index that is based on contributing area, local steepness, and planform curvature. Locations where tillage induced

ephemeral gully erosion occurs is calculated by applying a headcut advancement model. Sediment transport capacity is determined using AnnAGNPS procedures.

The RUSLE2, EphGEE, and AnnAGNPS were applied and compared with observations on Watershed 11 of the USDA-ARS Deep Loess Research Station located near Treynor, Iowa. The predominant soil was Monona silt loam (fine-silty, mixed, superactive, mesic Typic Hapludolls). Daily runoff and sediment yield were monitored at the watershed outlet from 1975 through 1991 during a period when the field was farmed with contour-planted, conventional-tilled corn (Zea mays, L.) and a grassed waterway was located in the lower 200 m of the watershed. A DEM was created at 3 m resolution from 0.31 m contour lines (Fig. 1) and was used to define locations of potential ephemeral gully channels and knickpoints.

Measured sediment yield from the watershed averaged 14.6 Mg ha^{-1} y^{-1}. RUSLE2 predicted sheet and rill sediment delivery to the ephemeral gully channels was 36 Mg ha^{-1} y^{-1}. Cross sections #1 and #2 (Fig. 1) of the potential ephemeral gully channels showed sequences of erosion and deposition that varied in space and time. At cross section #3, EphGEE predicted an ephemeral gully 1.6 m wide if no waterway was present, whereas only sediment deposition occurred when a waterway was simulated. With the waterway included, predicted sediment yield from the waterway outlet was 13.7 Mg ha^{-1} y^{-1}, similar to observations. These encouraging preliminary results suggest that distributed of sheet, rill, and ephemeral gully erosion will soon be enable precision conservation planning in agriculture.

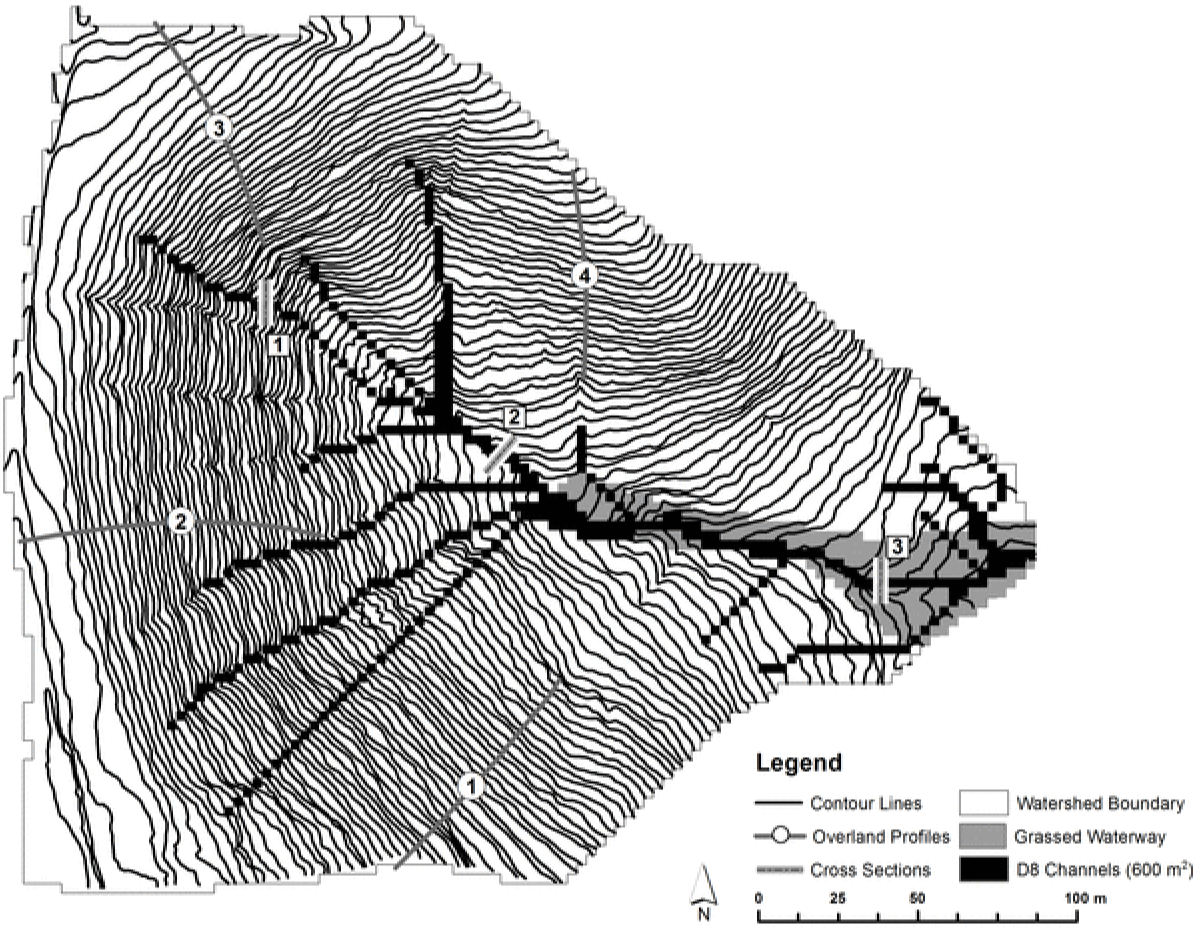

Figure 1. Topographic map (0.31 m contour interval) of Watershed 11 at Treynor, Iowa, illustrating four appropriate RUSLE hillslope flow profiles, concentrated flow channels determined using a D-8 method based on a minimum contributing area of 600 m2, and the location of three cross sections used to evaluate the behavior of EphGEE in response to runoff events predicted by RUSLE2.

Simulation of Sediment Transport due to Dam Removal and Control of Morphological Changes

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Keywords: Sediment Transport, Dam Removal, Sediment Control, Optimization

When a dam is significantly deteriorated and is no longer able to serve the purpose for which it was constructed, or the costs of repair and maintenance exceed the expected benefits, the dam may need to be decommissioned (or removed). In the United States (US), dam removal in a river or stream is an effective engineering approach to restore river ecosystem. However, the downstream impact of sediments released from the reservoir post dam removal is a major concern. For reservoirs with large sediment deposits, released sediments may significantly change the river morphology in both the reservoir and the downstream channels. If reservoir sediment deposits contain contaminants, sediment release may cause further environmental hazards downstream. Before decommissioning a dam, it is important to study sediment transport and morphological changes upstream and downstream of the dam site that may result from dam removal.

The mechanics of sediment erosion and transport following dam removal is highly complicated due to the non-uniform spatial distribution of sediment in reservoirs and downstream river channels. In general, sediment transport processes are unsteady, nonlinear, and interacting with dynamic river flows. Quick release of reservoir sediments by a complete dam removal may result in a supercritical flow in the river reach near the former dam location. Eroded sediments usually deposit immediately downstream. A headcut may be triggered and migrate upstream through delta deposits if reservoir bed materials are cohesive. As a result, bank erosion and channel widening are important adjustment processes. Even if the dam removal process is gradual, river floodwaters during a storm may entrain a large portion of the deposits and pass it over the low-head dam. The bio-geomorphic impact of dam removal on the riverine environment is long-term and long-range both upstream and downstream. Thus, the assessment of potential impacts of dam removal on river hydrological and geomorphological environments requires integrated model capabilities to simulate multi-scale processes in river flow dynamics, morphodynamics, and ecosystem services.

This paper presents two examples of post dam removal sedimentation studies in the US. Two different one-dimensional (1D) channel evolution simulation models were used: CCHE1D (Wu and Vieira 2002) and CONCEPTS (Langendoen 2000), respectively. Both models are capable of simulating multiple flow regimes during the period of dam removal and multiple channel sedimentation processes. The first example is the application of CCHE1D to assess the long-term (up to 10 years) morphological response to the removal of Marmot Dam in the Sandy River, Oregon (Figure 1a). The second example is a CONCEPTS study of the sediment dynamics due to removal of dams along the Kalamazoo River, Michigan (Figure 1b). To mitigate the downstream impact of eroded sediments, CONCEPTS was used to evaluate the erosion, transport, and deposition of sediments over a 37-year period for three different dam-removal scenarios.

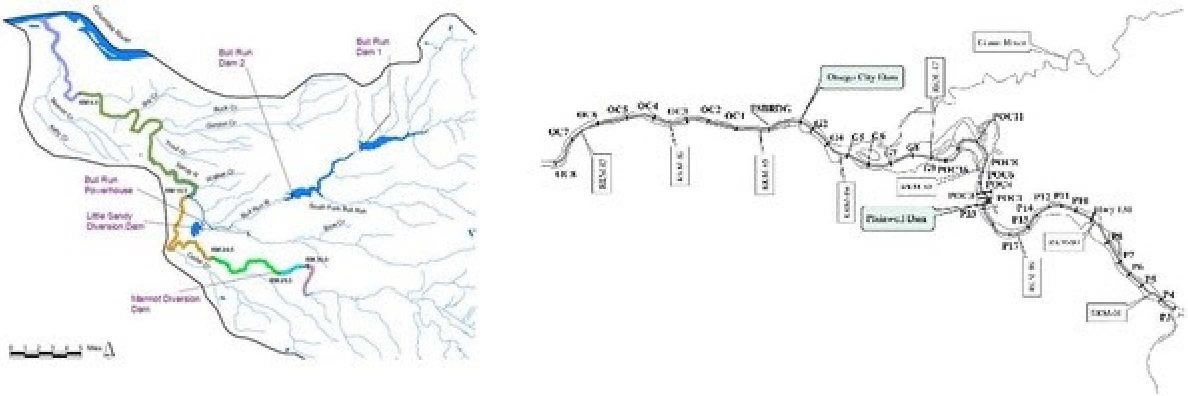

Figure 1. (a) Map of Sandy River basin (Stillwater Sciences 2000); (b) Map of study reach on the Kalamazoo River, Michigan.

To provide the most effective management plan to decommission the dam and release the reservoir deposits, it would be best if one could establish the optimal reservoir sediment release schedule (or the time-dependent controlled released process) so that the downstream impact of sedimentation can be minimized. Thus, this paper further presents a simulation-based optimization tool (Ding et al. 2013) to search for optimal control of sediment releases for minimization of morphological changes in the Sandy River after the Marmot dam was removed. This integrated optimization tool consists of a channel evolution simulation model (CCHE1D) and a well-established minimization algorithm (i.e., the Limited-Memory Quasi-Newton (LMQN) method) for optimization of nonlinear flow and sediment transport processes. An adjoint sensitivity model for nonlinear and unsteady flow dynamics and morphodynamics was developed to quickly search for the best solution of the optimal control schedules of flow and sediment transport. The optimal result of controlled sediment release during the dam removal can provide engineering management guidance to plan a better scheduled dam decommissioning if releasing reservoir deposits can be operated. It is expected that this kind of integrated approach with combined model capabilities of simulation and optimization can provide the best management solution to lower the impact of dam removal and to restore river ecosystem.

References

Ding, Y., Elgohry, M., Altinakar, M. S. and Wang, S. S. Y. (2013). Optimal Control of Flow and Sediment in River and Watershed, In: Proceedings of 2013 IAHR Congress, Tsinghua University Press, Chengdu, China, Sept. 8-13, 2013, 13p.

Langendoen, E. J. (2000). CONCEPTS – Conservational channel evolution and pollutant transport system,' Software Manual, US Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS.

Stillwater Sciences (2000). Numerical modeling of sediment transport in the Sandy River, OR following removal of Marmot Dam. Technical Report, Prepared for Portland General Electric, Portland, Oregon.

Wu, W., and Vieira, D.A. (2002). One-dimensional channel network model CCHE1D 3.0. Technical Report No. NCCHE-TR-2002-01, National Center for Computational Hydroscience and Engineering, University of Mississippi, University, MS.

Sensitivity of the Apalachicola-Chattahoochee-Flint River Basin to Changes in Land Management

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Keywords: Climate change, Land management, Agricultural assessment, Overland flow and sediment transport

Land use changes in watersheds are directly related with the runoff generation processes of the hydrological system and subsequent overland sediment transport. As a result, to understand the hydrological responses to land use change is important for water resources management, particularly with respect to agricultural practices. In this study, a sensitivity assessment is performed to see the potential impact of land use change in the Apalachicola-Chattahoochee-Flint (ACF) River Basin to the runoff generation and resulting sediment yield in the river.

The ACF River Basin is located at the Florida Panhandle region in the northern Gulf of Mexico. At the downstream of ACF River Basin, Apalachicola Bay hosts the largest oyster production site in Florida. In the recent 20 years, the ACF River Basin land use has changed dramatically, with a general trend of decrease in agricultural land and forested land (high permeability) and increase in residential land (low permeability). By comparing the runoff generation and sediment yield using the present land use data and future land use projection, a sensitivity assessment of ACF River Basin to land use changes is conducted.

The hydrological model used in this study for runoff generation and sediment yield simulation is the Soil and Water Assessment Tool (SWAT) model. The SWAT model is one of the most widely used hydrological models for natural watershed assessment. It is recognized as a distributed, physically-based, continuous-simulation model. In a previous study (Chen et al., 2014), a fully calibrated SWAT model has been developed in the ACF River Basin for runoff generation and sediment yield simulation based on the present land use data. In this study, the newly generated future land use projection is applied to the developed SWAT model to assess the potential impact of land use change on the hydrological system.

For the interpretation of the assessment results, previous studies have shown that precipitation over the ACF watershed will be altered with climate change (Hagen and Bacopoulos, 2012; Wang et al., 2013; Chen et al., 2014). Therefore, the impact of land use change in this study is quantified by two precipitation assessments: 1) the daily average impact; and 2) the impact during extreme events. The daily average impact assessment is based on long-term daily runoff and sediment simulation using SWAT. For impact assessment during extreme events, different scenarios are generated using different land use change projections and climate change projections. The future climate change projections have been produced in previous studies (Wang et al., 2013; Chen et al., 2014). By combining the climate change projections and the newly generated land use change projections, the climate and landscape controls on the ACF River Basin hydrological system in the future is evaluated in detail.

The findings from this study provide new insights into the interaction between the ACF River Basin hydrological system and the changing environment. By identifying the key controlling factors on the watershed, a deeper understanding on the future of ACF River Basin will be achieved scientifically and operationally. On the other hand, the output of this study also provides valuable information on streamflow and sediment load for marsh, oyster, and sea grass studies at the downstream of ACF River Basin. Furthermore, by showing the potential change in future runoff and sediment load based on different land use change scenarios, the study helps coastal resource managers to make more informed decisions on the development plan of Apalachicola area.

References

Hagen, S. C. and Bacopoulos, P. (2012). "Coastal Flooding in Florida's Big Bend Region with Application to Sea Level Rise Based on Synthetic Storms Analysis." Terr. Atmos. Ocean. Sci. 23: 481-500.

Wang, D., Hagen, S.C., and Alizad, K., (2013). “Climate Change Impact and Uncertainty Analysis of Extreme Rainfall Events in the Apalachicola River Basin, Florida.” J. Hydrol. , 480, 125-135.

Chen, X., Alizad, K., Wang, D., and Hagen, S.C., (2014). “Climate Change Impact on Runoff and Sediment Loads to the Apalachicola River at Seasonal Scales and a Preliminary Event-based Assessment.” J. Coastal. Res., Submitted.

Modeling of Fluvial Geomorphic Processes in River Channels Impacted by Agriculture

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Keywords: River sedimentation, Channel migration, Local scour, Bank erosion, Numerical simulation, CCHE2D, CCHE3D, CONCEPTS

Fine-grained sediment yield from agricultural watersheds is a concern for protecting water resources and environment. A large portion of the sediments can be contributed by channel erosion processes including channel incision, headcut migration, bank erosion, or local scouring. In-stream structural measures such as drop structures to control channel grade, and spur dikes, large wood and planting of riparian vegetation to control bank erosion have been installed to reduce channel erosion and resulting sediment yield.
In the past decades, computer simulation models have been developed to help researchers and engineers understand and resolve these sedimentation problems. Among others, ARS/USDA has developed the one- dimensional CONservational Channel Evolution and Pollutant Transport System (CONCEPTS) for flow and sediment transport routing including bank erosion in river channels with large spatial extents. NCCHE/UM has developed the multi-dimensional CCHE2D/3D computer models for simulating these processes in more detail at smaller spatial scales, thus emphasizing localized problems. Applications have demonstrated the effectiveness and usefulness of these models. The paper will address major channel sediment problems in agricultural watersheds and discuss numerical models developed and tested for solving these problems.
Developing BMPs at the watershed scale to reduce in-stream fine-grained sediment loadings is ineffective if channel sources are excluded. Channels in agricultural lands are often disturbed to manage runoff and sediment from uplands, which may result in extensive channel erosion. Current watershed models do not adequately incorporate channel erosion processes. CONCEPTS was successfully used to determine in-stream sources of fine sediment and their rates relative to upland sources at the watershed scale. Fig. 1 shows the effects of land use change and targeted streambank protection measures on sediment yield in the urbanizing Shades Creek watershed near Birmingham, AL.
Many flood control dams in the United States are reaching their design life or sediments emanating from agricultural activities have severely reduced reservoir storage capacity, which may require the decommissioning of dams resulting in large downstream increases in sediment loads when stored material in the reservoir is eroded. CONCEPTS has specific capabilities to study the rate at which the sediments in the reservoir are evacuated and the downstream impact on water resources. Figure 2 shows the post-dam removal incisional erosion processes upstream of the Otsego City Dam (model kilometer 6) on the Kalamazoo River, MI and the downstream transport simulated by CONCEPTS.
Local scouring caused by the dynamic interaction between channel flows, hydraulic structures and the sediment bed is an important threat to engineering structures and to a certain degree affects alluvial river evolution. Studies using laboratory experiments, field measurements, and numerical simulations have contributed to the understanding of the complex three-dimensional nature of the flow field around bridge piers and the associated turbulence characteristics. Progress in the numerical modeling of the scouring process and the prediction of the depth of local scouring under a variety of conditions (Fig. 3) have been made.
Bank erosion of alluvial river channels often results in the encroaching of valuable farm land, channel migration and degrading water quality. A bank erosion study is in general a very complex problem because it involves multiple processes such as bank surface erosion, bank toe erosion and bank material mechanical failure. These processes are related to several parameters: sediment properties of bank and bed materials, bank slope and height, and bank-material erodibility and shear strength,

as well as the flow conditions in the river channel (boundary shear stress, water depth, channel curvature, etc.). Numerical models can be applied to bank erosion studies by considering most of the processes and parameters. The CCHE2D bank erosion model is capable of simulating unsteady flows with non-uniform sediment transport and bed and bank erosion comprising cohesive/non-cohesive materials (Fig.4). This model has been applied to study real-world bank erosion cases in several natural rivers. These and additional examples of model verifications and applications to general sediment transport, bank erosion, headcut, and local scouring will be presented.

Due to the complexity of sediment transport and soil erosion problems, models designed for certain spatial and time scales will have to be applied collectively. An integrated approach to make updated numerical models available for research and applications would be the most cost-effective. The potential of further model development, refinement and future modeling needs for agricultural watersheds will be discussed in the full paper.

Using Computer Models to Design Gully Erosion Control Structures for Humid Northern Ethiopia

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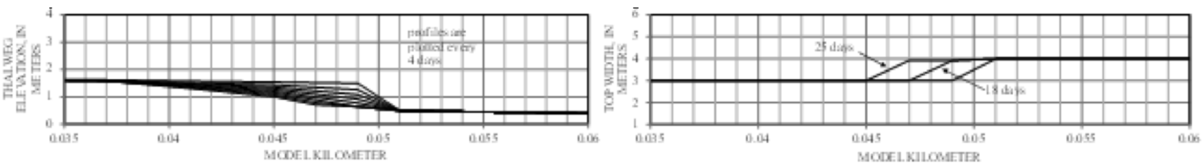
Keywords: Gully erosion, Erosion control, Ethiopia, BSTEM, CONCEPTS

Over the past five decades, gullying has been widespread and has become more severe in the Ethiopian highlands. Only in very few cases, rehabilitation of gullies has been successful in Ethiopia due to the high costs of constructing appropriate structural stabilization measures and the lack of suitable computational design tools in this developing country. The objective of the paper is to develop cost-effective measures to arrest gully formation in the Amhara Region of northern Ethiopia. The research was conducted in the Debre-Mewi watershed located about 30 km south of Bahir Dar, Ethiopia. Gullying commenced in the 1980s following the clearance of indigenous vegetation and intensive agricultural cultivation, leading to an increase of surface and subsurface runoff from the hillside to the valley bottoms. Gully erosion rates were 10 to 20 times the measured upland soil losses. Water levels, measured with piezometers, showed that in the actively eroding sections, the water table was in general above the gully bottom and below it in the (self-) stabilized sections. Current best management practices to control gully erosion typically consist of closely-spaced check dams in the upper portions of degraded watersheds (Fig. 1). Check dams reduce the effective slope of the channel, thereby reducing the velocity of flowing water, allowing sediment to settle and reducing channel erosion. Check dams have been fairly effective in the dryer Tigray Region of northeastern Ethiopia. However, they have been ineffective to control erosion from gullies formed in vertisols as flow often bypasses the check dams. Check dams also have been unable to halt the formation and headward migration of head cuts, which can be as large as 3 to 4 m (Fig. 1).

The US Department of Agriculture computer models BSTEM and CONCEPTS were tested for their ability to simulate gully-forming processes, and then used to develop effective gully stabilizing measures in vertisols. BSTEM is a spreadsheet tool for simulating stream bank erosion of a single bank profile. It has been used worldwide to evaluate bank stability conditions and to design stream bank stabilization measures. CONCEPTS is a process-based, dynamic computer model that simulates open-channel hydraulics, sediment transport, channel morphology and the impact of in-channel protection measures on channel morphology. CONCEPTS has been used throughout the mid-continental US to site grade control and to evaluate the impact of bank protection works at the reach and watershed scale. Both models predicted the location of gully bank failures well with the observed groundwater depth and vegetation characteristics in the Debre-Mewi watershed. Further, the validated models indicated that any gully rehabilitation project should first stabilize the gully bed by arresting the head cuts as any continued incision will destabilize gully banks.

BSTEM was used to determine stable head cut and gully sidewall slopes in vertisols given a range of soil properties, groundwater dynamics and vegetation characteristics. It was found that head cuts up to 5 m in height are stable at slopes of about 40 degrees. CONCEPTS was then used to determine the surface protection needed to prevent erosion of the head cuts regraded at 40-degree slopes. The evaluated gully had a 40-degree slope head cut of 1 m high with a bottom width of 2 m and a depth of 2 m below the head cut; gully sidewall slope is 60 degrees and gully slope is 0.01 m/m. A steady discharge of 2 m^3/s was used, which is approximately expected for a large thunderstorm in the 17 ha subwatershed draining the gully. Other parameters assumed were Manning n downstream of gully is 0.05, Manning n upstream of gully is 0.04, critical shear stress for soil erosion is 4 Pa, and soil detachment coefficient is 0.2 mm s^{-1} Pa^{-1}.
Two scenarios for the regraded head cut were tested with CONCEPTS: (1) bare soil and (2) rock cover stable under a 2 m^3/s flow, where the rock cover was extended about 8 m upstream to protect against the accelerating flow. For the bare soil, the head cut slope was reduced from about 0.83 to 0.12 m/m (Fig. 2a). The surface erosion extended over a length of about 12 m. The erosion of the regraded head cut produced mass failures over a length of 3 m above the eroded head cut (Fig. 2b). With a protective rock cover, no erosion of the regraded head cut and gully bottom occurred. Though, minor erosion at the toe of the gully sidewall occurred. This could be prevented by placing rocks also on the toe of the gully sidewalls.



Natural, technical, and computational resources in developing countries such as Ethiopia to design and implement effective measures to halt pervasive land degradation processes are lacking or severely limited. A gradual introduction of computational modeling technology of increasing complexity could have major benefits. The presented study employed two relatively simple computer models to develop a new approach (derived from one used successfully in the midcontinental US) of gully-head stabilization to halt the formation and expansion of vast gully systems in the vertisol-dominated region of northern Ethiopia. Demonstration projects are currently being installed to investigate the effectiveness of this new approach.

Posters

Water Resources Planning and Management

Comparison and Specification of the Most Appropriate Interpolation Statistical Method and GeoStatistic for Zoning of Quantitative Underground Water Parameters in Semnan Plain and Studying their Changes

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Keywords: Quantitative parameters, Underground water, Geo reference, Viogram, Interpolation

Nowadays, because of water shortage in our country especially, in desert and semi –desert areas, optimized management and the use of these resources are important and necessary.
In these areas, according to surface water resources shortage, underground water resources are the most important for supplying the water of agricultural, industrial and drinking sections.
The purpose of this project is to carefully evaluate the methods of locative interpolation for zones of the underground and surface water resources parameters in Semnan plain during studied statistical course.(since water year 78-79 to 88-89).
Because the classical statistics have not been able to spot locative distribution of underground water quantity parameters so, the data related to 31 shafts in Semnan plain was used and the methods of geo reference such as simple kriging, normal kriging, simple kokriging, normal kokriging and the methods of Inverse Distance Weighting (IDM) with valences 1 to 5 and Local Polynomial Interpolation (LPI) with various valences will be studied. After normalizing the data, drawing the variogram was done. In order to choose an appropriate model for evaluating on practical viogram, We used minimum Root Mean Square Error (RMSE). Then, with using the method of cross validation and minimum MAE, the most appropriate method of interpolation was selected. The results showed that for the zones of depth of underground water, the method of kriging was high precise compared to the other methods (MBE, MAE).
These results also show the decrease of stagnation surface and the increase of the depth of underground water during studied statistics course on the plain level.

Establishing Active Flood Forecast System by Using 3D BIM Technique

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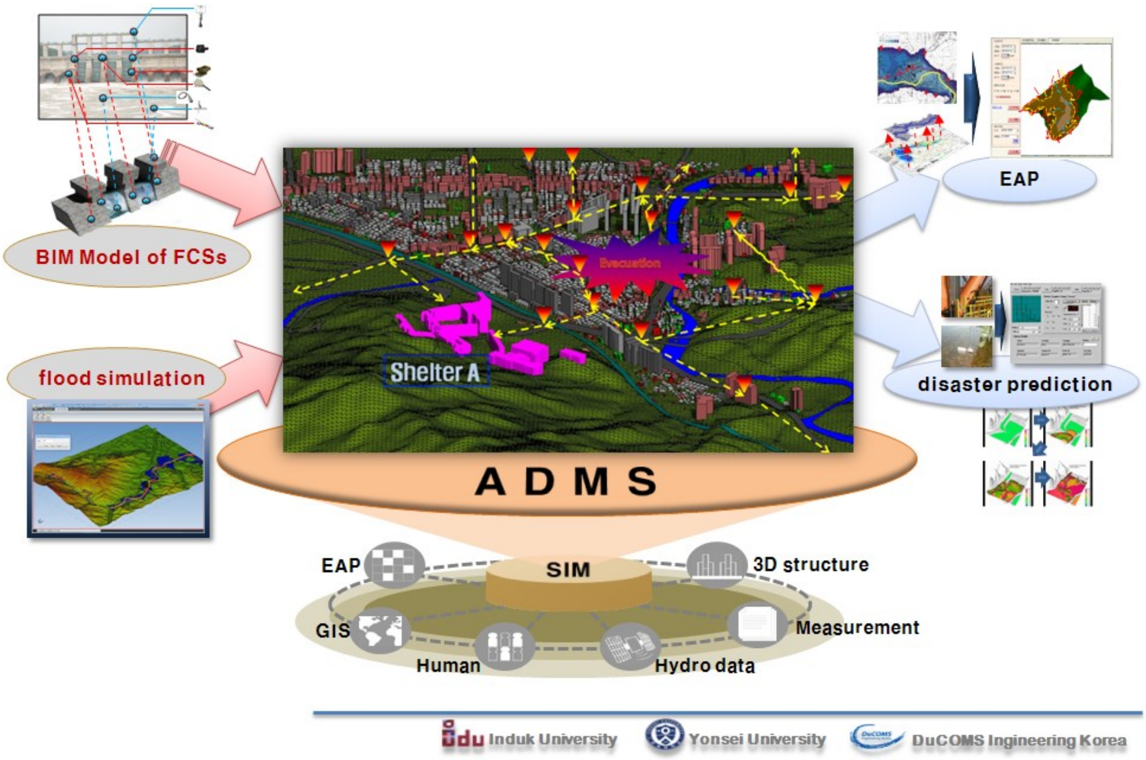
Keywords: Active flood forecast System, Extreme flood, 3D BIM, 1D & 2D flooding simulation

According to abnormal climate phenomena, the frequency of extreme floods has been increased worldwide. Also, lowland flood damages due to long-standing dams and levee breaks occur often all around. Consequently, it is the trend that flood risk mapping has been developed by computer system construction. The computer system has enabled the organization(s) assigned to cope with flood damages and has improved the work efficiency of authorities in charge.
This research outlines the plan to build an integrated flood damage forecast system based on BIM technology, which is rising globally in the field as well as civil engineering.
BIM technology has been introduced to architectural and constructional fields and includes some internal properties of structure. BIM information has more accuracy and visibility than the flood damage forecast system based on previous GIS. The possible rainfall hyetograph can be drafted preceding rainfall analysis according to the return periods and duration times. It bases on 1- and 2-dimensional flooding simulations.
The result of inundation depth and basin was embodied in the system by being converted to the BIM standard information model.
The ultimate goal of the integrated flood damage forecast system is to be used for disaster prevention such as evacuation routes simulations and for flood damage assessment by involving the BIM properties beyond the existing 3D visualization.
The mimetic diagram of Active Disaster Management System (ADMS) is shown in Figure 0 below.
BIM information of Flood Control Structure (FCS) and the result of flood simulation can be used through this system. Furthermore, the real-time 3D EAP and the disaster protection can be seen in 3D by using existing EAP, GIS, Human resources and measurement.



This system being created through the collaboration of universities and companies, such as Induk University, Yonsei University and Ducoms Engineering Korea Inc.
In this study, the simulation of disaster action is performed according to the disaster prediction of flood control structure and Emergency Action Plan (EAP) by connecting the standardized information model and the flood control structure based on Building information system (BIM). In addition, the study is aiming at developing the active combination disaster prevention system and building the 3D BIM model of the flood control structure to illustrate the image about disaster information of flood control structure.

Evaluation of Ecosystem Services in Strategic Environmental Assessment for River Basin Planning

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Keywords: Integrated plans for river basins, Ecosystem Services, Strategic Environmental Impact Assessment, Water Management

Abstract: River Basin Planning includes four aspects, namely, flood control, water utilization, water conservation and integrated river basin management. The implementation of a river basin planning would not only promote the development and utilization of water resources in the basin, but also have impacts on the ecosystem and socio-economic system of the basin. How to accurately assess these long-term, holistic and cumulative impacts is an important problem for the practice of strategic environmental assessment. There is still a lack of mature assessment methods, and mainly they were used to be analyzed qualitatively in strategic environmental assessment for river basin planning in China. In this article, the value of ecosystem services is used as an assessment index for conducting strategic environmental assessment for river basin planning. This paper defines the implication and classification of the watershed ecosystem services value, and analyzes the ways and features of the impacts on ecosystem services for the planning. Assessment methods for different scale river basin planning on the effect of ecosystem services value have been established, and the procedures, index system, measuring methods and sources of parameters are analyzed. This study could provide technical support for the strategic environmental assessment for river basin planning and the planning and management of river basin.

Study on Guide-Wall Type and Flow Characteristics of Open Channel Confluence

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Keywords: Confluence, Free surface, Guide wall, Numerical simulation, VOF method

As a kind of key sites in hydraulic engineering, open channel confluence own complex flow regime and special hydraulic characteristics determined by various factors. It is rather necessary to give a profound study on open channel confluence.

Based on research of open channel confluence all over the world, guide wall at the stag point of confluence was proposed, for the purpose of improving flow pattern and reducing upstream backwater with smoothly flow around the confluence. Then, physical model of confluence between Xiangfeng Changkeng mountain stream and drainage channel. Confluence flow regime was observed under checked flood as well as designed flood. Hydraulic parameters, velocity and water-depth, also were obtained.

With a brief introduction of turbulent simulation models and water surface capturing approaches, the proper generalized mathematical model was determined considering the available computing facilities. A simple comparison of different water free surface capturing approaches was illustrated. Successfully, particular hydraulic phenomena, dammed water and secondary flow, were achieved using varied guide-wall type. Junction flow regime and hydraulic characteristics were performed subsequently, verified by empirical data of Xiangfeng Changkeng Mountain Stream.

For reliability, velocity and water depth results from numerical solutions were compared with empirical data, and showed good agreements. Three wall types, line wall , polygonal line wall, and arc wall, were specified on its scale and location. The relation between guide wall scale and upstream damming was built. It is found that damming along mainstream decrease with the increasing of guide wall length, while damming along tributary increase with the larger guide wall length. For varied confluence angle and discharge ratio, flow regime improved apparently under the construction of guide wall, especially in the situation of relatively large confluence angle and discharge ratio. Besides, phenomenon of secondary flow would be serious for larger confluence angle and discharge ratio.

Experimental and Computational Hydraulics

Structure of Thermal Convection Development in a Closed Water Body with Aquatic Plants

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Keywords: Aquatic plant, DO, Underwater luminance, Thermal convection, Water quality, Nutrients, Vegetation abundant density, Rate of vegetation abundance

In some closed water bodies, the fluid flow tends to stagnate because of insufficient inflow and outflow. Hence, hydraulic characteristics are different from those of river or irrigation canals. When the water is undisturbed in a closed water body, the fluid is stratified based on vertical density distribution. In these bodies, the main fluid movement of the environmental substances in the water is caused by the convective flow based on thermal disturbance.

On the other hand, the water quality purification which uses an aquatic plant is proposed in a closed water body. The method is to purify the water quality by excluding the nutritive salt to the outside of the body after absorbing it to aquatic plants in a close water body. To make use of the method in the body with floating aquatic plants, we have to transport from bottom to surface the nutritive salt which accumulate at the bottom of the body. When we apply the aquatic plants for the water quality purification in a closed water body, firstly, it is important for us to comprehend what the aquatic plants influence in the body.

In this study, we particularly focused on the mechanisms underlying the generation and development processes of convective flow based on water surface cooling in a close water body with aquatic plants, and we clarified the generation and development processes of thermal convection by a field observation and a numerical experiment. First we conducted a field observation and evaluated the effect of aquatic plants to the convection and the variation of water quality in a closed water body. We then constructed a simulation model for convective flow and examined whether or not this is an actual phenomenon based on a comparison with the results of the field observation.

We clarified the generation and development processes of thermal convection by the field observation and the numerical experiment. The following results about the influence of aquatic plants on the in a closed water body were obtained.

(1) The generation and development process of thermal convection by water surface cooling is classified into an initial stage, where a multitude of small convection cells are generated; a transient stage, where the horizontal scale of the convection cell is increased; and a quasi-steady stage, where the convection cell continues in a comparatively steady state afterwards.

(2) A density difference was formed horizontally because of the coverage on the water surface, and this resulted in horizontal convection. This phenomenon affects the speed at which the convection cell develops vertically. Especially, the development speed in the boundary part showed the tendency which grew compared with the case of no coverage.

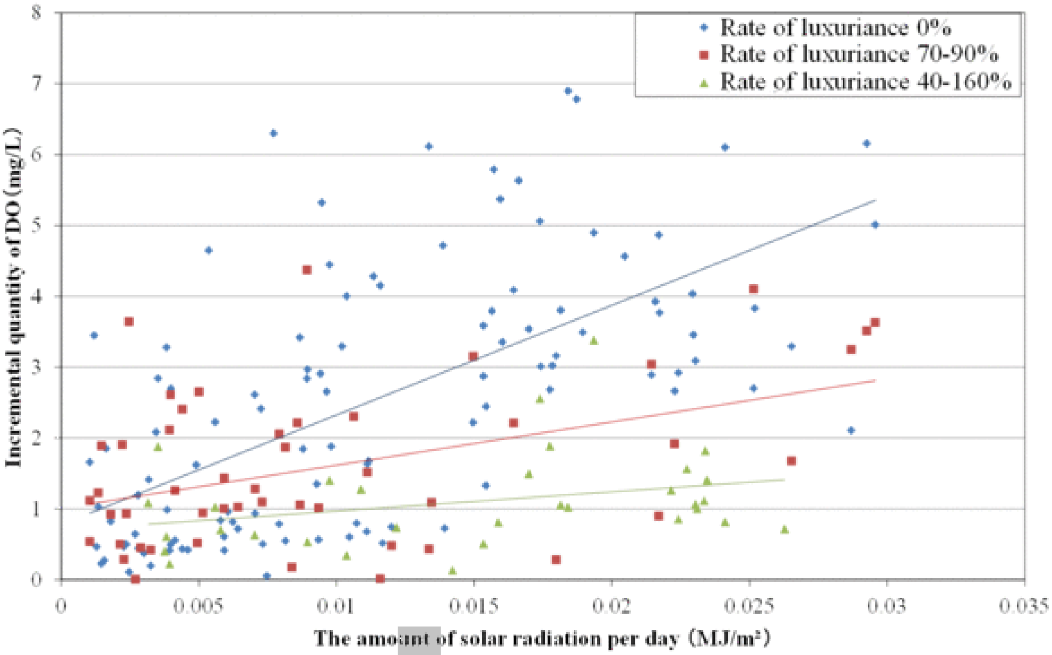

Fig.1 The effect of luxuriance of aquatic plants to the variation of DO

Numerical Modeling of Flow in Curved Channels with Various Sinuousness

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Keywords: Meandering, Curved channel, Numerical model

It is well known that the flow in curved channels is much more complex than the straight channel. Due to the centrifugal force, the helicoidal flow (sometimes, this is called as the secondary current in curved channels) and super-elevation of water surface are induced in curved channels. In order to simulate such complex flows, 3D numerical model is required. However, 2D numerical model is favorably chosen by practical engineers because of relative simplicity in implementation and application compared to 3D model.

The purpose of this study is 2D numerical modeling of open-channel flow in bends in order to investigate the influence of channel sinuousness and flow discharge on flow characteristics. The depth-averaged Reynolds equation and finite element method are adopted as governing equation and numerical method for 2D numerical flow model. All of conditions or parameters given through experiments in sine-generated curved channel with 30°, 60°, and 110° maximum deflection angles are applied identically to numerical model. The results of flow characteristics depending on the flow discharge and channel sinuousness are analyzed.

Comparison between a Well-Balanced Godunov Scheme and the Classical Finite Difference Scheme in Solving the System of Shallow Water Equations (SWEs)

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Keywords: Hydrodynamic model, Godunov scheme, Well-balanced, Finite difference, Shear stress, Transport of pollutants

The serious impact of the urban wet weather discharges (UWWD) on the deterioration of the quality of receiving water bodies necessitates the control of these discharges and more precisely their particulate phase that is responsible of conveying most pollutants. The deposits accumulated during dry weather period inside sewer networks highly contribute to this pollution through sedimentation and erosion processes. These processes are governed by hydraulic parameters (water depth, velocity, bed shear stress…) that for the moment aren't well reproduced by the hydraulic modules integrated in the solid transport models. So, refining the former would be a potential track to ameliorate the latter. This paper presents a one-dimensional model based on solving the system of SWEs using a well-balanced Godunov scheme. This model is applied on an urban catchment of "Le Marais" in Paris. The results obtained are then compared: on one hand with those obtained inside the sewer system by another model based on finite difference method, which is usually used by softwares of pollutants' flux calculation, and on the other hand with measurements taken at the outlet of the sewer system (height, speed, flow discharge). This comparison shows that the proposed scheme yields better estimation of the hydraulic parameters than those obtained by the classical scheme. These promising results could permit us to enhance the predictive power of the models of flux pollutants' calculation by integrating the developed hydraulic module.

CFD Modeling in Tunnel Spillways

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Keywords: Spillway, Tunnel, Modeling, CFD, LES

The Computational Fluid Dynamic (CFD) techniques being applied for the simulation of the operating behavior and performance prediction as well as the design optimization in the spillway flow. This study examines the applicability of (CFD) software, Fluent, to estimate to the aeration in the spillway. The standard k-e model was used to simulate the velocity, pressure and aeration fields along to the spillway and the Large Eddy Simulation (LES), compared with the model measurements. The air entrainment rates obtained from de CFD analysis are compared with values calculated by the empirical equations. Recently, the numerical methods have been developed rapidly with rising computer technology and advanced numerical methods. The CFD models are more flexible and require less time, cost and energy than physical hydraulic models.

Modeling Sediment Deposition from Marine Outfall Jets

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Keywords: Turbulent flow; Suspended sediment; Mathematical models; Marine outfall; Jets; Deposition

1. Introduction

Municipal wastewater is an important source of anthropogenic pollution in coastal waters and the suspended sediment present a significant part of this pollution. For guidance, the variation interval of the concentration of Total Suspended Solids (TSS) in the raw municipal wastewater (The values indicated are the values after the preliminary treatment "screening, grit removal, flotation") is from 150 to 500 mg/l in France (Degrémont and Suez 2005). However, the European Directive 91/271/EEC, determines the requirements for discharges from the secondary treatment as 35 mg/l of TSS or a minimum percentage of reduction of 90% in relation to the TSS load of the influent.

The study of suspended solids deposition from low concentrated particles-laden jets as municipal wastewater discharge has been performed for only few scenarios in nonstratified ambient (Neves and Fernando 1995, Ernst et al. 1996, Bleninger and Carmer 2000, McLarnon 2001, Cuthbertson and Davies 2008, Lee 2010). The common point between these research works is considering the concentration of solid particles small enough in the discharge so that the presence of these particles has no significant influence on the jet trajectories over a wide range of forcing conditions.

The objective of the present work is to present a simple model that accurately predicts the deposition from low-concentrated particle-laden turbulent jets in different scenarios. Our proposed model is a Lagrangian model that takes advantage of the preferential concentration phonemene. The unidirectional coupling (fluid-sediment) is used in the modeling because the concentration of solid particles in the municipal wastewater discharge is small enough and does not affect the hydrodynamic developement of the jet.

2. Lagrangian integral modeling for deposition in the nearfield

Unidirectional coupling between the fluid mouvement and the sediment transport is successfuly performed in order to study the deposition from low-concentrated particle-laden turbulent jets in natural waters. A developed bidimensional lagrangian integral model is used in this study.

The deposition from each slice (Figure 1) depends on the difference between two acting velocities, the first velocity the particle settling velocity and the second velocity is the jet entrainment velocity. The deposition begins when the first velocity is greater than the second.

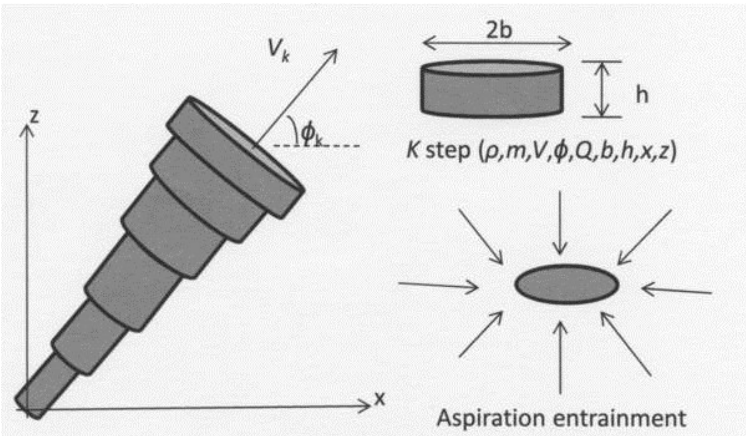

Figure 1. Structure of the marine outfall jet.

Eleven laboratory experiments were selected from litterautre and used to validate the poposed model. The experiments consist of inclined and horizontal buoyant jets in stationary ambient, horizontal buoyant jet in coflowing ambient and nonbuoyant horizontal jet in stationary ambient. Globally, the model shows good agreement with experimental data especially when we have high deposition rates from the nearfield which makes the deposition mechanism studied here the dominant mechansim (Figure 2).

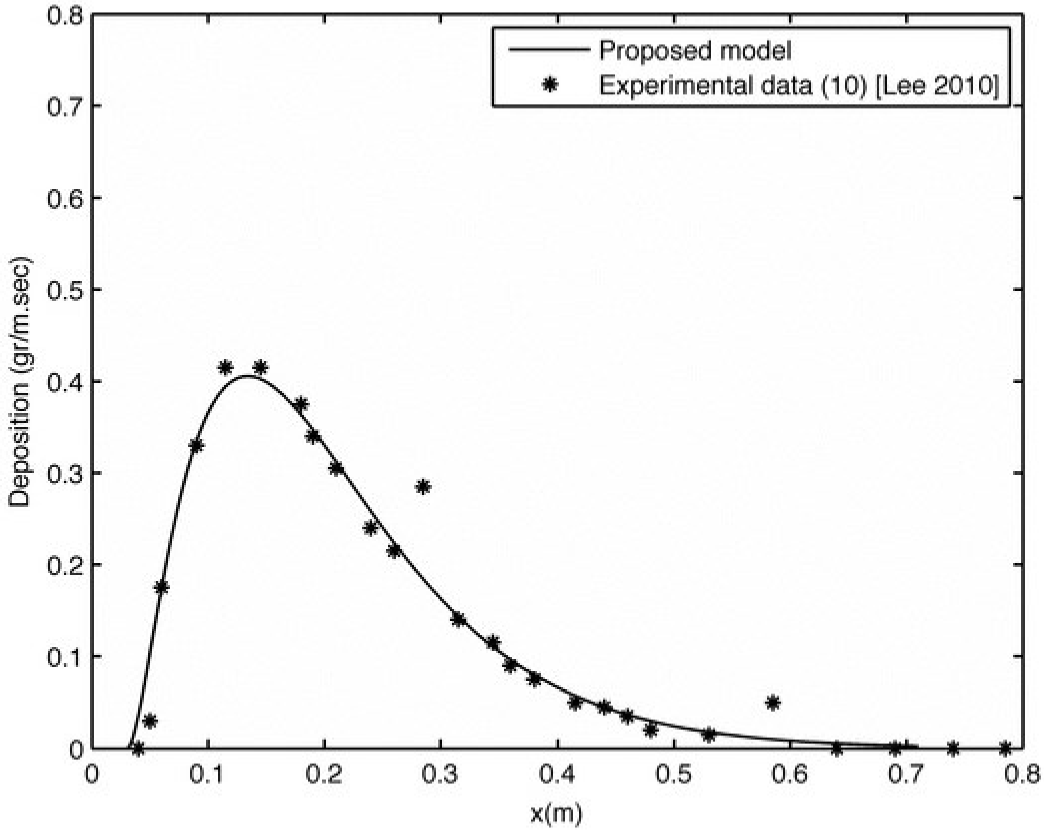

Figure 2. Model validation for the category of horizontal non-buoyant jets in stationary ambient.

3. References

Bleninger, T. and Carmer, C., 2000. Sedimentation in Particle-Laden-Jets: Experimental and numerical study on sedimentation of suspended material from non-buoyant horizontal jets in unbounded ambient. Institutsbericht, Monographie, Institute for Hydromechanics, University of Karlsruhe, Germany.

Cuthbertson, A. J. S. and Davies, P. A., 2008. Deposition from particle-laden, round, turbulent, horizontal, buoyant jets in stationary and coflowing receiving fluids. J. Hydraulic Engineering 134(4), 390-402.

Degrémont and Suez, 2005. Memento Technique de l'Eau. Lavoisier, 10th edition, France.

Ernst, G. J., Sparks, R. S. J., Carey, S. N. and Bursik, M. I., 1996. Sedimentation from turbulent jets and plumes. J. Geophysical Research 101(B3), 5575-5589.

Lane- Serff, G. F. and Moran T. J., 2005. Sedimentation from Buoyant jets. J. Hydraulic Engineering 131(3), 166-174.

Lee, W. Y., 2010. Mixing of horizontal sediment laden jets. PhD thesis, University of Hong Kong.

McLarnon, C. P., 2001. Sedimentation from a finite volume buoyant jet. PhD thesis, University of Dundee.

Neves, M. J. and Fernando, H. J. S., 1995. Sedimentation of particles from jets discharged by ocean outfalls: A theoretical and laboratory study. J. Water Science and Technology 32 (2), 133-139.

Correction Coefficients for Stream Dilament Theory

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Keywords: Stream filament theory, Potential flow, Momentum flux, Kinetic energy flux correction factor

The stream filament theory is often used to simplify the description of flow processes in pipes and open channels. As a prerequisite for this theory, the flow quantities have to be uniformly distributed in the flow profile. But, in reality, this is not the case. In order to account for this fact, the respective equations are adjusted by means of the momentum flux and the kinetic energy flux correction factor. Provided the flow profile does not change and the distribution of velocity in the cross-section is known, this approach is exact. However, if gradual changes in the flow profile are taken into account as well, the one-dimensional approximation of velocity may lead to inaccuracies which are reflected in different results with the different approaches. The precise reasons for theses inaccuracies, however, are not specified in the textbooks. This is unsatisfactory for the student and the lecturer as well as for the technician.

Thus, the case of a gradual widening of an inviscid, rotationally symmetric flow is calculated three-dimensionally in the following paper. It specifies the exact distribution of the flow quantities in the cross-section. Afterwards, the fluid flow is described one-dimensionally. By comparing the coefficients in case of a three-dimensional and a one-dimensional description, the deviations caused by the one-dimensional approximation can be determined.

Furthermore, it appears that - with regard to the examined case and a surface perpendicular to the main flow direction - both the mean momentum and the energy balance can be described exactly by a one-dimensional equation. As a prerequisite for this, it has to be possible to calculate the respective velocity coefficient from the three-dimensional velocity distribution. In addition to this, the pressure distribution has to be considered as well.

An outlook on a generalisation of the approaches presented in this paper completes the remarks.

Development of a New Volume-Of-Fluid Algorithm for Capturing Sharp Fluid Interfaces on Arbitrary Meshes

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Keywords: Volume of fluid (VOF); Interface capturing; Unstructured mesh; Normalized variable diagram (NVD); Normalized variable and space formulation (NVSF); Two-phase flow

This paper presents a new volume-of-fluid interface-capturing method (M-HiRAC) on meshes of arbitrary topology, mainly based on both the Compressive Interface Capturing Scheme for Arbitrary Meshes (CICSAM) formulation, put forward by O. Ubbink and R. I. Issa (*J. Comput. Phys*. 153, 26 (1999)), and the Higher Resolution Artificial Compressive (HiRAC) formulation, recently developed by J. A. Heyns et al. (*Int. J. Numer. Methods Fluids*. 71, 788 (2013)). Although no explicit interface reconstruction is needed, M-HiRAC is capable of modeling complex interface phenomena precisely, such as interface rupture and coalescence. By theoretical analysis, it is concluded that the modified HiRAC (M-HiRAC) overcomes two inherent drawbacks of the original HiRAC, in terms of the basic algebraic differencing schemes and the far-upwind reconstruction technique for arbitrary unstructured meshes. To evaluate performance of the newly proposed scheme, other five classic interface-capturing schemes presented in the past decades are adopted to compare with M-HiRAC for various academic test cases. The numerical results clearly show that M-HiRAC leads to more accurate interface predictions on arbitrary meshes, especially at high Courant numbers, by reducing numerical diffusivity and preserving shape of the interface.

Groundwater Hydrology, Irrigation

Applied Multivariate Statistical Techniques on Groundwater and Surface Water: Case of Soummam Area, Algeria

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Keywords: Surface water and groundwater; Cluster analysis; Discriminant analysis; Analysis of variance; Soummam basin; Algeria

Multivariate statistical methods, i.e., cluster analysis (CA), discriminant analysis (DA) and analysis of variance (ANOVA), were used to assess spatial variation in the water quality of the Soummam basin, Algeria. The application of hierarchical cluster analysis, based on all possible combinations of classification method, showed three main groups of samples. The group 1 samples are exclusively composed of surface water. Groups 2 and 3 samples are consisted of groundwater. Discriminant analysis (DA) was assigned about 98.6% of the cases grouped by CA. All groups are super-saturation with Ca-montmorillonite, dolomite, gibbsite, K-mica, kaolinite and quartz, and all these groups are under-saturation with albite, anhydrite, anorthite, $CO_{2(g)}$, gypsum, halite, melanterite and smithsonite. The ANOVA results indicate that the saturation indices of each of the mineral phases are significantly except chalcedony and quartz ($p > 0.05$).

Experimental Analysis and Numerical Modeling of Nitrogen and Phosphorus Transport in Soil under Municipal Wastewater Applications

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Keywords: Numerical Model, Nitrogen, Phosphorus, Transport, Soil, Municipal, Wastewater

Because of water scarcity and the subsequent need for the use of new sources of water (e.g. wastewater and effluent) in agriculture, there is also a need for more research to evaluate the potential impacts of using such sources on the soil system and the groundwater quality. Simulation models can be used to predict nitrogen dynamics and phosphorous in a soil water– plant system. In the present study the simulation accuracy and performance of the Hydrus-1D model to predict NO3 - N and phosphorous- leaching has been evaluated and compared to experimental lysimeter data. More specifically, the effects of irrigation using four types of water (wastewater, effluent, mixture of freshwater and effluent, and freshwater) on three types of soil (sandy loam, loam, and clay loam) has been investigated both experimentally and numerically. Barley was planted as a common agricultural crop. The leachates from lysimeters have been collected and sampled at the beginning, middle and end of the growing season. These samples have then been analyzed for nitrate and phosphorous.

Overall a good agreement between experimental- and numerical-model results is obtained, wherefore the model overestimates the mean nitrate- and phosphate leaching during the growing season of the crop slightly. Both the experimental and numerical simulations indicate that the effects of both the irrigation water and the soil type on the nitrate leaching are significant ($p<0.05$). For all four, but the wastewater treatment experiments, the highest and lowest nitrate leaching are found in sandy and loamy soil, respectively, whereas for the wastewater irrigation scheme nitrate leaching is still higher in loamy than in clay soil .The numerical simulations show that the highest amounts of nitrates are transferred for treated wastewater and the lowest ones for mixtures of freshwater and effluent. The process of nitrate leaching is also found to be a close function of the plant requirement. Thus the highest rated of nitrate leaching is observed in the middle of the growing season, when the crop barley needs the least amount of nitrate. The average nitrate leaching to the root zone in all cases is found to lie between 23 and 77 % of the original nitrate content in the irrigation waters. On the other hand, the phosphorous transfer to the root depths turns out to be insignificant, as it amounts to only 0.6 to 1.6 %. Nevertheless, for all three nitrate-loaded wastewater schemes, the NO3- N levels in the leachate are still below the permissible limit. This reassuring result means that wastewater with high concentrations of nitrogen compounds (up to 53.6 NO3-N and 10.3 PO4 - P mgl-1) can just be treated through an intermittent application to the land surface.

No significant differences in the nitrate leaching for the treatments of effluent and mixture of freshwater and effluent, respectively, have been observed which shows that the soil and plant system has a high potential for the filtration and removal of nitrate and phosphorous. From both the experiments and the numerical simulations it is found that soil with a loamy texture is the most suitable for irrigation with wastewater and effluent. In conclusion, our study shows that the use of diluted wastewater can be a suitable management strategy for reducing the leaching of impurities in wastewater and so to reduce the effects of probable hazards on the soil.

Monitoring Groundwater Depth and Quality in an Agriculture Dominated Region of North-Western India

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Keywords: Groundwater, GIS, Depth Quality

Worldwide, agriculture accounts for 70% of the total water consumption, compared to 20% for industry and 10% for domestic use. Excessive withdrawal to meet the needs of increasingly intensive cropping is leading to lowering of water tables in several areas. This is also causing the rise in water table in areas where its use is restricted due to quality considerations, leading to spread of salinity problems (Prabhakaran et al., 2009). The advent and rapid spread of energized pumping technologies have enabled speedy groundwater development which has lead to the emergence of land use and cropping systems dependent on its reliability. This has helped in bringing green revolution in India, particularly in the north-western region. Agriculture from irrigated land contributes around 30% of India's gross domestic product (GDP).Therefore, risks related to groundwater levels are a cause of serious concern (Custodio, 2002).

Kaithal district represents an agriculture dominated area in north-western India. The groundwater development in the district has taken place without proper understanding of its occurrence in time and space (CGWB, 2006). The present study analyses the effect of overexploitation on sustainability of the groundwater resource in the area. Depth to water level and quality data from 79 observation wells from 1974 to 2012 has been used in the study. The analysis was done in GIS environment using ILWIS software. The study has revealed serious problems of lowering of groundwater levels and deterioration of quality due to over-exploitation in the region. The problem was found to aggravate during the last ten years.

It was revealed that excessive pumping has resulted in lowering of levels in most parts, particularly in fresh quality zone of the study area. However, stable water table and salinity conditions continued to prevail in southern parts. The average rate of depletion in groundwater levels was observed to be highest in Gulha block whereas the levels in Kalayat and Rajaund blocks showed negligible decline during this period. A comparison of the post-monsoon (October) levels with the respective pre-monsoon (June) levels showed that from 1999 onwards, the water table depicted no net replenishment during monsoon. The comparison of 1987, 1997 and 2007 spatial maps showing the elevations of groundwater levels above mean sea level indicated a shift in the groundwater flow from north-east to south-west (in 1987) to that from south to north-west (in 2007). The changes in groundwater quality during this period were also found to corroborate with these observations. The study found that groundwater was safe for drinking and suitable for other domestic uses. The quality was found to be good to moderate in Gulha, Pundri and Kaithal blocks, whereas doubtful to non-suitable in Rajaund and Kalayat blocks. A part of Rajaund block was identified as critical having high value of salinity.

The study visualizes a potential threat to the quantity and quality of groundwater which may cause serious socio-economic consequences. Thus the resource requires judicious management. To arrest the declining trend of groundwater levels, it is necessary to regulate withdrawals and augment the aquifers with artificial recharge. To arrest the declining trend of groundwater levels in critical parts of the district, it is necessary to regulate withdrawals and augment the aquifers with artificial recharge. Change in the cropping pattern and establishment of water harvesting systems is urgently required in order to improve the water balance. Moreover, application of modern irrigation techniques like drip irrigation system and sprinkler irrigation system, are needed to be encouraged. Special attention is required for the southern and south-western part of the district where the groundwater is saline and rising at many places due to inadequate withdrawal. The results also emphasize the need to promote awareness among the end users of their water quality, to protect groundwater aquifers and to implement proper management strategy for sustainability of the resource. Strict regulations are needed to be implemented to reduce the risk of groundwater contamination by fertilizers and pesticides.

Conjunctive use of groundwater with canal water and proper selection of crops in southern and south-western part of the district can be useful to counter the problem of salinity. Strict regulations are needed to be implemented to reduce the risk of groundwater contamination by fertilizers and pesticides.

References

CGWB, (2006). Dynamic ground water resources of India. Central Groundwater Board, Ministry of Water Resources, Govt. of India, New Delhi.

Custodio, E. (2002). Aquifer over-exploitation: what does it mean? Hydrogeology Journal, 10: 254-277.

Prabhakaran, N., Gurugnanam, B., Vasudevan, S. and Joseph Santhanaraj, S. (2009). Irrigation water quality status studies through GIS in upper Manimukha sub-basin, Villupuram District, Vellar basin, Tamil Nadu, India. Natural Environment and Pollution Technology, 8(2):257-260.

Urban Water Management

Integrating Urban Rainwater Utilization into Mainstream Water Management in Accra, Ghana, the Literature Review

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Keywords: Rainfall, Climatic variability, Water demand, Water supply, Rainwater runoff challenges

Abstract Accra, the capital city of Ghana faces serious water management challenges and the situation is likely to escalate in the future if the situation is not addressed. Monumental municipal water projects and groundwater extraction in dry areas of Accra, and substantial rainfall in other areas have provided a generally available water supply. This leads to the view that water is an abundant resource - and, perhaps, to its unnecessary waste. But the limited availability of water is becoming increasingly clear in Accra with the increasing pace of urbanization. The increase in impervious surfaces from development accompanying population growth has resulted in even more stormwater runoff carrying pollution to rivers, lakes, and beaches. Climate change has compounded water resource challenges, at the same time that increasing population has added demand to existing water supplies. These emerging water challenges in Accra only increase the stress on critical water supplies and demand a re-examination of current water management practices. The longstanding reliance on centralized water delivery systems in Accra means that opportunities to integrate alternate local sources of water to meet local water demand are often overlooked. As the water crisis in Accra gets to its peak, there is a dire need of reform in water management system. Rooftop Rainwater Capture is a sustainable practice that can help address these challenges. However, this can only be done when proper documentation of the merits and demerits of the rainwater capture in terms of quality, quantity and design is available. For example, what are the economic, environmental and health implications for proper management of rainwater in Accra? This study aims at addressing the question: How can urban rainwater utilization be integrated into mainstream water management, and why is it an option for effective urban water management in Accra?

Comparative Assessment of a Distributed Model and a Lumped Model for Estimation of Sediments Yielding in Small Urban Areas

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Keywords: Erosion, Hydrologic modeling, Sediment modeling, Urban planning

Introduction
Increases in urbanization during XX century, have brought as one major problem the increased of sediment production. Hydraulic erosion is one of the major causes of increasing of sediments in small urban catchments. Such increments in sediment yielding in header urban catchments can caused obstruction of drainage systems, making impossible to capture urban runoff, increasing runoff volumes and thus exacerbating problems of urban flooding. For example, some estimations made in the city of Barcelona (Spain) indicate that around 20.000 T/year of natural sediment arrive to the sewer, from the upstream natural basins. Besides of these problems, there is the fact of runoff water pollution is associated to runoff volumes. For example, levels of sediment concentration are highly correlated to pollutants transport as Phosphorus and Nitrates. For these reasons, it is more and more important to study of sediment production in urban watershed for properly analyze and solve problems associated to sediments.
The study of sediments production has improved with the use of mathematical modeling. Modeling has been highly used by water resources planners, water quality managers, engineers and scientists for comprehension of processes that drive sediment production and interactions between them. Modeling can be done by empirical or physically based models. The first ones are useful for estimating sediment yielding for continuous time step and for big lumped areas. Although, empirical models does not capture responses to high intensity and short duration events, sources of erosion, long time changes and/or sediment deposition rates. For these reasons, physically based models could be more useful for the study of local factors as sediment detachment and flow transport. In view of the above, numerous distributed physically based models have been developed. However, some authors state that distributed models must be carefully applied because of their high complexity, they have over-parameterization problems, unrealistic data requirement, cell resolutions effects on outputs and/or non extrapolating conditions (Woolhiser 1996; Merrit, Letcher et al. 2003).
According to the above, it is proposed a new physically based model applicable to small header urban watersheds that includes the advantages of distributed physically base models, but with more realistic data requirements. Additionally, in this paper the model proposed is compared with a lumped model, reviewing the results, the advantages and disadvantages between the both of them.

Methodology
The study consists in apply RUSLE model, and the new distributed physically based model in a watershed located in the Principality of Andorra. The watershed drains an area of 36.2 ha through L'Aviar drainage. It was realized a bibliographical searching, for determine appropriated parameters for modeling. Second, events were defined, searching those with higher intensities and short duration. Last, the models were applied.

RUSLE Model
RUSLE 2.0 is a new, advanced erosion prediction technology that uses USLE empirical structure of use in the Universal Soil Loss Equation (USLE), developed in 1985 for the Agricultural Research Center (ARS) of the United State Department of Agriculture (USDA). RUSLE2 uses modern erosion and computer science to greatly extend the basic USLE structure (Equation 1). According to ARS web site, RUSLE2 now have a computer interface that makes it easily used and adaptable to special conditions.

$A = R.K.L.S.C.P$	Equation 1

Where: A = net detachment (mass/unit area), R = erosivity factor, K = soil erodibility factor, L = slope length factor, S = slope steepness factor, C = cover-management factor, and P = supporting practices factor.
RUSLE2 (also RUSLE1) is still regularly used as regulatory and planning tool for government agencies. For that reason, it has been continuously updated and it is available in the web site http://www.ars.usda.gov/Research/docs.htm?docid=5971, as RUSLE2 (Jan 19, 2005) the latest release of RULSE by ARS (USDA 2005).

Distributed Model proposed
Model proposed parameterize watershed properties discretizing it by square elements, using a Geographic Information System (GIS) based software designed for that purposed. Hydrological model simulates precipitation losses and overland and channel flow routing. Modified Rutter-Gash interception model and Green – Ampt infiltration model are used to accommodate spatial and temporal variabilities due to changes in the rainfall, land cover and/or soil properties and generates a temporally-spatially varied hyetograph. Overland and channel flow are routing using kinematic wave approximation of 1D Saint-Venant equations. The erosion/sedimentation rates are calculated using Foster and Meyer (1972) solid mass continuity equation. Sediment is routed from one cell to another in 8 possible directions. Deposition is take into account if sediment concentration in the flow exceeds transport capacity, which is estimated by Engelund-Hansen (1967) or Yang (1973) model (Julien 1998). An explicit finite difference technique is used for the routing of 1-dimensional channel and overland flow.

Expected Results
In the present study a comparison between a simplified lumped model and a distributed model will be presented. The main goal will be verify the reliability of each model in case of few available field data. The study pretend to evaluate difficulties presented in the application of each type of model in real watersheds. For that reason, both models will be applied in Aviar watershed of Principality of Andorra which is a small watershed of 36.2 ha.
Another goal of the study will be analyze how each model performs when similar parameters are used as inputs. It will be compared differences in watershed conceptualizations, hydrological and sediments models, and their influence in outcomes (flow volumes, times to peaks and local effects of sediments transport).

References
Engelund, F. and E. Hansen (1967). A monograph on sediment transport in alluvial streams. Teknisk Forlag, Copenhagen, Denkmark Tecnologic University, Hydraulic Lab.
Foster, G. R. & L. D. Meyer. (1972). A closed-form soil erosion equation for upland areas. In: SHEN, H. W., ed. Sedimentation: Symposium to Honor prof. H.A. Einstein, 1972 Fort Collins, CO. Colorado State University, 12.1-12.19.
Julien, P. Y. (1998). Erosion and sedimentation. Cambridge, Cambridge University Press.
Merrit, W. S., R. A. Letcher, et al. (2003). "A review of erosion and sediment transport models." Environmental Modelling & Software 18: 761-799.
USDA. (2005). "Sitio web modelo RUSLE." 2009, from http://www.ars.usda.gov/Research/docs.htm?docid=5971.
Yang, C. T. (1973). "Incipient motion and sediment transport." Journal of Hydraulic Engineering Division. ASCE 99(10): 1679-1704
Woolhiser, D. A. (1996). "Search for physically based runoff model—a hydrologic El Dorado?" Journal of Hydraulic Engineering 3: 122-129.

River, Estuarine and Coastal Dynamics

Estimation of Wave Run-up in the Northern Indian Ocean Using WAM Model

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Keywords: Wave run-up, Wave height, Wind speed, Swell, Indian Ocean

The aim of this study is to estimate the wave runup on selected beaches around the northern Indian Ocean. The runup has been estimated using ERA-Interim, which is the latest global atmospheric re-analysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). ECMWF uses the global Wave Model (WAM) model to calculate two dimensional wave spectra. Distances between the model grid points and the beaches have been calculated by a great circle calculator. The beach slopes have been calculated by Google Earth for all locations, except Maldives beach, which was assumed as an imaginary beach because the method of calculating the slope could not be used there. The significant wave height as well as the peak wave period at the grid points is assumed to be the same at the beach. The most frequent estimated runup is between 0.5 m and 1.0 m, which is produced by swell coming from the southern Indian Ocean for all locations except Sri Lanka, India and Maldives shores, where the most frequent runup value is less than 0.5 m. However, the extreme wave runup occurs with the largest wave heights during summer monsoon in July. Generally, the high wave height depends on wind sea. The mean elevation of the runup for all locations is 0.56 m. It is comparable to the measured values obtained by (Stochdon et al., 2006) at several beaches in USA and the Netherlands who found the mean value of dissipative sites (84 cm) for all experiments.

Modeling the Effect of Tidal Current Energy Extraction on Hydrodynamics at Zhaitang Island, China

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Keywords: Tidal energy extraction; Numerical model; Turbine farm; Hydrodynamics

This paper presents a three-dimensional (3-D) numerical modeling study for simulating tidal current energy extraction and its effects on the hydrodynamic process at Zhaitang Island. An existing delft3D-Flow module is refined to simulate tidal power output by adding momentum sink term into the momentum equations. The refined model is validated against measured water level and tidal currents from shipboard ADCP transects at the study site. According to the distribution of tidal flow velocity and the power density at the mid-flood and mid-ebb of a mean spring tide, two potential sites located in the tidal channel and at the south of Zhaitang Island are appropriate for turbine farm layout. Wakes will develop downstream of tidal turbine farms owing to extraction of axial momentum across the turbine rotor planes. First, a numerical simulation is employed to study the influence of an isolated turbine on the structure of wake downstream. Then, a series of numerical experiments are carried out to investigate the effects of different array configurations on the hydrodynamics and power output. The model results demonstrate that flows are attenuated inside the array and accelerated around the array, the staggered grid array turbines can absorb more power from tidal flows than rectilinear grid array turbines .It also indicates that the magnitude and extent of the observed impacts of turbine farm layout in tidal channel are greater than that around headland.

Propagation of Distant Tsunami across East Sea

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Keywords: Tsunami, Shallow water equation, Second-order upwind scheme, Run-up height

1. Introduction

Tsunamis are generally triggered by impulsive undersea ground motions. They are not dangerous in deep sea due to small wave heights. However, they are very disastrous in shallow zone.

In 1983, the Central East Sea Tsunami occurred on the western coast of Japan propagated across the East Sea and caused loss of a human life and property damage on the eastern coast of the Korean Peninsula. Also, Tsunami damage has occurred in the eastern coast of the Korean Peninsula by earthquakes occurred in the East Sea near the western coast of Japan. A fundamental way to prevent unusual tsunami attack is to construct a safe zone along the coastline based on an inundation map developed by simulating historical and probable maximum tsunami events (Cho et al., 2004).

In this study, a distant propagation of tsunamis generated near the western coast of Japan is numerically investigated. The numerical model is first employed and applied to simulation of the Central East Japan Tsunami occurred in 1983. The maximum run-up heights are predicted at Imwon Port, Korea and compared with available field observed measurements.

2. Numerical Model

In numerical simulation of a distant propagation of tsunami, few finite difference models are reported. The numerical model developed by Cho and Yoon (1998) is based on the shallow-water theory. However, the application of the numerical model is limited to the case of constant water depth if a uniform finite difference grid is employed. In other words, both numerical models have a limitation that spatial grid size and time step sizes should be changed continuously as the water depth changes. Cho et al. (2007) developed a practical numerical model to simulate the distant propagation of tsunamis in real topography. This model can release the limitation of spatial grid and temporal step sizes, however, the governing equations of this model are derived on constant water depth. That is, this model has to be cautious in being employed in real topography and some limitations should be included during numerical simulation.

3. Results

In this study, a modified dispersion-correction scheme describing tsunami propagation on variable water depths is proposed by introducing additional terms to Cho et al. (2007)'s scheme. The governing equations used in previous works are slightly modified to consider the effect of a bottom slope and the numerical dispersion of the proposed model replaces the physical dispersion of the governing equations.

The following figure shows one of final results for run-up heights at Imwon Port. The predicted run-up heights will be compared with the available field observed data.

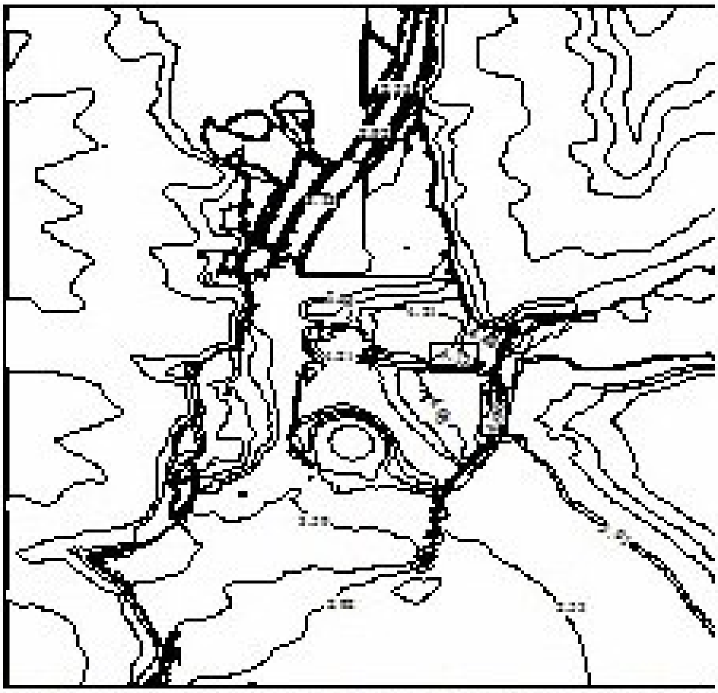

Figure. Run-up heights at Imwon due to 1983 Central East Tsunami

Bridge Scour and It's Monitoring Using GSM Enabled Sensors – a Laboratory Study

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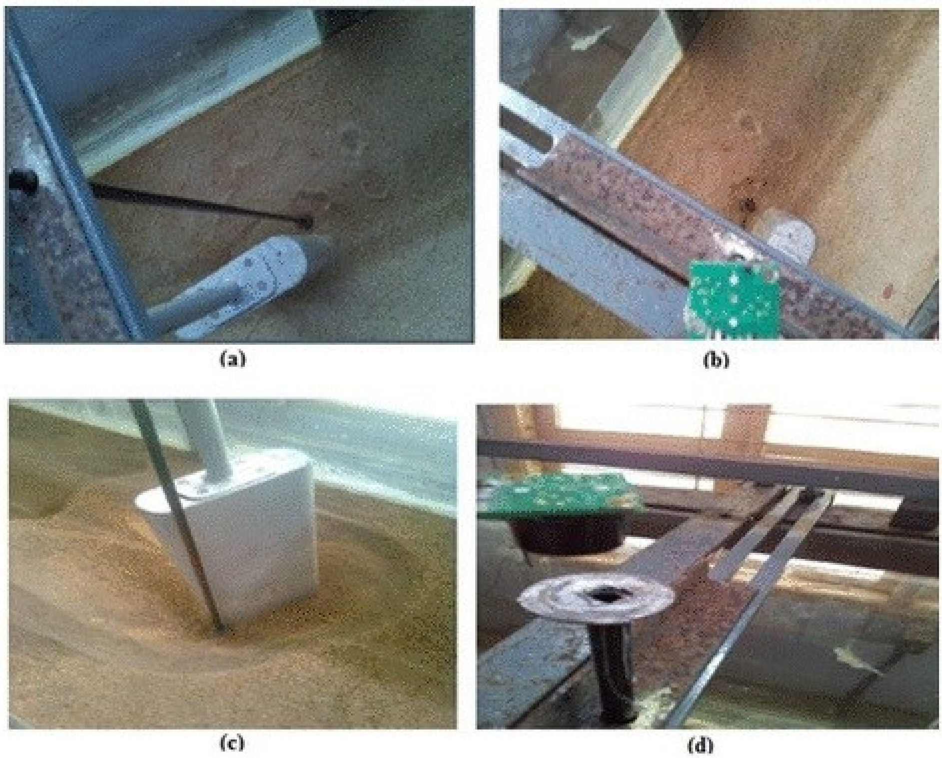
Keywords: Pier, GSM enabled Sensors, Scour, Distress signal, Bridge stability

Local scouring around the bridge pier occurs because of flow separation and developing several vortexes around the bridge pier. Such scour can cause failure of the bridges especially during the river floods. This study presents an in-situ scour monitoring system by using the Global System for Mobile (GSM) scour monitoring unit carried out on a physical model under clear water condition on cohesion less bed material. Round nosed pier models at 5 different angles are considered for these experiments and the scour is monitored using GSM enabled sensors. Scour failure occurs suddenly without prior warning or signoff distress to the bridge. However, there are many challenges to monitor the processes of scour, such as measuring equipment are essentially critical, especially during the floods. Monitoring devices connected to GSM sensors are install near to bridge pier. Using the scour data provided by GSM unit is used to sound alert for the local administration regarding the real time safety evaluation of the bridge.
The facility used for laboratory study is a tilting, re-circulating flume. It is 0.6 m wide, 0.58 m deep and 16.85 m long. The whole section is then filled with sand layer of 0.1m thickness. The slope of the channel is fixed based on the criteria of incipient motion condition. To determinate of scour depth standard point gauge and with GSM based monitoring sensors were used and duration of flow is 8 hours. The sliding pole with GSM monitoring unit is used to measure the total scour depth at bridge piers as show in the Fig 1.



(a) (b) (c) (d)

Figure 1: Experimental setup showing ultrasonic GSM enabled sensor placed on sliding pole

The GSM monitoring unit are placed at critical point where maximum scour is likely to occur. After comparing the result using GSM Scour monitoring unit the maximum variation of scour was found to be around 8 %. The GSM enabled sensors allows for continuous monitoring of streambed elevations and scour conditions. The GSM Monitoring sensors can be quickly designed and installed and it is cost-effective system. When the scour crosses a certain limit the indicators alert the station and thus preventive measures can be taken at that point so as to avoid the bridge collapse.

References

Kosnik P.E ,"White Paper: Tilt meter-Based Bridge Scour Monitoring" Infrastructure Technology Institute Structure Hydraulics & Hydrology,2000.

Moustakids. "Monitoring scour around bridge piers and aboutments using the radio frequency identification(RFID) technology".journal of hydraulic EngineeringASCE,321(1):59-65 2010.

Raudkivi, A.J. and Ettema, R. Clear-water scour at cylindrical piers. Journal of Hydraulic Engineering, ASCE, 109(3): 339-350,1983.

Sediment Transport and Morphodynamics

Comparison of Computational Models to Determinate Sediment Transport in Rivers

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Keywords: Sediment transport, Rivers, Comparison

1. Introduction

Fundamental research on sediment transport has been conducted at NCCHE in past years. NCCHE researchers proposed formulas for determining the fractional transport capacities of bed load and suspended load, which take into account the hiding and exposure effects among different size classes. In addition, formulas for the calculations of sediment deposit porosity, settling velocity, movable bed roughness and sediment transport over steep slopes were also developed. These formulas were calibrated using a large data set that included experimental and field measurements.

The newly proposed sediment transport capacity formulas were tested independently against many different experiment and field data, including Brownlie (1981) data sets, and Toffaleti (1968) data sets. Wu et al. formulas were also compared with some existing formulas, such as Ackers and White (1973) formula and its modification by Proffit and Sutherland (1983), Engelund and Hansen (1967) formula, Yang (1973) formula, and the SEDTRA module (Garbrecht, et al. 1995). Wu et al. formulas can provide reliable predictions for the fractional discharges of bed load, suspended load, and bed-material load.

2. Method

In this study it was compared some computational methods and the amount of sediment transport was determinate in the Papagayo river basin area, a region pertaining to the 20th hydrological region located close to the cost of the state of Guerrero in the country of Mexico. The Papagayo river basin includes in its territory the capital of the State of Guerrero, Chilpancingo, and therefore, possible changes in the future use of sediment transport, (i.e. irrigation, storage, supply populations, industrial and ecological use) are of major political relevance to this region.

The software package used was CCHE1D to simulate the sediment transport in dendrite channels networks of the Papagayo river, using Arc View, the digital elevation model of the Papagayo river and the channel network and sub basin (TOPAZ), and the rainfall-runoff simulation upland soil erosion (AGNPS).

3. Conclusions

After to revise some sediment transport models and the characteristics of the Papagayo river in the country of Mexico, it concludes that the best sediment transport models to apply to this Mexican river are the models developed by the National Center for Computational Hydroscience and Engineering (NCCHE) of the University of Mississippi, in the United States.

The amount of sediment transport of the Papagayo River was determinate by this software and the results will be used for design of some hydraulic structures at the Papagayo River.

References

Vieira and Wu. (2002). National Center for Computational Hydroscience and Engineering (NCCHE). University of Mississippi, USA. Technical report No. NCCHE-TR-2002-5.

Wu and Wang. (1999). Movable bed roughness in alluvial rivers. Journal of Hydraulic Engineering, 125 (12), 1309-1312.

Wu et al. (2000). Nonuniform sediment transport in alluvial rivers. Journal of Hydraulic Research, 38 (6), 427-434.

Observing Dynamic State of River-Mouth Bar and It's Control in the Yuragawa River

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Keywords: Yuragawa River, River-mouth bar, Topographic change, Field observation, Spur dike, Flume experiment, Numerical simulation

The Yuragawa River is located at the north of Kyoto Prefecture in Japan, topographic changes of river-mouth bar is continuously activated by sediment transport due to river flow and sea wave. On October 2004, a large part of the river-mouth bar was eroded by the flood flow of the typhoon No.23. After that, the river-mouth bar has developed along the right bank only, and the river-mouth channel has been fixed along the left bank. This situation may cause some problems such as bank erosion, washout of bank protection works and harmful effects on other coastal structures. Effects of water discharge during flood periods on responses of the river-mouth bar are also not clarified. Therefore, the risk of high water level caused by a river-mouth clogging is high. In order to avoid these problems and risk, it is important to understand the characteristics of the topographic change of the river-mouth bar and its cause, and to propose a control method of the bar geometry.
In this study, the temporal variations in geometrical properties (e.g., surface area and shape) of the river-mouth bar were analyzed on the basis of the hydrological and topographical data in the Yuragawa River estuary. The effects of the river water discharge and the sea wave height on the geometrical properties of the bar were also investigated. As for the bar control, the effectiveness of spur dikes, which can change the flow direction, for erosion of the bar was evaluated by means of flume experiments. The two-dimensional numerical model (iRIC Project) was also applied to further investigate the effects of spur dike on the bar control. The simulation results were verified against the experimental results.
The results obtained in this study are summarized as follows:

- Although the surface area and volume of the river-mouth bar showed the short-term fluctuations due to flood, they also showed the increase tendency on a long-term basis. The flush condition of the river-mouth bar sediments due to flood does not depend on the width of river-mouth channel and the surface area of the bar but on flood discharge. The formation of river-mouth bar may be mainly activated by an increase of longshore sediment transport rate in winter season; the surface area of the bar has a strong correlation with wave height.
- In the experiment without spur dikes, the scour depth of the river-mouth channel became large because the flow converges into the channel. On the other hand, in the experiments with the spur dikes, the erosion of the river-mouth bar became active and the scour depth of the river-mouth channel became small because the spur dikes redirected the flow toward the river-mouth bar. Sediments deposited at the upper part of the spur dikes because the flow intensity was weak there. And, the channel bed was eroded at the lower part of the spur dikes because of the secondary current around them.
- The simulation results showed that the surface area and height of the river-mouth bar considerably decrease in the early stage of the flood period, and that the decrease rate after that is relatively small. Over 3000 m3/s of flood discharge accelerates the erosion of the bar, and it also decreases its surface area remarkably. The mechanisms of flow which takes a long way around the spur dikes and river bed variation process are clarified by the reproduction calculation of the experiments.

Figure 1. River-mouth bar at the Yuragawa River, Japan.

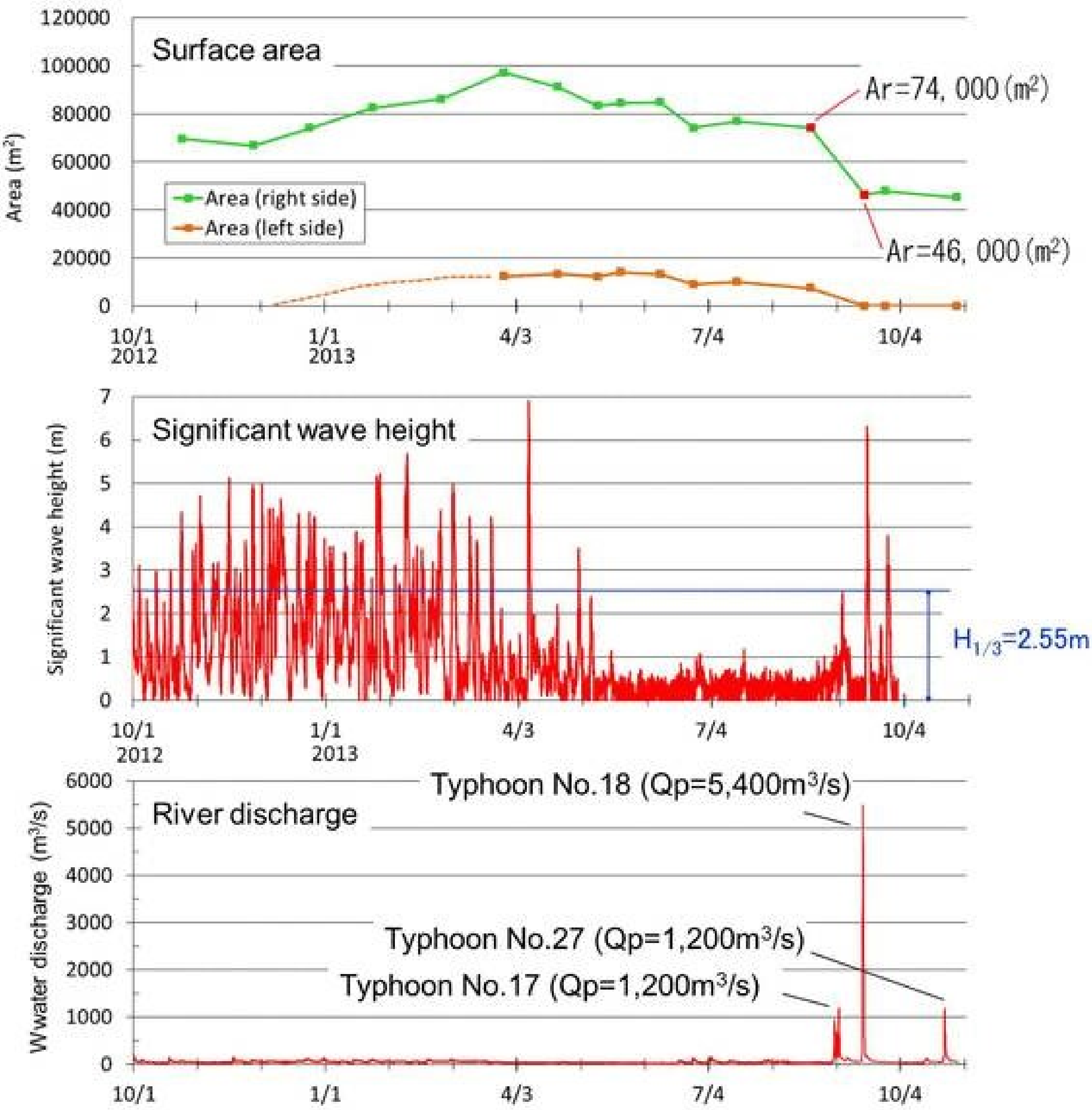

Figure 2. Temporal variations in surface area, as well as significant wave height and river water discharge.

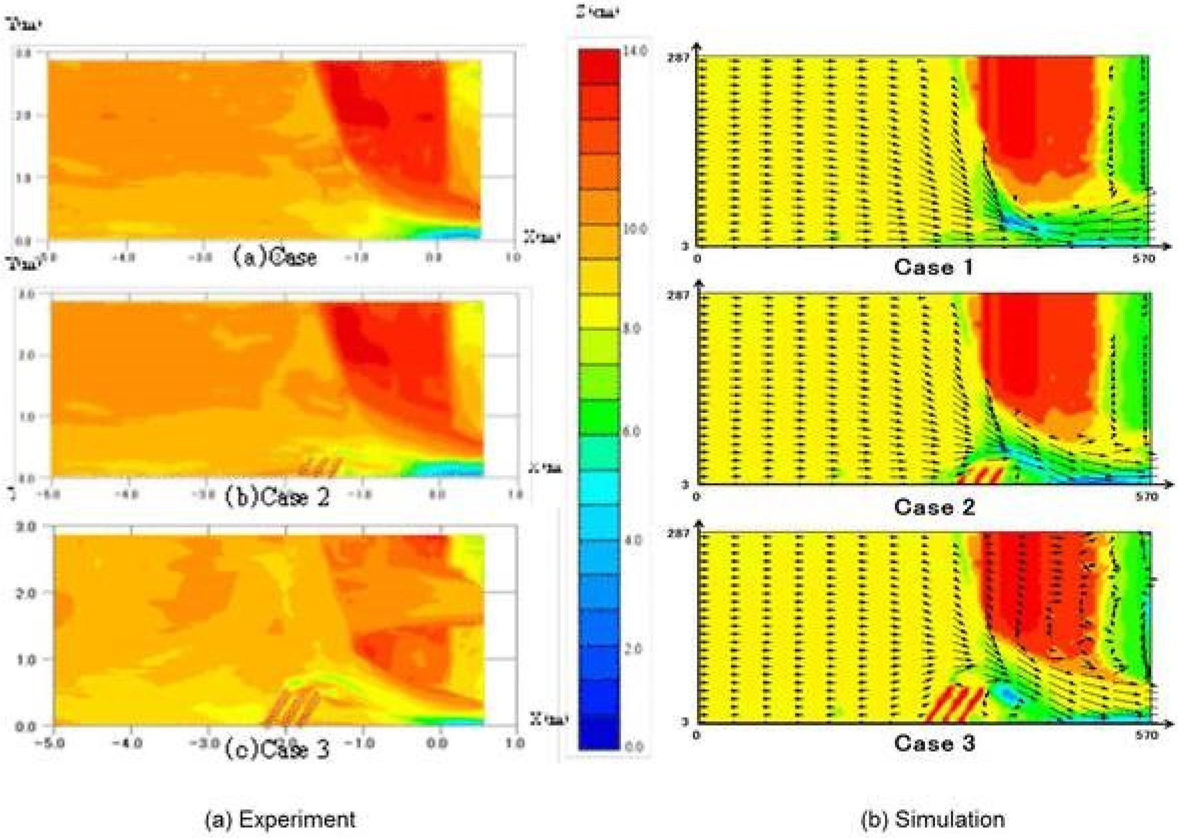

Figure 3. Effects of spur dikes on control of river-mouth bar.

2D Mathematical Modeling for Fluvial Processes Considering the Influence of Vegetation and Bank Erosion

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Keywords: Fluvial process; Influence of vegetation; Vegetation stress term; Non-cohesive bank erosion; 2D numerical model

A 2D mathematical model for fluvial processes capable of considering the influence of vegetation and non-cohesive bank erosion is established based on a body-fitted coordinate system in this paper. The authors have improved a previously developed simulation model by taking into account the impact of vegetation with a vegetation stress term in the momentum conservation equation. A simple simulation method is adopted in the bank erosion model. Simulation runs were performed for a conceptual alluvial channel, the results of channel plan-form and cross section changes suggest that the 2D model predictions agree acceptable with the classic theories of channel pattern formation considering the effect of vegetation.

Study on Sediment Deposition and Erosion Processes Upstream of a Check Dam

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Keywords: Textural behavior, Central Tendency, Kurtosis, Sorting, Platykurtic

Check dams are the most important structures to control erosion and for stability of streams. The study region in India has three seasons of the year. The rainfall is received in the area during monsoon season. The study area covers South Gyujarat region of Gujarat state, Vansda of Navsari district from (Ambika river basin). The check dam of Vansda taluka of Navsari district, South Gujarat region, which is mainly hilly area with densely thick forest, was selected for the study pupose. This study area is part of the Ambika river basin. The average annual rainfall of this study area is 1920mm. The sediment samples were collected from the study regions. First sample was taken from 20 m upstream of the check dam and second sample was taken approximately 500 m upstream the check dam. The grain size distribution was carried out using sieve shaker and sieve set having mesh sizes 19, 16, 13.2, 11.2, 9.3, 8, 6.3, 4, 2, 1, 0.5, 0.25, 0.125, 0.075, 0.063 mm. The grain sizes are distributed using Wentworth scale. The sediment distribution is presented graphically as cumulative percentage retain on D vs particle size (D).

The objective was to identify the textural behavior of sediments eroded from the catchment and deposited behind the check dams. Grain characteristics such as mean, median, mode, sorting, kurtosis, skewness and grain size distribution were computed from the analysis of samples collected. The study was also carried out for the storage of water for the two consecutive years. The grain size distribution is due to the variation in local condition of topography, catchment characteristics, crop pattern and the soil type of the catchment area. The analysis results showed that most of sediment samples of South Gujarat region are fine gravel, very fine gravel and very coarse sand. The sediments are platykurtic type, poorly sorted and skewed. The volume of sediment deposited behind the check dam has been work out. The erosion rate for the catchment area has been derived form the actual volume of sediments trapped behind the check dam.

References

R. FERNANDEZ LUQUE, R. VAN BEEKN, Erosion and transport of bed-load sediment, Journal of Hydraulic Research, 1974, 14,127-144.

Canton, Y., Domingo F., Sole –Benet A.,Puigdefabregas, J.,(2001), Hydrological and erosion response of a badlands system in semiarid SE Spain, Journal of hydrology Vol.252,pp.65-84.

Romero-diaz,A., Alonso-sarria,F., Martinez-lloris, M., (2007), Erosion rates obtained from check-dam sedimentation (SE spain). A multi-method comparison. Catena Vol.71, pp.172-178.

Drift Velocity for Sediment-Laden Downward Jets

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Keywords: Drift; Sediment-laden jets; Two-phase; Concentration; Velocity

The study of two-phase jets is a field of great interest, not only because of the need of understanding in industrial applications and natural processes, but also because there remain numerous theoretical challenges and unsolved problems in the field. In fluvial hydraulics, the study of sediment-laden jets has attracted considerable attention. Lots of achievements have been reported from both experimental and theoretical points of view.

Considering the complication of sediment-laden jets, in the previous studies, more attention was paid to the experimental observations, representatives of which were the achievements reported by Singamsetti (1966), Muste et al. (1998), Jiang et al. (2005), and Hall et al. (2010). By virtue of the experimental observations, some characteristics of two-phase jets were found, which promoted the developing of the theoretical researches. For instance, the turbulence model for sediment-laden jets was proposed and used by Al Taweel and Landau (1977), and Sun and Faeth (1986). Jiang et al. (2005) predicted the velocity distributions based on two-phase conservation equations and found that the velocity difference between sediment and fluid was the setting velocity of particles. However, with the increasing of the inertia particle and concentration, several factors, such as the particle inertia and collisions between particles will have significant effects on the movement of sediment-laden jets, which were not taken into account reasonably in the aforementioned studies.

Recently, Zhong et al. (2013) has investigated the sediment transport in turbulent open channel flows by employing the two-phase mixture model derived from two-fluid model. The drift velocity, a key parameter in this model, which is defined as the difference between the sediment-water mixture and individual phase was obtained by using the perturbation approach. The theoretical expression for drift velocity reflected any mechanism of the sediment suspension including the effects of turbulence, collisions between particles, and the particle inertia. The result is helpful for us to understand the properties of sediment-laden flows.

In this work, we intend to obtain the drift velocity for sediment-laden downward jets by applying the two-phase mixture model. Furthermore, the velocity and concentration distribution for solid phase are analyzed. For verification, comparisons with experimental observations are presented. Results show that the effect of particle inertia can be ignored under the condition of low concentration or small diameter. However, with the increasing of the value of inertia, its effect on the behavior of sediments become obvious, and should be taken into account.

References

Singamsetti, S.R. (1966) Diffusion of sediment in a submerged jet. J.Hydraul. Div., Am. Soc. Civ. Eng. 92(2), 153-168.

Muste, M., Fujta, I. and Kruger, A. (1998) Experimental comparison of two laser-based velocimeters for flows with alluvial sand. Exp. Fluids 24, 273-284.

Jiang, J.S., Law, A.W.K. and Cheng, N.S. (2005) Two-phase analysis of vertical sediment-laden jets. J. Eng. Mech. 131(3), 308-318.

Hall, N., Elenany, M., Zhu, D.Z. and Rajaratnam, N. (2010) Experimental Study of Sand and Slurry Jets in Water. Journal of Hydraulic Engineering-Asce 136(10), 727-738.

Al Taweel, A.M. and Landau, J. (1977) Turbulence modulation in two-phase jets. Int. J. Multiphase Flow 3, 341-351.

Sun, T.Y. and Faeth, G.M. (1986) Structure of turbulent bubby jets -I. Methods and centerline properties;-II. Phase property profiles. Int. J. Multiphase Flow 12, 99-126.

Zhong, D.Y., Wang, G.Q. and Wu, B.S. (2013) Drift velocity of suspended sediment in turbulent open channel flows, Journal of Hydraulic Engineering.

Interaction between Offshore Utilisation and the Environment

Hydrodynamic Response of Fixed and Floating Offshore Wind Turbines for Wave Conditions Encountered in Greek Seas

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Keywords: Offshore wind turbines, VOF method

In recent years there has been a rapid growth in the use of Renewable Energy Sources and especially of wind turbines, as part of the overall trend towards sustainable development. In this frame, the use of offshore wind turbines increases due to their advantages as opposed to onshore wind turbines, i.e., the improved wind conditions of open sea, the elimination of disturbance of shores and the flexibility of using larger offshore areas for the installation of larger wind parks. For design purposes offshore wind turbines can be distinguished in two types: fixed and floating turbines, where the main criterion for selecting the preferred type is the water depth. So, for water depths up to 30-40 m the bottom-fixed type is commonly used for offshore wind turbine which rest directly on the seabed, while at water depths greater than 30 m a floating structure is utilized to support the turbine. In this paper the wave-structure interaction, focusing on hydrodynamic loading and response, is simulated for both a fixed and a floating wind turbine under typical wave conditions encountered in Greek seas. For the fixed case a monopile type structure rested directly at the sea bottom was simulated, while for the floating type a Spar-Buoy type structure was used. Simulations were performed using the commercial CFD code ANSYS-FLUENT, which is based on a finite volume discretization. Our aim is: (a) to investigate the capability of the numerical tool to simulate the hydrodynamic loading and response of a fixed or floating structure under wave loading conditions typical of Greek seas, (b) to extract reliable numerical hydrodynamic results usable for the analysis and design of fixed and floating wind turbines in Greek seas environment. For these purposes the unsteady, turbulent flow induced by wave propagation past a fixed or floating structure was simulated using the VOF formulation for the free-surface treatment, and the SST k-ω model for the turbulence closure. First, the corresponding turbulent flow with wave height of 1m, wavelength of 100m and a period of 8s without the presence of a turbine was considered for method validation, i.e., to verify the capability of accurate simulation of wave propagation, as well as to serve as a basis of comparison for the cases with fixed and floating wind turbine structures. Results are presented for a bottom-fixed monopile structure with diameter of 6m at water depth of 20m, as well as for a Spar-Buoy floating structure at water depth of 100m. Three cases of incoming wave characteristics were considered with maximum wave height of 5. Under these conditions, the results include the diffraction of waves, the separated velocity field, the distribution of the dynamic pressure induced by the oscillatory flow on the wall of the fixed and floating structures, as well as the drag and lift force coefficients.

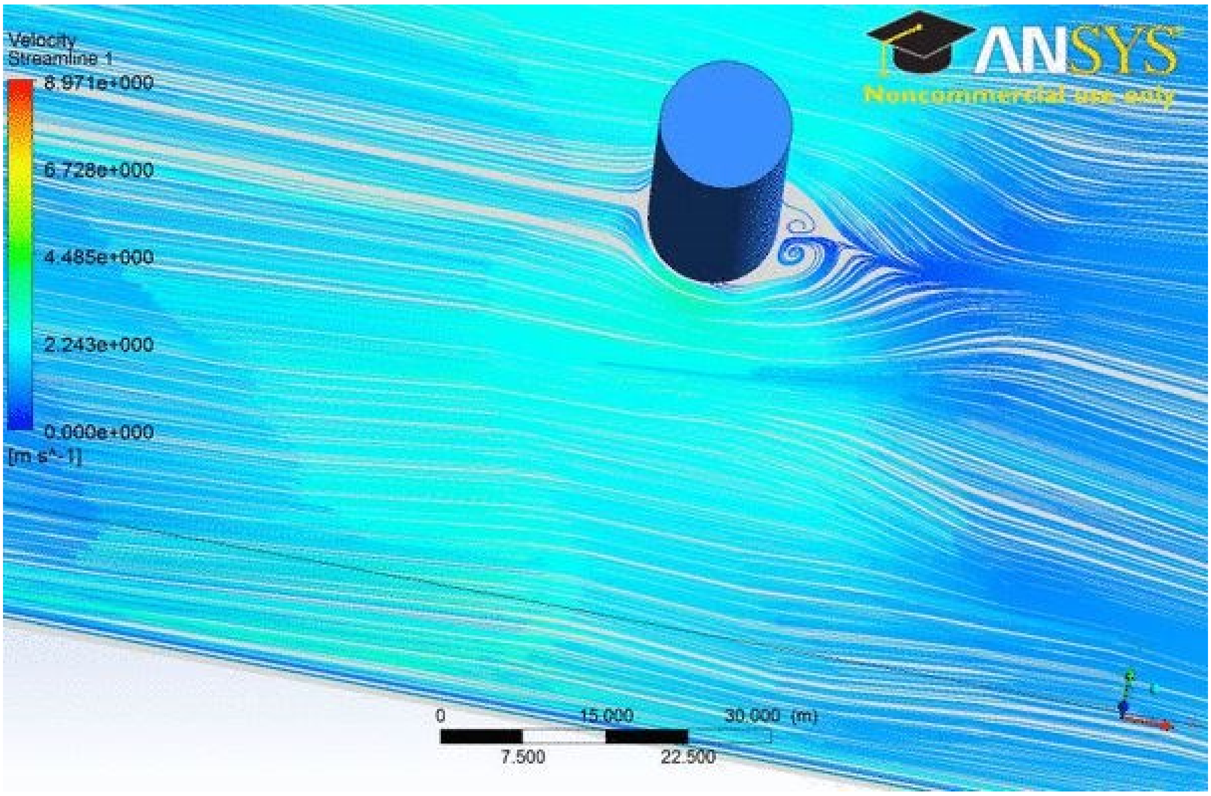

Figure 1. Flow separation induced by the wave propagation.

Climate Change, Adaptation and Long-Term Predictions

Impact of Sea Level Rise on Coastal Disasters at Chiayi Coast

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Keywords: Sea level rise, Coastal erosion, Coastal inundation, Land subsidence, Wetland

Chiayi County located on the south-western Taiwan, it is a typical poverty county dependent on agriculture; most of the people rely on agriculture, aquaculture and fishery. As the aquaculture demand, excessive extraction of groundwater has caused serious land subsidence; this was leading to lowland flooding and seawater intrusion. Meanwhile, Chiayi coast currently suffered on beach erosion and storm surge overtopping. If sea level is rising, all of the problems may be more seriously. In this paper, we discuss the coastal disasters may happen in Chiayi coastal zone and assess the impacts affected by the sea level rise.
We analyzed tidal data measured at Wenkung site during 1983~2013. The result shows that the relative sea level of ChiaYi coast has been rising about 45cm(including ground subsidence). Sea level rise will bring more seriously adverse effects on the coastland, so how the sea level rise will be impacted to this county was assessed in this paper. The result shows that the main affected area concentrated at the seashore villages as Budai and DongShih regions, these two villages also suffered severe coastal hazards caused by land subsidence. 1m sea-level rise would affect more than 58 thousand people, with a 4812 hectares inundated area and cause of 74.6 meters shoreline retreat and the economic loss may be approached to $NT 57 billion. Table 1 shows the flooded area simulated by the SOBEK and Table2 shows affected wetland area of the major wetland. The more seriously problem is an offshore sand bar called Waisunding will be disappeared. This barrier plays as a physical breakwater to prevent wave and storm surge attacked the coast directly. However it is already migrating landward and thinning because of wave over-washed and a deficit in sediment supply, sea level rise will accelerate its submerged speed and cause more severely coastal disasters to Chiayi, Table 3 shows the area of Waisundin barrier immerged by sea level rise. All the detail impacts will be discussing in our full paper.

Table 1 Maximum inundation situation

Sea level rise(cm)	Maximum inundation (10 year return period)		Maximum inundation (25 year return period)	
	area(ha)	Depth(m)	area(ha)	Depth(m)
0	3091.25	0.490	4535.55	0.595
25	3211.05	0.512	4672.26	0.628
50	3239.18	0.529	4721.32	0.669
75	3401.36	0.588	4838.15	0.731
100	3595.37	0.649	4932.87	0.791

Table 2 Wetland affected by sea level rise

Title	Oweko	Putsu Estuary	Haumeliao
Area	1538 hectares	2397 hectares	922 hectares
Species	Plants:290 Birds:206	More than 168	More than 266
Influence by SLR	21% by 50cm 42% by 100cm	38% by 50cm 50% by 100cm	54% by 50cm 69% by 100cm

Table 3 Waisundin barrier immerged by sea level rise

Sea level rise (cm)	Immerged area(km^2)
25	1.85
50	3.55
75	5.05
100	7.12

Determination of Tide Harmonic Constants and Mean Sea Level at Algiers Harbor from Tidal Data Processing

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Keywords: Tide, Tide gauge, Mean sea level, Harmonic analysis, Harmonic constants

The ocean tide is the periodic variations in sea level due to the Moon and Sun attraction effects. It is the apparent relative movement of these celestial bodies that generates gravitational force causing periodic and wave movement of ocean water masses.
In order to determine a national vertical datum for Algeria, the National Institute of Cartography and Remote Sensing (INCT) has completed the installation of an automatic acquisition tide gauge (Log_aLevel) at the Algiers harbor (Algeria).
The aim of the harmonic analysis is to determine the amplitude and phase of the harmonic constants which are the unknown of our problem. To determine these, we should analyze the observation series by adopting the least squares adjustment method.
The harmonic analysis of tide gauge measurements from Algiers station, provided by the INCT under the INCT/CTS convention and for over one year of observation, permits us the determination of the harmonic constants of the tide and the mean sea level at the Algiers harbor.
Note that the identified components can be used for predicting a tide. The processing of these data allows us to detect a difference 9.8 cm between the current reference and the mean sea level determined in the context of this work.

Climate Change Effect on Water Resources for the Yangtze River Basin

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Keywords: Temperature, Precipitation, Runoff, Climate change, Water resources

The Yangtze River is the biggest river in China and Asia and the third one in the world. It has the length of about 6300 km and its basin occupies the areas of 180×10^4 km^2, about 1/5 of the continent area of China. It provides the total water resources of 36% in China. Due to the growth of population and expansion of agricultural, energy and industrial sectors, the demand for water has greatly increased; therefore, it is important to investigate the climate change effects on the water resources in the Yangtze River basin.

In this study, the data during the period of 1961-2010 were used to investigate climate changes, and they come from 138 meteorological stations. The abrupt change time and linear trends of time series were investigated by means of the M-K non-parameter test and linear regression methods, the runoff change by the observed daily runoff, and the relationship between climate elements and runoff through the relative analyses.

The results showed that, the time scale of 50 years can be divided two periods, i.e., previous period (1961-1990) and later period (1991-2010) if year 1990 was considered as the limit. Those two periods presented obvious different characteristics of the climate and then water resources. Where the mean annual temperature is concerned, in the previous period the weak linear trend occurs, while in the later period this kind of the linear trend gets to about 0.51℃/10 yr. With respect to the annual precipitation, its linear trend is about 1.4 mm / 10 yr for the previous period, characterizing slight increase trend, while the significant decreasing trend with -33.7 mm / 10 yr appears in the later period. For the runoff, there is a negative trend during all the 50 years. Its value of the previous period is -36.2×10^8 m^3 / 10 yr, however, in the later period this kind of the negative trend rises to -882.3×10^8 m^3 / 10yr. In other words, the runoff is significant decreasing in recent 20 years.

In summary, it could be concluded that is in recent 20 years both the precipitation and water resources significantly decrease due to the climate warming for the Yangtze River basin. This is dangerous signal!

A Study of the Impact of Sea Level Rise on Erosion and Inundation at Batu Pahat Coastline, Johore, Peninsular Malaysia

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Keywords: Climate Change, Sea Level Rise, Numerical Modelling, Inundation, Erosion, Salinity Intrusion

Peninsular Malaysia with 1,630km coastline and associated coastal zone area is a valuable national asset. It provides gateway for world commerce, inland trade, recreational areas and most bio-productive area for marine life. In recent years coastal erosion has resulted in damage and loss of agriculture land, mangrove forests, house, roads and recreation beaches. Many factors contributed to the erosion in Peninsular Malaysian coastline either it is human induced or a natural phenomenon due the Climate Change and Sea level Rise (SLR). The SLR projection for Peninsular Malaysia is predicted to have a mean between 0.07 – 0.14 m in the year 2040 and a mean between 0.25 - 0.52 m in the year 2100. SLR affecting the equilibrium of the hydrodynamics processes at the coastline around the world. Combination of extreme weather events and SLR (IPCC, 2012; Mclean, 2009) can cause increased levels of inundation and storm flooding, increased current velocities which will accelerate coastal erosion and damaged to infrastructures and saltwater intrusion.

In 2009 NAHRIM has carried the study to determine the rate of erosion of Peninsular Malaysia coastline using Remote Sensing and GIS. The results of the analysis by comparing the shoreline using a topographic map (year 1980 to 1999) and with satellite images (year 2006 to 2009) found that throughout the 1,630 km coastline analyzed experienced erosion rates as well as the stability of different magnitude. The surveyed coastline has shown that 6.55% experienced accretion, 23:59 % which is in the category of erosion and 69.86 % were in stable condition.

A pilot detail study was done in 2013 at entire 75km coastline of the district of Batu Pahat, Johore which experiencing severe erosion and coastal flooding and also possibly inverse Vertical Land Motion (VLM). Study area is located at the southern stretches of Malacca Straits situated between Peninsular Malaysia mainland and Sumatra. The area is generally flat terrain with two major rivers flow naturally called named Sg. Batu Pahat and Sg. Parit Botak and another two controlled by tidal gate which known as Sg. Senggarang and Sg. Punggor. The Objectives of the study are to understand the hydrodynamic of the study area by numerical model (i.e. Mike 11, Mike 21 and ArcGIS), to simulate potential inundation area cause by 0.253 m (NAHRIM 2010) and extreme 1 m (IPCC, 2012; Mclean, 2009) of SLR and to evaluate the impact of inundation to residential area, population, road network and mangrove area.

Baseline model result estimated that 5.4% of the residential area and 71.4% of mangrove area already affected under exiting condition. Northern region which is on lower elevation in more vulnerable to SLR as compare to Southern. Currently, the residents in this area are already concerned about the effects of wave intrusion during the monsoon season that may damage the wooden houses or road network. Overtopping of wave and storm surge into the low-lying area at the hinterland is prevented by the existing rock revetment which itself under treat of collapse because of severe erosion on its toe.

Further increase in SLR will results in a permanent loss of residential area to the sea. From the study it is estimated that 14% of the coastal area will be permanently lost to the sea by the end of the century. This will become more serious in 2100, when there will be higher waves on higher water levels. If no actions been taken to prevent the storm surge and overtopping of wave, the low-lying residential settlement and plantation plots will be submerged by salt water which may be harmful to agricultural land and effected the livelihood of the population in the study area.

Eco-Hydraulics and Eco-Hydrology

Numerical Modeling of Flow in Open Channel with Vegetation Patch

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Keywords: Vegetation patch, Wake flow, Numerical simulation

Flow through porous media has attracted a lot of attention, such as, researches on water through piles in coastal engineering, air through reactor in chemical engineering, flow through vegetation patch, et al. In this study, a k-epsilon model was used to model the flow around a vegetation patch. And the numerical results were compared with experiments. A good agreement of velocity and turbulence characteristics was found between the numerical and experimental data. And the results helped us to understand the adjustment mechanics of the flow through porous media.

Numerical Investigation of Seaweed Expansion by Constructing Grounds on a Filled Sea Caldron

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Keywords: Sargassum bed, Sea caldron, Tidal current simulation, Multi-level density flow model, Germling particles tracking, Euler-Lagrangian transport model

1. Introduction

In the Seto Inland Sea, Japan, there are many sea caldrons resulting from submarine erosion by tidal currents. In some of them, the accumulation of marine sediments worsen the environment of fishing grounds. One of the measures for improving the environment is to construct seaweed bed by filling up the caldrons. In this study, to access the seaweed bed newly constructed on a filled caldron, tidal current is firstly numerically estimated. Secondly the possibility for the self-formation of seaweed bed (*Sargassum* bed) on the filled area is examined based on the estimated reach of the germlings released from the natural *Sargassum* beds and transported by the estimated tidal current, by means of the germling particles tracking method.

2. Numerical Models

A multi-level density flow model and an Euler-Lagrangian transport model (Fujihara et al., 1997; Nakata et al., 2000) are employed for tidal current simulation and germling particles tracking, respectively. The multi-level density flow model consists of the momentum equation with *f*-plane and hydrostatic approximations, the continuity equation, the equation of free surface, the diffusion equations of water temperature and salinity, and the state equation of density. These equations are discretized by the finite difference method on the staggered grids. In the discretization, the explicit time-marching scheme is employed for unsteady terms, the second-order upwind scheme for convection terms, and the central difference for diffusion terms. The Euler-Lagrangian transport model tracks particles that represent the germlings of seaweed transported in the flow fields computed by the above-mentioned flow model.

3. Study Area and Computational Conditions

The artificial seaweed bed will be constructed on the filled caldron whose original maximum water depth was 27 m, in the Seto Inland Sea, Japan. The caldron is filled up to 5 m below the mean sea surface. The tidal current simulation is carried out for the domain of 10 km (east and west) × 6 km (north and south) including the artificial seaweed bed area. The whole domain is discretized into 50 m × 50 m square meshes horizontally and 10 levels vertically (2 m interval from depth of 0 m to 10 m, 4 m interval from depth of 10 m to 26 m, and deeper than 26 m as one layer). As open boundary conditions, the tidal current velocities are given at the west boundary and the free outflow condition is applied along the east boundary. Along the imaginary north boundary and land boundary, the non-slip condition is applied. The germling particles tracking is carried out using the results of tidal current simulation to estimate the possibility for the self-formation of seaweed beds in and around filled area. Since the natural *Sargassum* beds consisting of the *Sargassum horneri* are found in the study area, the germling of the *Sargassum horneri* is selected as a target species. The particles representing germling are released from the observed natural seaweed bed. Since the *Sargassum horneri* is a yearly plant, the expansion of germling particles is evaluated in terms of "the efficient area ratio" by third generation. The ratio is defined as the ratio of the settled area of the particles to the area artificially constructed.

4. Results

Computed maximum flow fields during the flood at 1 m deep before and after filling the caldron are shown in Fig.1 and Fig.2, respectively. The main flow direction is south-east at the flood. Difference of the flow velocities between these two cases are found at the central part of the strait and the filled area. The germling particles tracking result by third generation with neglecting survival ratio is shown in Fig.3. The result shows that approximately 40% of the filled area is covered with germling particles by three years, and thus it is concluded that the *Sargassum* beds would expand naturally on the filled area from generation to generation.

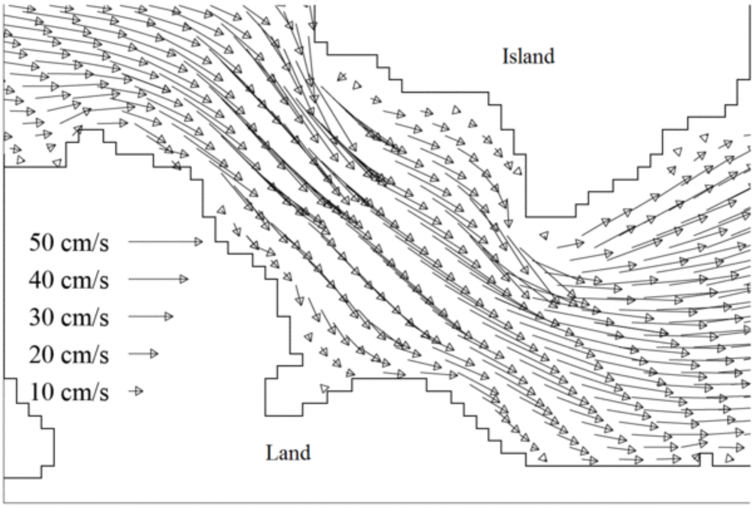

Figure 1. Computed flow fields before filling.

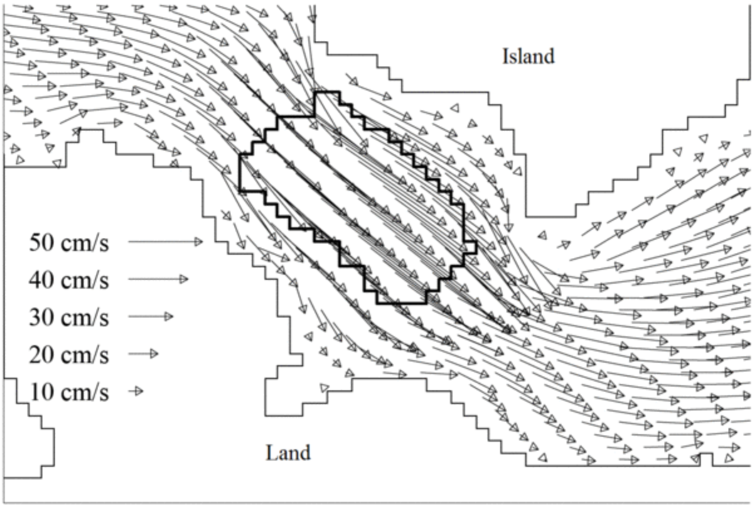

Figure 2. Computed flow fields after filling.

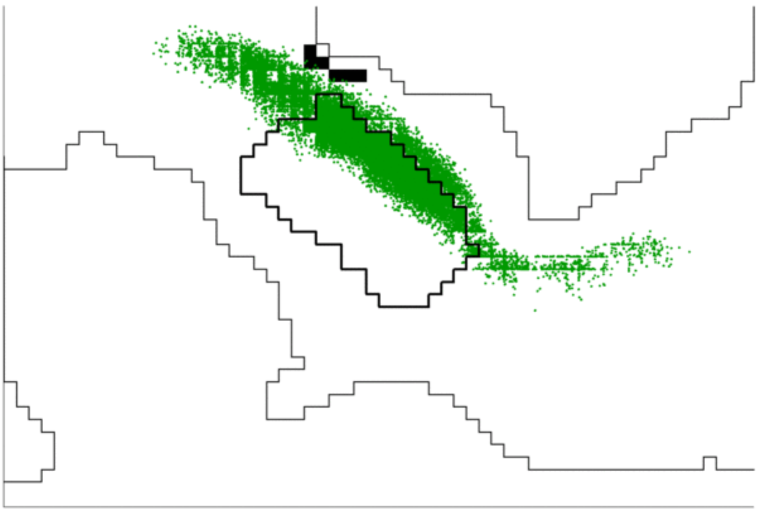

Figure 3. Distribution of settled germling particles in the third generation.

5. Conclusions

In order to access the seaweed bed artificially constructed by filling a sea caldron, change of tidal current and the expansion of the seaweed bed from the existing area are numerically examined. The result shows that the changes of tidal current appear at the central part of the strait and the filled area, and that the seaweed bed (*Sargassum* bed) would be formed in the filled area.

References

[1] Fujihara et al.: Numerical simulation on the transport of brown sole eggs and larvae using an Euler-Lagrangian method, Fisheries Engineering, 34(2), 147-154, 1997 (in Japanese with English abstract).

[2] Nakata et al.: Effect of blows on the transport and settlement of brown sole (Pleuronectes herzensteini) larvae in a shelf region of the Sea of Japan: numerical experiments with an Euler-Lagrangian model, Journal of Sea Research, 44, 91-100, 2000.

Attenuation of Nitrate and Chloride Impacts in Porous Media by Reuse of Rice and Food Residues

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Keywords: Nitrate, Chloride, Rice and food residues, Reuse, Attenuation

In recent years, decreasing environmental impacts, safeguarding consumer health, and developing recycling and reuse streams have been increasing interest in agricultural and industrial activities. As for agricultural activities, large amounts of agricultural residues are discharged, for example, from the harvesting of rice, instant coffee and tea manufacture. Particularly, rice is a staple food of over half the world's population and the rice production reached about 718.3 million tons in 2011. However, most of these residues are burned as wastes, which result in the production of carbon dioxide, or the greenhouse gas. Additionally, surplus nitrate fertilizers and animal waste disposal lead to nitrate pollution in a field. Both groundwater and surface water can be contaminated by excess nitrate as a result of agricultural activities. From the perspective of prevention of human and climate health and establishment of a recycling-based society, it is necessary to develop new technologies to reuse agricultural residues for useful purpose.

This paper investigated the potential use of agricultural residues for attenuating nitrate in porous media. Some quantity factors such as the mass recovery fraction, dispersivity and retardation factor were identified using temporal moment approaches based on a time series of nitrate concentration. Moreover, quantity parameters for assessing the potential use of agricultural residues were also discussed.

In this study, silica sand was selected to reflect a sandy aquifer having a relatively high hydraulic conductivity. In addition, Andisols, which are agricultural soils, were also used in order to investigate the difference of the degree of nitrate attenuation associated with a soil type. Column experiments were conducted using three types of rice residues including rice husk, rice straw and rice bran and two types of food residues such as used coffee grounds and tea wastes, which were homogeneously mixed with soil materials. In order to examine the effect of the amount of these residues on nitrate transfer, the weight of soil materials equivalent to the column height of 1.5 cm, 2.1 cm and 3.4 cm was replaced with residues of interest. In column experiments under saturated conditions, KNO3 solution was employed. From a practical viewpoint regarding salt transfer in a cropland, chloride ion was also employed. Pore water samples at the end of the column were taken at specific intervals to measure the concentrations of nitrate and chloride ion. Experimental breakthrough curves (BTCs) which are the relation between the elapsed time and the concentration of nitrate effluent are obtained from the results. Observed BTCs exhibit the reduction of peak concentration with the mixture of residues. This implies that the use of agricultural residues affects the change of pore structure at microscopic level. In order to identify quantity factors which reflect mass attenuation, dispersivity and retardation, BTCs were analyzed using temporal moment analysis.

From the practical point of view, larger dispersion contributes to a significant mixing or dilution of solute in a field. The experimental results demonstrated that, on average, the mixture of agricultural residues including rice and food residues result in slight increase of the solute dispersivity in both soil materials. The range of the dispersivity in silica sand is the same as that in Andisols. Moreover, it is inferred that each anion has its own degree of solute spread through soils mixed with residues due to a larger specific surface of residues.

On the other hand, retardation of nitrate ion is an effective phenomenon as mass reduction of nitrate in soils by the denitrification is anticipated. The results revealed that the mobility of solute decreases by using all residues except for rice straw, although the use of rice straw mixed with silica sand shows a tendency of slight retardation in nitrate ion. This may be attributed to the nature of these rice and food residues having the surface hydrophobicity and the negative charge of surface, providing the increase of the velocity of anion. In Andisols, the solute mobility increases despite of the mixture of agricultural residues and the kinds of anion. For chloride ion, which is toxic to plants in soils,

the increase of the mobility may contribute to avoid salt accumulation in rootzones and prevent against salinization. Therefore, the use of agricultural residues is likely to enhance the chloride leaching from the rootzone or subsurface.
The results of the mass recovery fraction (MRF) associated with rice husk and rice straw are estimated for nitrate ion as a function of the weight percentage of residues. The degree of nitrate mass reduction is of interest and of significance during a course of transport to avoid nitrate leaching with a high concentration in groundwater. The MRF is the ratio of the amount of effluent solutions to that of influent solutions. In all experimental cases except for the results in rice straw mixed with silica sand, values of MRF are less than the unity. Up to 63% and 52% attenuation of the total mass can be found using rice husk and rice straw in both soil materials, respectively. It is inferred that a part of anions may be strongly adsorbed onto the surface of agricultural residues and/or may be trapped within pores. Therefore, the use of rice straw has a little effect on nitrate attenuation compared with the use of rice husk. As a whole, the degree of nitrate attenuation in Andisols is larger than that in silica sand. This finding is attributed to the complex geometry of the soil particles the aggregate structure in Andisol. As for nitrate ion, natural degradation of solute mass in a cropland is expected to attenuate the impact on water quality in groundwater.
The results of MRF for chloride ion are also estimated. Compared with MRF for nitrate and chloride ion, the degree of chloride attenuation is different from nitrate attenuation in all experimental cases. The results imply that solute transfer may be affected by not only the types of soil materials but the kinds of anions. Moreover, the results show that solute attenuation appears with a low weight percentage of residues. This indicates that the use of agricultural residues in soil has a potential to the attenuation of nitrate or chloride ions.

References

[1] Zhang, Y., Ghaly, A.E., Li, B.: Physical properties of rice residues as affected by variety and climatic and cultivation onditions in three continents, Am. J. Appli. Sci., 9(11), pp.1757-1768, 2012.
[2] Das B.S. and Kluitenberg G.J.: Moment analysis to estimate degradation rate constants from leaching experiments, Soil Sci. Soc. Am. J., 60(6), pp.1724-1731, 1996.
[3] Eguchi S. and Hasegawa S.: Determination and characterization of preferential water flow in unsaturated subsoil in Andisol, Soil Sci. Soc. Am. J., 72(2), pp.320-330, 2008.

Water Flow Engineering based on Green Technology as an Alternative Replacement of Air Conditioner for Simple House

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Keywords: Air conditioner, Water flow technology, Environmental

Temperature rising in major cities in Indonesia is comparable with the use of air conditioner. Data shows that the use of air conditioner with certain brand in Indonesia in 2011 reach 1.66 million units. The use of air conditioner does not only require 42.5% of the total consumed electricity but also trigger freon leak which damage the environment. According to ANSI/ASHRAE 55-1992, thermal comfort standards in Indonesia are between 22.5o-26oC. To reduce the consumption of energy and the environmental impacts, it requires an alternative cooler which is able to replace air conditioner. One of the alternatives is by using a water flow through pipes.

This cooler system uses rainwater stored in a tub, rainwater temperature is then decreased 20-220C by using a cooling machine modified by salt water replacing freon. Thus, it is more eco-friendly. Then, the cooled rainwater pumped into the copper pipes on the roof ceiling. Temperature difference between rainwater flowing in the pipes and the room temperature causes heat transfer through the process of conduction. The rainwater which has absorbed the room heat will be streamed back to the tub. This cycle repeats until the room reach desired temperature.

This concept does not only boost its efficiency to 28.5 %, but it is also more Eco-friendly as it uses rain water conservation. The concept is more economical as it only costs USD 8 per month compare to the cost of air conditioner, USD 40 per month.

Remote Sensing and Field Monitoring

Correction of the Short-Range-Forecast Rainfall from MAPLE and KLAPS Models

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Keywords: Rainfall forecasting, Forecasting rainfall correction, MAPLE, KLAPS

Korea Meteorological Administration (KMA) has introduced several rainfall forecasting models from abroad and developed its own forecasting models. KMA provides other disaster prevention agencies with the results of its forecasting activities in real-time systems. However, the forecasting models tend towards under-prediction for heavy rainfalls causing significant problems to disaster prevention professionals in the application of the provided data for the flood prediction purposes. Thus, this problem was approached in this study.
To process this study, first, we selected the storm events in the applied watersheds and the evaluation criterion for quantitative rainfall forecasting. Second, to improve the under-prediction rainfall data forecasted by MAPLE and KLAPS, we proposed three effective correction methods: 1) a fixed coefficient correction method using a regression analysis (statistical method) for past data; 2) a changed coefficient correction method that employs real-time conditional merging; 3) a mixed coefficient correction method harmonizing the fixed and changed methods. Each of these methods was used for comparing the pre-correction and post-correction rainfall forecasting data with reference to the observed rainfalls, and its forecasting data improvement level was assessed. Lastly, an additional analysis was performed to determine the effect of system lagged time of each model on the accuracy of rainfall forecasting.
This study performed a comparative analysis considering a model-specific system in lagged time after correcting differences through conversion. The results revealed that MAPLE had better RMSE with raw-data than KLAPS and that KLAPS had higher improvement effects than MAPLE. The comparison of both models favored the use of MAPLE data with changed coefficient correction method. To summarize, the changed coefficient correction method showed the highest general improvement effects in both models. Independent of this result, it is necessary to reduce the system lagged time in addition to enhancing the performance of the model itself in order to enhance rainfall forecasting performance of KLAPS.

Information Management and Decision Support Systems

Developing Flood Damage Analysis Method based on the BIM and GIS Standard Information Model

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Keywords: Flood Damage Analysis, BIM (Building Information Model), damage cost, MD-FDA

As urban flood damages caused by global warming and abnormal climate phenomena have been exacerbated, the forecasting technology of the damages has been rapidly developing as well. Thus, it is important for government and local administrators to have decision support systems in order to forecast and prepare for the possible damages.
As a main part of the decision support system, especially for extreme cases, the flood damage cost estimation per building or per region is an important index for preventing disaster. The purpose of this research is to study accuracy, visualization and individual cost of damage estimation using information models based on both BIM(Building Information Model) and GIS(Geographic Information System).
The BIM technology which offers total information including construction cost cutting and structure maintenance is becoming a state-of-art technology in architecture as well as civil infrastructures.
In this research, the flood damage cost was assessed based on existing GIS information and building properties in the BIM information model. This technology is able to estimate not only the damage cost of flood level, but also calculate in advance building destruction by flow velocity and damage for pedestrians using attributes of each floor.
In this study, MD-FDA(multi-dimensional flood damage analysis) method is used to estimate flood damage and local damages of apartment and public buildings can be obtained based on BIM information.
Finally, it is possible to estimate regional damage for a given site.

Geoscience Foundation for Decision Support for Arctic Ports in Changing Climate

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Keywords: Arctic ports, Climate change, Geoscience

The safety of navigation and the ability to develop safe ports and coastal infrastructure in Arctic harbours depends on the availability of detailed information on seabed bathymetry, sediments and their dynamics as well as on coastal geomorphology and processes. Arctic harbours generally experience issues of ice cover, nearshore ice impacts, waves, tides and currents, shoaling, coastal erosion, and flooding in storm surges, relevant to both maintenance of existing infrastructure and construction of new facilities. Onshore infrastructure is affected by permafrost, which may extend underwater. These issues are linked and influence sediment transport, resuspension, erosion and sedimentation. The ability to predict these accurately, model future scenarios and inform decision-making with respect to dredging, construction, maintenance and investment is vital to planning port operations and management. To successfully address these issues, stakeholders require understanding of the bathymetric setting, shore-zone geomorphology, onshore and sub-bottom geology and geotechnical conditions, wind, wave, and surge climatology, ice and current dynamics, and sediment sources and sinks. Assessment of the current state of the harbours and of their potential change under different management and climate change scenarios will guide decisions such as defining the best locations for harbour dredging; evaluating navigation channel stability and required frequency of dredging; estimating potential sediment volumes available for extraction; defining appropriate frequency for repeat hydrographic surveys; developing efficient shore protection measures; optimizing location of infrastructure installation; defining vessel characteristics and limitations for port entrance; designing land reclamation plans; defining offshore/onshore dump sites for dredged materials; and identifying safe anchoring sites inside and outside of the harbours. The paper will compare and contrast geoscience knowledge and climate related issues at four Canadian Arctic ports − Iqaluit, Qikiqtarjuaq, Tuktoyaktuk and Churchill.

IS for Decision Support in Usage of Landscapes after Re-Cultivation

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GEO-TOOLS, Czech Republic

Keywords: Information system; Decision support system, Data mining; Multi-criterial analysis; Complex system; Fuzzy logic

The information system (IS) MARE was developed as the system for information and risk evaluation. The system is based on integration of problem-aimed data from monitoring of dynamic processes in hydrology, hydrogeology and hydrochemical status of a landscape and selected geodynamic processes. This system enables to carry out a sensitivity analysis and to evaluate related scenarios as a base for knowledge initial based decisions about concepts of regional development or, as a base for more effective and more complex evaluation of variants of activities for revitalization or hazard avoiding. The system has been tested on areas of Most and Chabarovice, which are the water-flooded residual pits after open pit mining.

In the last century, there were extensive changes done the landscape in the areas of the testing Brown coal mining in two steps there. Groundwater level was lowered by deep mining in the first step. The open pit mining as the second step was followed by partial filling in of the residual pits by dumps and/or flooding of the pits by water creating artificial lake at the end. Thus, a brownfield environment was created, which structure changes significantly in time and space, changing the conditions for possible various utilization due to this. Accountable decisions about next exploitation of these landscapes and areas ask for complex information based on multidiscipline approach. It is the only way how to take into account all the possible risks, which could limit the intended development.

The areas, which have been chosen as a model location, have a lot of very unusual parameters, which make unusable common methods used in landscapes or civil engineering. The outputs from IS MARE allow to the future users of these landscapes with non-standard natural conditions to carry out more easily a monitoring of complex interactions between natural processes and technologic systems as a base for evaluation of future exploitation or of different actions by integration of different points of view. Thus, it will be possible to choose and usage for a specific part of the landscape in such a way, which will not be disturbed nor limited by specific features or functions nowadays and in the future, too.

IS MARE is a system which integrates all the work with data, also the collection of them, transfer, storage, multicriterial evaluation, visualization of results including early warning launching, when exceeding of thresholds. The system with features of artificial intelligence is based on database principle and this tool namely for prediction and modelling of interventions into landscape in an area of natural risks (landslides, contamination, flooding, dryness). This system enables to archive relevant data for prognostic and competent evaluation, both historical and present-day ones, in real time, due to all the currently available monitoring technologies. The system integrates also GIS, algorithms for decisions in complex tasks, tools for modelling and algorithms for interpreting of results.

The goal of the system development was to establish means for user-friendly creating and administrating of database of all the data related to forming and utilization of a landscape (namely hydrologic, hydrogeological and geological data). For example, the slope stability criteria setting to load capacity of the foundations or the settlement of underground will be important for the possible future civil engineering. For the usage for free-time activities, the trends in quality and amounts of surface and ground water will be important. The user will get an overview about real possibilities and limits for future incorporation into free-time scenarios, which should be used as a mean for avoiding damages due to too ambitious projects. Such examples have been known nowadays.

The systems for support of decisions generally include supporting tools for evaluation and controlling processes, which help their users to search and evaluate different variants of solutions and decisions. The tested localities are characterised by complex geologic, geotechnic and hydrogeologic conditions.

This system also enables to administrate the localities based on both historic and newly created analysis for strategic and operating decision about technical exploration.
The results of this work can be used over long time period due to the fact, that there will be next open pit mines closed in next years. The aim when creating the IS MARE will also be to secure its easily extension ability also for the other environmental data, which makes it possible to use also for other areas touched by human activities, such as re-cultivation, or on areas endangered by geo-hazards etc. We suppose, the users will be mostly owners and estate-keepers or authorities.
Conclusion: The ambition of the IS MARE is to create the most comprehensive database of all the actually available data from different scientific areas and to connect them sophistically in user-friendly environment with the possibility of their multi-criterial evaluation including possible development trends. Among the criteria, there is for example the contamination of water by metals from dumps, eutrophication, nutrients from dumps and coal seams, abrasion of banks, stability of slopes, setting down, firing-up of seams, amount of rains, level of underground water, partial pore pressure, level of surface water, air temperature, soil temperature, pH and Eh of water, mechanical stress, 3D movements of soils and undergrounds.
We can see the indirect profit particularly in possibility of more effective decision-making from the point of view aimed to long-time exploitation of hydrological revitalised landscape and in possibility to avoid potential risk, i.e. to make proposals of preventive precautions aimed to savings on following rehabilitations.

Acknowledgment
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Mini-Symposium: Impacts of Climate Change

Modeling the Impacts of Climate Change on Groundwater Recharge in the Taleghan Watershed, Iran, from an Ensemble of Global Climate Model Projections

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Keywords: Climate change, Recession curve analysis, Groundwater reserve, Bar watershed

Groundwater is the source of nearly 35% of global human water withdrawals, and even of about 42% of the total global irrigation water withdrawals (Döll et al., 2012; Siebert et al., 2010). It is a more reliable and safer water source than surface water, because its use is less impacted by seasonal or inter-annual flow variations (e.g. drought periods), and, because it is much better protected from anthropogenic pollution. Due to the increased temporal variability of surface water flows in the wake of climate change, there has been and will be, more so, in the near future, a higher demand for groundwater (Taylor et al., 2013; Kundzewicz and Döll, 2009). In fact, this has already led in some semi-arid and arid regions with intensive irrigation (Iran) to groundwater abstraction rates exceeding groundwater recharge, i.e. to strong groundwater depletion (Wada et al., 2012). To support a sustainable groundwater management, it is necessary to assess the renewable groundwater resources, i.e. the long-term average annual groundwater recharge. Modeling the impact of climate change on the future renewable groundwater resources under various scenarios can help to identify regions with significantly-changing groundwater resources and thus inform on the planning of possible measures for climate change adaptation. In this study the SWAT- (Soil Water Assessment Tool) semi-distributed hydrological watershed model has been applied to estimate the shallow groundwater recharge at the watershed scale. The study site is the Taleghan watershed, located northwest of Teheran province, Iran, which is one of the most important areas from which considerable water for human- and agriculture uses is generated. The dominant land-use types of the watershed are mixed-range- and agricultural lands. The input data for the SWAT- model have been prepared using the digital land-use and soil maps with monthly rainfall data measured at the main rain gauge station as well as other meteorological variables such as wind speed, relative humidity, solar radiation, and temperature collected within the watershed. The SWAT model has been calibrated based on 34 years of monthly streamflow recorded between 1959 and 1993 and then validated on the remainder of the streamflow time series from 1993 to 2011. In the subsequent step, downscaled climate predictions from an ensemble of climate models (GCM) have been imported into the SWAT-model to estimate the past (for reference) and future groundwater recharge. The results indicate that future groundwater recharge all over the watershed will be decreased due to the impact of climate change in the region, namely, higher temperatures and less precipitation.

References

Döll P, Hoffmann-Dobrev H, Portmann F T, Siebert S, Eicker A, Rodell M, Strassberg G and Scanlon B R 2012 Impact of water withdrawals from groundwater and surface water on continental water storage variations J. Geodyn. 59/60 143–56.

Kundzewicz Z Wand Döll P 2009Will groundwater ease freshwater stress under climate change? Hydrol. Sci. J. 54 665–75.

Siebert S, Burke J, Faures J M, Frenken K, Hoogeveen J, D¨oll P and Portmann F T 2010 Groundwater use for irrigation—a global inventory Hydrol. Earth Syst. Sci. 14 1863–80.

Taylor R G et al 2013 Ground water and climate change Nature Clim. Change 3 322–9

Wada Y, van Beek L P H, van Kempen C M, Reckman J W T M, Vasak S and Bierkens M F P 2010 Global depletion of groundwater resources Geophys. Res. Lett. 37 L20402.

Mini-Symposium: Modeling Methodology for Agricultural Research

Effect of Random Spatially Soil Properties on Rectangular Foundations Vibration based on Half Sapce

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Keywords: Spatial variability, Rigid 3D foundation, Random soil properties

In this paper, the effect of spatial variability of soil properties on the dynamic response of rigid rectangular foundations resting on viscoelastic half space is studied. Dynamic stiffness matrix formulated with conjunction of the discrete Green's functions is used to compute the dynamic impedance functions.

Considering a shallow foundation as massless having rigid body motion resting on half-space, the dynamic response can be calculated rigorously basing on the three-dimensional elastodynamics using the formulation of stiffness matrix with conjunction of the discrete Green's functions. These later are computed through the Thin Layers Method (TLM). Indeed, soil layers have subdivided into N sublayers in which the nodal displacement vector may be linearized (Kausel, 1981; Kausel, 2006). The Green's functions are obtained by inverting the global stiffness matrix through a spectral decomposition in terms of the eigenvalues (Kausel, 1982), and after performing Fourier transform inversion, one gets displacement discrete Green's functions for uniform horizontal and vertical distributed loads in spatial domain as developed in (Pais, 1988; Hadid and Berrah, 2002; Berrah and Hadid, 2003). The vertical, horizontal, rocking and torsion compliance functions are analyzed.

Soil properties of interest are: shear modulus, density, damping and Poisson's coefficients, considered as spatially random fields. The soil-foundation interface is discretized into several equal elements as constant (disc) leading the Green's functions applied. The stratum depth, H= 3B, is divided into 12 sublayers. The soil is modeled in first time as viscoelastic homogeneous medium with the following properties:

- Average shear modulus: 40 MPa
- Average mass density: 1800 kg/m3
- Poisson's ratio 0.33
- Critical damping ratio: 5%

However, the dispersion observed in soil data comes from both the spatial variability which greatly influences the behavior of large structures and from errors in testing. Thus, it is hardly surprising that mechanical properties of soils vary from place to place within resulting deposits. In principle, spatial variation of soil properties can be characterized in detail, but only if a large number of samples is available. In reality, the number of tests required far exceeds that which would be practical. Thus, for engineering purposes, one assumes that spatial variability of soil properties is decomposed into a deterministic trend, and a random component describing the variability about that trend (Fenton,1990).

In order to investigate the heterogeneous character of soil, the shear modulus, density, fraction of critical damping and Poisson's ratio are modeled herein as spatially random fields. For the random simulation of the medium, the spatial variation is considered only in the vertical direction and the chosen random variables are defined by their moments of order 1 and 2, which are respectively the mean, and the variance supposed estimated from in situ samples. Indeed, the mean shear modulus increases with some power exponent of depth (Hadid and Afra, 2000). Let the variable property fp(z) assumed to be a one-Dimensional homogeneous stochastic process defined as a function of the deterministic function f0p(z) describing the trend in space, taken in practice as the mean of measured values, and an added fluctuation random function Δfp(z) with zero mean and variance equal to unity.

The shear modulus is assumed to be lognormally distributed, this choice is motivated by the fact that this soil property is positive parameter, and lognormal distribution enables analyzing its large variability. However, for soil media, it is well known that density ρ, fraction of critical damping β and

Poisson's ratio v are bounded in practice between two extreme values, so, the probability distribution appropriate for a random variable whose values are bounded is the Beta distribution.
The analysis carried out in this paper indicates that shear modulus and Poisson's ratio are of prime importance. So, density and fraction of critical damping variability can be neglected in a dynamic analysis of foundation response.

Keyword Index