News of the German Coastal Engineering Research Council

KFKI aktuell

Editorial

Coastal protection – an ongoing task

Coastal protection is a precondition for the preservation and development of the living and economic environments of the approx. 1.1 million hectares of lowlands bordering the North and Baltic Sea. As the acting administrative body within the German Federal government, the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) feels obliged to accept responsibility especially for rural communities as well as for towns situated in tidal areas. For this reason, governmental funds are appropriated accordingly each year within the framework of the communal task "Improvement of agricultural structure and coastal protection" (GAK).

The implementation of coastal protection measures is the responsibility of the German Federal states, who also decide on priorities. The Federal government finances 70% of GAK expenditure. The Federal government and Federal coastal states have reached agreement on a basic coastal protection strategy eligible for financing, itemised as follows:

- careful monitoring and assessment of hydro-morphological and climatic changes along the coast, development of impact scenarios; (research activities within the framework of the German Coastal Engineering Research Council [KFKI]);
- guarantee of a definite protection standard for low-lying coastal areas (provision of absolute protection not possible);
- basically no setting-back or abandonment of dikes (line-oriented coastal protection), also no land reclamation through the construction of new dikes seaward of existing dikes;
- creation of a second dike line where this is possible (areal coastal protection);
- new dike profiles should be designed so as to permit unproblematic adaptations at a later stage (flexibilisation);
- the structural design of other coastal protection structures should be such as to permit significant height increases at a later stage;
- the continued practice of beach replenishment as a "soft" coastal protection option;
- furtherance of the protection of islands and holms, as they also serve to protect the mainland coast;
- the most urgent coastal protection measures should be carried out first (setting priorities).

This strategy has proved its worth, for despite the fact that all of the measures proposed after the catastrophic storm surge of February 1962 have not yet been fully implemented, it has warded off serious damage by the potentially more destructive subsequent storm surges of 1976, 1990, 1994 or 2007 in an unspectacular way.

Between 1973 and 2009 the German Federal government together with the German Federal coastal states invested over 4 billion € in coastal protection. Moreover, on 20th January 2009, the planning committee agreed on the special framework plan "Coastal protection measures as a consequence of climate change". According to this plan, the Federal government pledged to appropriate an extra 25 million € annually to the Federal coastal states between 2009 and 2025, i.e. a total of 380 million €. By this means, the coastal states are in a position to spend about 182 million € of overall investment funds annually on coastal protection measures up to 2025, even with a cut in the GAK budget. This means that the Federal government has reacted positively to the demands of the coastal states by contributing a greater share of the investment costs for coastal protection measures than in the past.

The Federal states may also draw on funds from the European Agricultural Fund for Rural Development (EAFRD) of the EU. This body is also interested in allocating appropriate funds for coastal protection from 2013 onwards. The Federal government supports this proposal.

Although much has happened over the past 30 years, there still remains a great deal to be done. This not only concerns the completion of construction projects in practice but also the furtherance of research work. During this time period about 80 projects have been successfully financed primarily from funds provided by the German Federal Ministry of Education and Research (BMBF), and there is still undoubtedly a considerable need for further research in order to improve our understanding of the processes that take place in the coastal environment so as to respond to these correctly. Coastal protection measures and the safeguarding of maritime shipping cost a lot of money. For this reason, new findings from applied research must be put to good use in order to arrive at proper, economically viable, and hence sustainable solutions.

I believe that politicians have become sensitized and that the course has been set – so far as was possible – to advance coastal protection also in the future not as an end in itself, but for the well-being of people living along the coast.

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MudSim (03KIS66-67)

Description of the dynamics (formation, development and transport) of fluid mud based on physical processes and their mathematical implementation for sediment management in coastal waters

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The progressive extension and development of maritime shipping lanes in tidal estuaries has led to an increase in the siltation of ports and port approaches, and to some extent also the siltation of sections of navigation channels. This not only has a negative effect on estuarine habitats but also incurs additional costs on account of the fact that the maintenance of silted-up waterways is very expensive. By means of a new numerical modelling technique it is hoped in the future to simulate and analyse the behaviour of fluid mud in order to optimise maintenance measures in ports and estuaries. For this reason, the aim of the project is to develop a numerical method for simulating the dynamics of fluid mud (formation, deposition, transport, fluidization, resuspension, consolidation).

Questions concerning suspended sediment transport will be investigated using hydrodynamic numerical modelling techniques. The presently established and tested modelling methods, however, are hardly capable of simulating the dynamics of fluid mud (also referred to as a highly-concentrated mud suspension). The reason for this is due to the special rheological properties of fluid mud, whose flow behaviour differs from that of a Newtonian fluid such as clear water. Despite this, hydrodynamic numerical models are generally based on the latter assumption.

In this research project an existing and well-proven hydrodynamic modelling technique was hence extended to simulate fluid mud. Basic requirements for the development of new methods for numerically simulating fluid mud include a study of rheological properties and the determination of characteristic parameters. For this purpose fluid mud samples were collected in the Ems and the Weser, and subsequently analysed. Initially the material was sieved to obtain particles with a grain-size of less than 63 µm. The grain-size distribution was then determined with the aid of a laser particle sizer. One of the most important characterisation parameters for the behaviour of fluid mud is the solid material content, i.e. the density, which varies in proportion to the latter. For this reason, different dilutions of the mud suspension were prepared in order to carry out a more detailed rheological analysis. By means of a rheometer in the CSS mode (controlled shear stress), flow curves and the viscosity of these suspensions were measured as a function of shear stress (Figure 1).

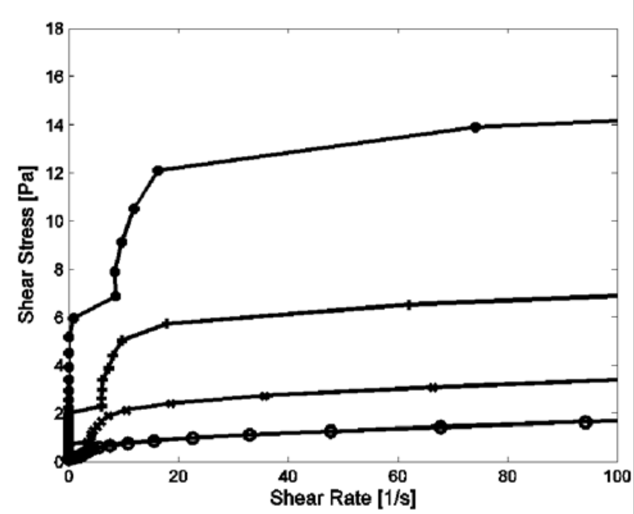

Figure 1:
Flow curves for a typical fluid mud sample at dilutions of 10% (*), 8,5% (+), 7,0% (x) and 5,5% (o) of solid material content.

In addition, the sediment density and the annealing loss were also determined. Based on the rheological investigations, parameterizations for a rheological model were determined as a function of solid material content. The rheological model used by Worrall-Tuliani (1964) includes a term especially intended for describing the degree of break-up of aggregates. The rheological model is incorporated in the numerical model as a viscosity formulation dependent on the solid particle content.

The implemented numerical model is based on an

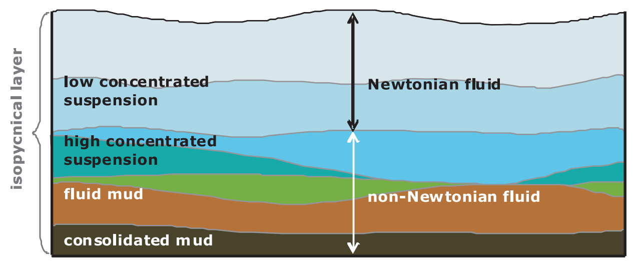

Figure 2:
Schematic representation of the isopycnal MudSim model.

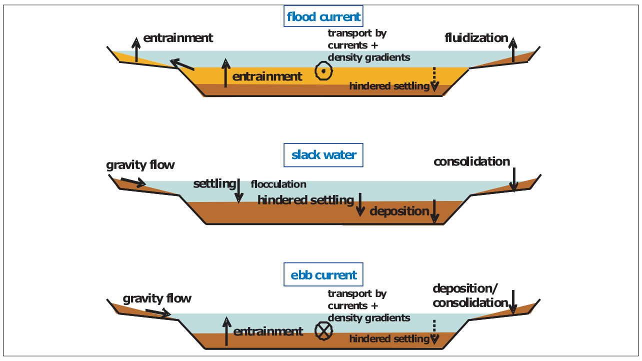

Figure 3:
Schematic representation of the changes in mud dynamics with tidal phase in a flow cross-section.

isopycnal approach. The vertical discretization in the numerical model is oriented to layers of constant density, namely isopycnals (Figure 2). The density classes and the number of density classes are predefined. The flow behaviour of the density layers is now determined using the rheological formulation for the viscosity. Depending on the density (concentration) of a suspension layer, this is either treated as a Newtonian or a non-Newtonian fluid (Worrall-Tuliani fluid).

The dynamics of fluid mud layers is realised by the formation and disappearance of density layers. In an estuary the occurrence of fluid mud can present can vary significantly with location and time (Figure 3), which is especially reproduced by the dynamic behaviour of the density layers. Processes such as hindered settling and entrainment are realised by mass transport between the density layers and the resulting enlargement or diminution of the affected layers. Horizontal transport is driven by flow, density gradients and gravitation.

Figure 4 illustrates the inherent dynamics of mud suspensions in the sectional model of the Dortmund-Ems canal (Figure 4), which extends from the Rhede tide gauge to Herbrum. The density distribution is shown during a flood tidal phase. The larger flow velocity of the water body results in a mobilisation of the considerably slower-moving fluid mud layers. This also gives rise to phenomena such as internal waves.

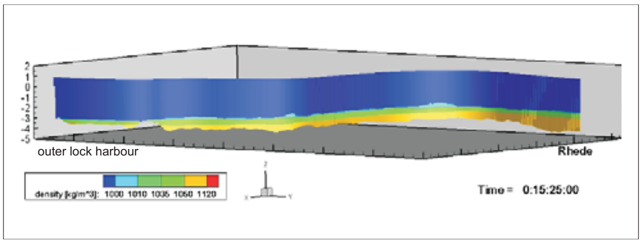

Figure 4:
Sectional model of the Dortmund-Ems canal from the Rhede tide gauge to Herbrum - representation of typical fluid mud layers during the flood tide (perspective visulation).

The further developed numerical method for simulating highly-concentrated mud suspensions forms the basis for an additional important component regarding the hydraulic engineering system analysis of fluid mud processes in estuaries, and hence supplements the well-proven hydromorphological modelling techniques which have so far been unable to take account of these processes. By means of the MudSim modelling technique it is hoped in the future to investigate the measures necessary, and the effect of these measures on mud transport and mud accumulation, in order to assess construction and maintenance work in the light of the possible occurrence of fluid mud. Moreover, it is hoped that this will improve existing and future strategies for the redistribution and deposition of highly-concentrated mud suspensions and consolidated mud.

Literature

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AufMod (03KIS082-088)

Development of integrated modelling systems for analysing long-term morphodynamics in the German Bight – overview and processing strategy

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The project was initiated by a framework bid for tender published by the KFKI in 2008 concerning large-scale and long-term morphodynamics in the German Bight. The key area of research interest is the German North Sea coast, with special emphasis on the coastal zone, foreshores and beaches, islands and tidal flats, as well as tidal rivers. The essential subject matter and basics of the investigation were stipulated in advance: plausible and consistent bathymetrical and sedimentological data must be implemented. Besides the currents generated by tides and wind, the currents induced by waves and wave-breaking must also be taken into consideration. The aims of the investigation consist in the definition and analysis of sediment transport paths, directions, quantities and balances. This demands a fundamental improvement of our understanding of the system governing long-term and large-scale sediment dynamics. This also includes possible methods for forecasting large-scale transport and bed evolution processes. It is important to consider different modelling techniques in the conceptual project strategy in order to also analyse the spread of the results obtained by the different methods and approaches. It is planned to incorporate the results in a database freely available for use by third parties. It is also intended to apply the implemented model systems for selected scenarios (anticipated climate changes, rise in mean sea, possible intensification of the wave climate). Because the tendered catalogue of requirements is very extensive, it can only be tackled within the framework of a larger collaborative project. In this regard, the following institutes have agreed to participate: the German Federal Waterways Engineering and Research Institute, the German Federal Maritime and Hydrographic Agency, the Christian Albrechts University in Kiel, the Senckenberg Research Institute in Wilhelmshaven, the University of Bremen, the University of the Federal Armed Forces in Munich, and smile consult GmbH.

The changes in bed forms primarily result from spatially and temporally varying loads on the waterway bed in combination with bed characteristics and the associated solid material transport mechanisms. In the project area, different spatial scales determine local conditions (e.g. scour, underwater dunes, channel sections, ebb deltas, estuary mouths), the behaviour of sub-domains (e.g. tidal flat drainage areas, island chains with foreshore zones, tidal estuaries) as well as the interactions between these sub-domains in the German Bight. Moreover, supra-regional interactions (North Sea – North Atlantic) should also be taken into consideration. Although the KFKI target focuses on large-scale sediment dynamics in the German Bight, it is important to take account of the spectrum of small, medium and large spatial scales because local changes can also have a long-term effect on large-scale behaviour via a hitherto hidden interactive system. The changes that occur at the spatial scales mentioned are coupled via different time scales, which must be accounted for in suitable morphodynamic models. Generally speaking, a distinction may be made between short-term (tidal cycle), medium-term (seasonal to annual) and long-term (decades) time scales. Depending on the case in question, it may also be necessary to consider episodically occurring extreme states, especially with regard to morphodynamics. The investigations carried out for variable structures must additionally take account of invariable structures fixed by maintenance (e.g. constructions such as navigation channels, specified island heads, training structures). Basically speaking, it is necessary to analyse the extent to which a combination of the different scales in space and time is possible by the application of

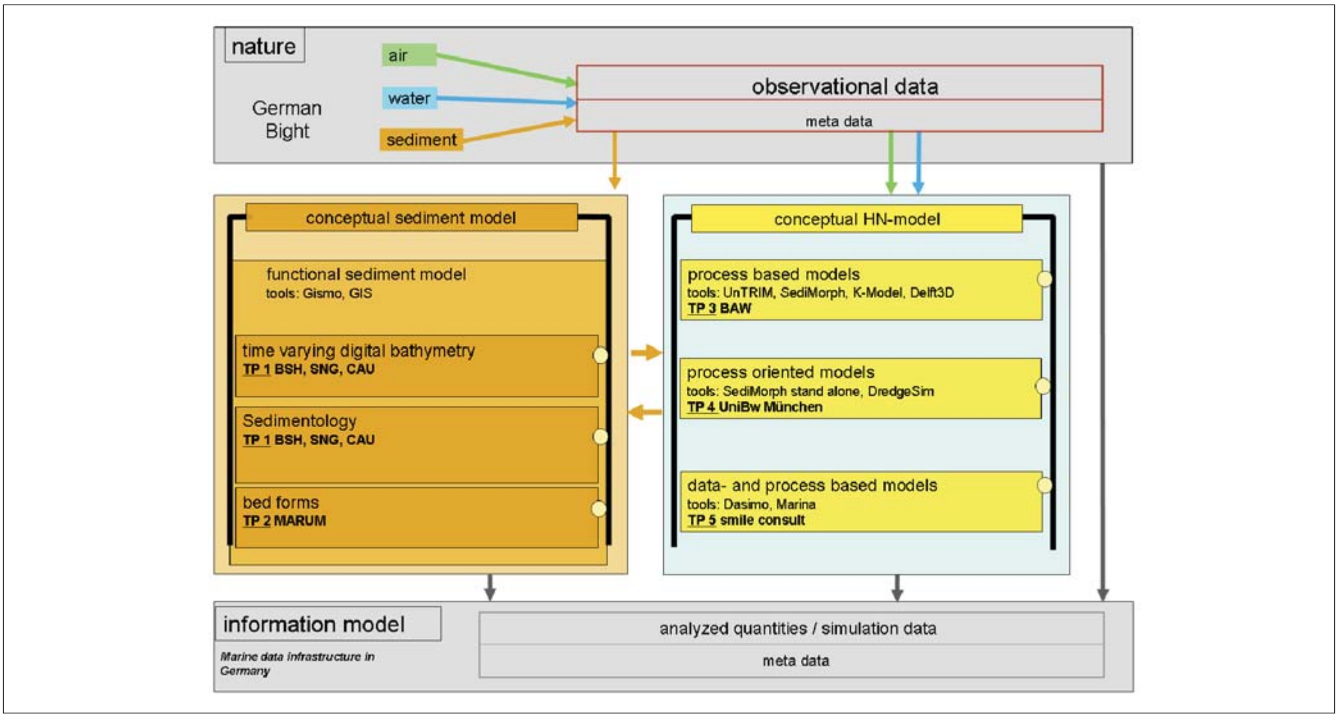

Figure 1: Integrated processing strategy

mathematical modelling methods. For this purpose it is presupposed in the joint project that a combination of data analysis methods, i.e. "bottom up" methods (process-based physical behaviour, partial differential equations) and "top down" methods (oriented to a known system state) is necessary. The sub-projects comprising the joint project may be classified according to this diversity of methods. The necessary basics include a detailed bed model, in which existing data within the framework of the joint project (sedimentology, bathymetry, bed profiles, and to a certain extent also constructions,...) are integrated and new data are introduced. By way of innovative information technology, the bed model will be used for morphodynamic analysis and forecasting. In the author's opinion, this is a very important central task extending beyond the completion of the joint project. Furthermore, the necessary data basis should include a detailed data base covering the oceanography and hydrology of the North Sea, especially the German Bight and the special conditions in estuaries and the drainage basins of tidal flats. Within the framework of the joint project, the bed model and the oceanographic-hydrological data base support the different approaches for the above-mentioned data-oriented methods of analysis (statistical analyses, spatial and temporal analyses, sediment balances) and the "top down" methods (e.g. profile analyses, analysis of geometrical and tidal characteristics, analysis of asymmetry and characteristic tidal values).

In order to diagnose the hitherto hidden interacting system, which can extend over different combinations of spatial and temporal scales, it is intended to implement different process-based models. Depending on the targeted space and time scale resolutions, these are oriented to different degrees regarding a detailed description of the physical processes. With regard to the implemented simulation methods or simulation components, it is basically possible to state the following classification scheme:

Hydrodynamics: water levels, discharges, currents (also density currents, secondary or circulatory currents), waves, wave climate as well as bed shear stresses resulting from currents and waves.

- Advection and turbulent diffusion of dissolved and particulate matter: salt, different fractions of suspended materials, settling velocities of particulate material
- Particle tracking: tracking of individual particles in the water body
- Sediment transport at the seabed: residual transport, characteristic transport patterns, erosion and sedimentation zones
- Morphodynamics: evolution of the seabed under interaction with bed loading

From a combination of the above-mentioned methods, it is hoped to gain a better understanding of the system governing the long-term morphodynamics in the German Bight within the framework of the joint project. In this context, it is necessary to analyse and document the range of validity of the model results based on a validation strategy and validation calculations referred to the available validation data.

By way of the joint project it is intended to create an integrated data base and the necessary tools to resolve questions regarding sediment dynamics and morphodynamics in the German Bight and in estuaries along the German Bight by means of an integrated approach. The integrated processing strategy chosen in the joint project is shown in Figure 1.

FlowDike-D (03KIS075-76)

Freeboard dimensioning of estuary and sea dikes under consideration of wind and currents

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Introduction

Many instances of damage to sea and estuary dikes may be traced back to wave overtopping. For this reason, wave run-up and wave overtopping are decisive dimensioning parameters for the freeboard dimensioning of dikes. Wave run-up and wave overtopping are investigated under consideration of dike geometry as well as wave height, wave period and the direction of wave attack (cf. EurOtop-Manual, 2007). Tidally-induced flow parallel to the dike as well

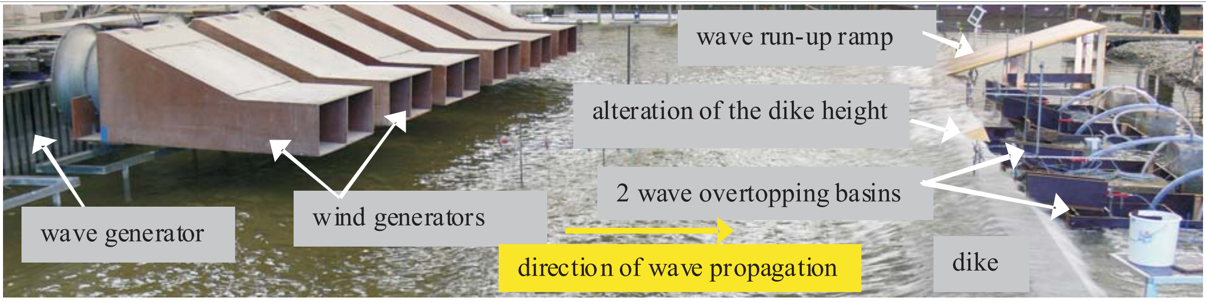

Figure 1:
Test rig, 1:3 sloping dike

as local wind fields have so far not been accounted for in these dimensioning formulae. The aim of the FlowDike-D project is to investigate wave run-up and wave overtopping under the influence of currents and wind in combination with different directions of wave attack as well as the implementation of these findings in existing dimensioning formulae for the wave run-up height and the overtopping rate.

Model experiments

In order to investigate these two aspects, i.e. flow parallel to the dike line and wind acting at right angles to the dike, physical model experiments were carried out in two test phases in the wave basin of the Danish Hydraulic Institute (DHI) in Hørsholm (Denmark) in 2009. In the first test phase (within the framework of the EU Hydralab project HYIII-DHI-5, Contract No.: 022441) the above-mentioned effect was investigated on a 1:3 sloping dike, whereas in the second test phase, a 1:6 sloping dike was tested. The FlowDike-D project is funded by the German Federal Ministry of Education and Research (BMBF) and represents a collaborative project between the RWTH Aachen Universtity (03KIS075), the Technical University of Dresden (03KIS076) and VanderMeer Consulting B.V.. The aim of the joint project on the one hand is to determine the wave run-up height and wave overtopping rate in relation to the wave attack direction, currents and wind. On the other hand, an attempt is made to identify the individual overtopping events and to quantify the corresponding flow processes on the dike crest. Besides the two different dike slopes, the tests were carried out for two crest heights in each case. The resulting four dike profiles were loaded by waves from a Jonswap spectrum. Figure 1 shows the model test rig in the DHI wave basin. The wave machine and wind generators are shown in the left of Figure 1. The waves influenced by the parameters wind, flow and direction of wave attack impacted and overtopped the dike (as shown in the right of the figure). During the tests the wave overtopping rate was measured for each dike crest height by means of two wave overtopping containers. A 2 m wide wave run-up plate was installed in order to determine the wave run-up height.

Results

The test results show that the wave overtopping rate decreases with an increase in the angle of wave attack. A wind field over the dike crest results in an increased wave overtopping rate, especially for low overtopping rates. These results agree with the findings of earlier investigations (De Waals and Van der Meer, 1992; Waal, 1996; Ward, 1996).

In further tests the influence of flow (as determined from flow-induced shoaling and flow-induced refraction) on wave development was investigated. This influence is not yet included in the existing dimensioning formulae for wave run-up and wave overtopping given in the EurOtop Manual (2007). An influencing factor $\gamma\beta$ has so far been used to take account of different directions of wave attack. In the FlowDike project the influencing factor $\gamma\beta,cu$ was introduced, which describes the effect of flow combined with the direction of wave attack on wave run-up and wave overtopping. The influencing factor $\gamma\beta,cu$ is no longer solely determined by the angle of wave attack, but by the wave energy angle, which differs from the wave attack angle on account of the flow. Based on the investigation results, different influencing factors $\gamma\beta,cu$ were thus determined for different wave energy angles. Good agreement is found with the formula of de Waal & Van der Meer (1992), which does not take flow along the dike into consideration.

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AMSeL(03KIS068)

Determination of the mean sea level (MSL) and analysis of highly-resolved tidal levels along the German North Sea coast: MSL + North Sea trends

Sea level changes in the German Bight

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Objectives

One of the main aims of the KFKI research project AMSeL was to analyse observed changes in the Relative Mean Sea Level (RMSL) along the German North Sea coast. Within the framework of the project a detailed investigation of the following aspects was undertaken, (i) which medium-term to long-term changes in the RMSL occurred in the past (approx. 150 years), (ii) whether an acceleration in the rate of change is evident in the observed data, (iii) whether significant differences exist in the RMSL development along the German North Sea coast and (iv) whether the analyses of the observed data may in some way contribute towards the development of robust regional sea level scenarios.

Data and Methodology

A total of 13 tide gauges offering long and qualitatively high-grade time series were included in the analyses (see Figure 1). All of the data sets used were corrected according to the gauge offsets determined in the KFKI project IKÜS (Wanninger et al., 2010). Highly-resolved data sets (at least hourly values) were used as far as possible for the investigations. These data initially yield relatively short (10-12 years) RMSL time series for many gauges. With the aid of the k-value method these were combined with the long backlog of half-tide level time series (by averaging high and low water levels). The k values used for this purpose were first checked for stationarity by different testing methods. The long RMSL time series generated in this way were analysed and smoothed by fitting parametric (e.g. first order polynomials) and non-parametric functions (here: Singular System Analysis, SSA). Whereas the results obtained by fitting parametric functions permit a direct comparison, and the functions themselves are capable of being extrapolated, non-parametric functions give a far better fit to the observed data, and acceleration phases may be detected more reliably. Within the framework of the AMSeL project a method was developed (Monte-Carlo-Autoregressive Padding, MCAP; Wahl et al., 2010) which permits smoothing of the time series right up to the margins in order to also obtain information regarding changes that have occurred recently. Besides the time series obtained from the individual tide gauges, different synthetic time series constructed from a specific number of individual time series were also analysed (Wahl et al., under review).

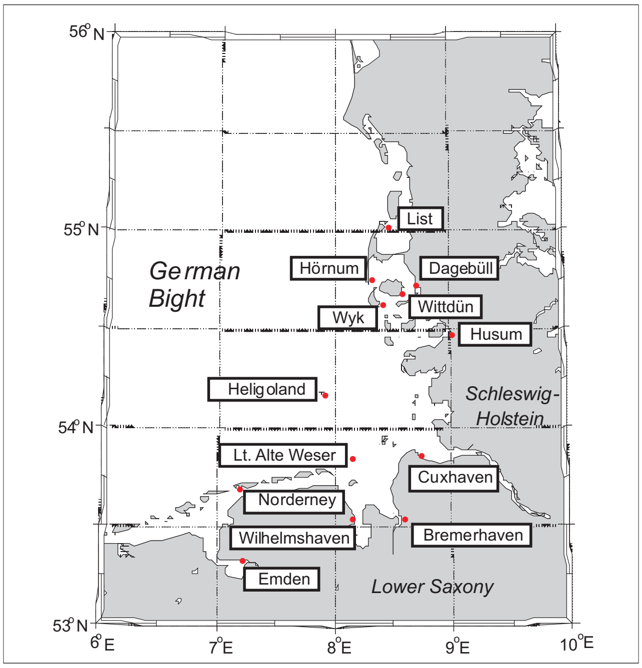

Figure 1:
Investigation area and tide gauges taken into consideration

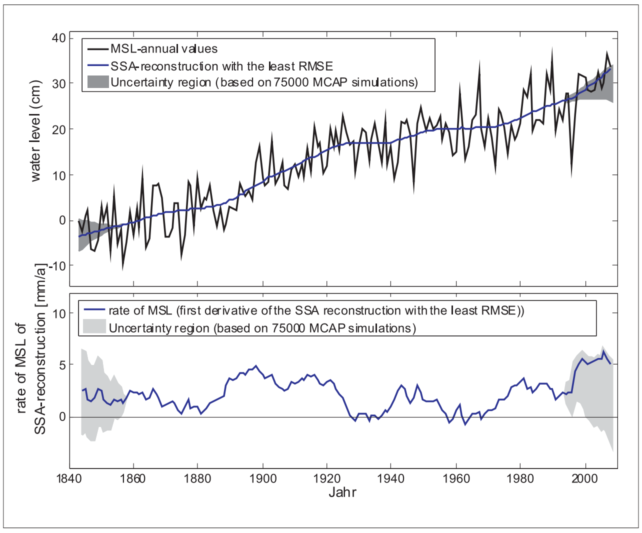

Figure 2:
Smoothed RMSL annual time series (upper) and rates of sea level rise determined from the latter (lower)

Results

Referred to the above-mentioned objectives, the following results may be formulated according our present-day knowledge: (i) The long-term trend derived for a synthetic time series for the entire German Bight covering the full investigation period (1843-2008) results in 2.01 mm/a, whereby this result includes a certain amount of hitherto unknown vertical movements. (ii) A consideration of shorter time periods for the same time series results in higher trends of e.g. 2.14 mm/a (for the period 1951-2008) or 3.60 mm/a (for the period 1971-2008). Based on these analyses as well as the SSA analysis (see Figure 2), an acceleration in the RMSL is evident over the past decades. Considering the entire observation time series, it is clearly evident that similar acceleration phases took place in the past which resulted in high level increases over certain periods. According to present-day knowledge, the recently observed acceleration cannot be described as unusual. (iii) In overall terms, the observed rate of sea level was found to be greater along the coast of Schleswig-Holstein compared with Lower Saxony. This is probably due to higher rates of land subsidence, which to date have not yet been conclusively quantified. (iv) By comparing the reconstruction for the German Bight with global sea level reconstructions, it was possible to verify considerable differences in variability. This implies that the application of global sea level scenarios for regional planning is at least dubious, and clearly indicates the need for further detailed analyses.

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AMSeL(03KIS068)

Investigation of tidal chains and residence times in the German Bight

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Objectives

Besides an analysis of the observed changes in the Relative Mean Sea Level (RMSL) along the German North Sea coast, a further aim of the KFKI research project AMSeL was to investigate tidal chronology from extreme high water and low water levels as well as the residence times of particular water levels. The following aspects were thus investigated within the framework of the project: (i) whether inter-annual or inter-seasonal changes or shifts in residence times are evident at the investigated tide gauges and how the residence time distributions appear at the individual gauges, (ii) whether there are trend developments at selected gauges regarding the residence times of storm surge water levels and the form that these take, and (iii) to what extent possible trends affect the concatenation of several sequential extreme water levels (both high and low water levels) and whether an increase in the number of very long sequences of elevated low and high water levels is to be expected.

appear at the individual gauges, (ii) whether there are trend developments at selected gauges regarding the residence times of storm surge water levels and the form that these take, and (iii) to what extent possible trends affect the concatenation of several sequential extreme water levels (both high and low water levels)

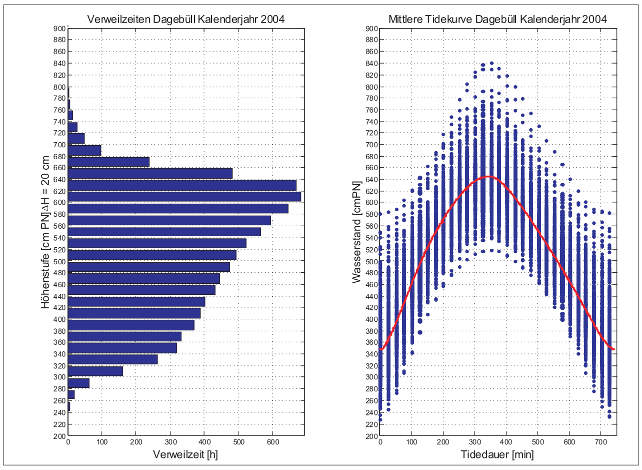

Figure 1:
Example of the distribution of residence times and representation of the spread of water levels referred to tidal chronology, Dagebüll tide gauge, calendar year 2004

and whether an increase in the number of very long sequences of elevated low and high water levels is to be expected.

Data, methodology, results

Based on the extensive data acquisition and evaluation of the 13 tide gauges investigated in AMSeL (see the contribution: AMSeL – Sea level changes in the German Bight) residence-time curves were generated from the available high-resolution and comparatively short coverage (10-12 years) tidal curves at one-minute intervals for different time periods (calendar years, water management years, summer half-years, winter half-years) (see Figure 1). For evaluating the residence times of storm surge water levels it was also possible to make use of fully-digitalised tidal curves for a group of 311 storm surge events recorded at the Cuxhaven tide gauge (time period 1901 to 2008) and 199 events recorded at the Hörnum tide gauge (time period 1936 to 2008) within the framework of the XtremRisK project. An event is classified as belonging to a group when the attained high water level is

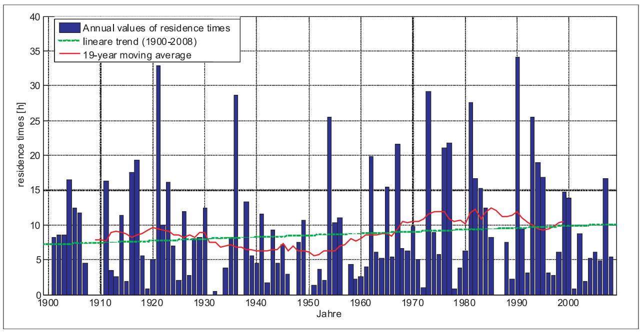

Figure 2:
Development of cumulative annual water level residence times due to storm surge events at the Cuxhaven tide gauge

greater than 1.5 m above the respective yearly average high water level. In order to estimate tendencies regarding the development of MSL the same time periods used in the MSL investigations were chosen for the trend investigations. For the overall time period 1901-2008 the Cuxhaven gauge shows a linear trend of 1.36 ± 2.89 min/year (see Figure 2).

For investigating tidal chains, storm surge chains and sequences of elevated low/high water levels it is possible to apply different definitions and restrictions regarding characteristics. All of the investigated tide gauges and evaluations were assembled in AMseL according to the definition of Lüders (1973). These were investigated and statistically analysed on the basis of sequence frequencies referred to exceeded height steps.

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Pegasus (03KIS077)

Development of an operational automated height monitoring system for tide gauges in the German Bight area

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In terms of content the PEGASUS project is based on the predecessor project IKÜS (03KIS056). The aim of IKÜS was to determine recent crust movements in the German Bight area. The resulting model was intended to combine the observations made using different measurement techniques (levelling, GNSS, gravity measurements and tide gauge recordings). The results of the IKÜS project showed significant level changes (as a rule, large-scale land subsidence) in the German Bight area. Vertical land movements and level changes were also given by tide gauges installed on the earth's surface. Accordingly, the long-wave water level changes recorded at the tide gauges represent a superposition of actual water level changes and changes in the level of the gauge itself (final report on the KFKI project IKÜS). In order to derive absolute changes in water level it is thus necessary to determine ground level changes. A sub-task within the framework of IKÜS was to develop a concept for monitoring the levels of the gauges. In the developed concept it was planned to equip important gauges with continuously operating GNSS (Global Navigation Satellite Systems) sensors. Owing to the exposed locations of the gauges, only geodetic GNSS receivers with a remote administration system at their disposal came into question for this purpose. The measured data from the latter are automatically transmitted to an evaluation station where they are processed. In the end, weekly coordinates of the GNSS reference points on the gauges are determined, which are related to a particular reference system or a level reference surface (spatial referencing).

In combination with level measurements between the GNSS reference points and the gauge fixed points and gauge datum levels, the levels of the GNSS reference points may be transferred to the gauge datum levels.

Within the framework of PEGASUS this concept was realised at a total of six stations. The gauge stations Knock, Alte Weser lighthouse, Dwarsgat front light, Cuxhaven Steubenhöft, Büsum and Dagebüll were fitted with the necessary equipment within the framework of PEGASUS. The GNSS devices necessary for this purpose were procured and made available by the German Federal Institute of Hydrology (BfG). In addition, the BfG provided the infrastructures necessary for data transmission, remote administration and data processing. The erection and maintenance of the stations was supported by the Regional Waterways and Shipping Administrations (WSV) responsible and the Schleswig-Holstein State Agency for Coastal Protection, National Parks and Marine Conservation.

The deployed GNSS systems consisted of geodetic double-frequency receivers manufactured by the Leica Company (GRX1200 series) in combination with absolutely calibrated choke ring antennae (Leica AT504GG). Moreover, an attempt was made to minimise all presently known level-influencing factors as far as possible during installation. This especially concerns the setup calibration (calibration with a radome and a tripod in the setup configuration) and mounting of the antennae at locations without reflectors in the immediate proximity of the antennae (minimisation of near-field effects).

In collaboration with the German National Meteorological Service (DWD), a mobile network transmission based communication channel was established by the BfG. All GNSS systems are equipped with a GPRS module, whereby the system SIM card is connected via the mobile network operator to a DWD server, which in turn is connected to the BfG network. The communication channel described above is bidirectional, which means that it is possible to control the GNSS systems from the BfG Intranet and the receivers are able to transfer the collected GNSS observations automatically to an FTP server belonging to the BfG. The receivers operate as stand-alone systems and intervention is only possible in exceptional cases (upgrades etc.).

All GNSS observations are pre-processed and quality-assured according to international standards. For the purpose of deriving long-term coordinate changes in scientific work the observed data are thinned to obtain values at 30-second intervals, which are made available in daily blocks on an FTP server. A quality check is then carried out on the observed data, whereby individual characteristic values, signal noise relationships, multi-path parameters and other information are computed and stored on a daily basis for each station together with GNSS measurements. Besides GNSS observations, additional information (descriptions, photographs, antenna models etc.) and levelling results (level difference: GNSS reference point – gauge fixed point/gauge datum) are stored on this server. By virtue of the stored information it also possible for other users to process the GNSS observations in any arbitrary reference frame and to transfer the coordinates to the gauge datum point. In combination with water level data above gauge datum, water level data are obtained which are related to the particular reference system chosen. All data stored on the FTP server are freely accessible to scientific users.

Processing was carried out in very close cooperation with the German Geodetic Research Institute in Munich (DFGI). This institute makes a major contribution towards the realisation of global reference systems. Moreover, the DGFI processes a part of the TIGA network (TIGA = TIde GAuge Benchmark Monitoring Project), whose task is to monitor the vertical movements of tide gauge stations distributed across the globe. Over 60 stations in the North and South Atlantic are thereby processed by the DGFI.

Within the framework of PEGASUS, processing was carried out using the Bernese Software 5.0 under deployment of products provided by the IGS (International Geodynamics Service). Besides the tide gauge stations, different IGS and EPN stations were also included. Processing was carried out from the large-scale to the small-scale. The coordinates of the GNSS tide gauge stations are determined in relation to a global reference system and finally transferred to the official regional reference systems. A coordinate solution for all IGS stations in a global reference system (IGS05) is published weekly by the IGS. This contains the up-to-date coordinates of the IGS stations in relation to a fixed coordinate system. Movements and hence the accompanying changes in the coordinates of these stations (e.g. due to surcharge effects, groundwater extraction, tectonics etc) are thus recorded. A selection of IGS stations serve as soft bearing points ("coordinate constraint solution") for the GNSS network of the BfG. The coordinates determined within the framework of PEGASUS are thus referred to the weekly coordinates of the IGS.

The coordinate solutions for the tide gauge stations resulting from the latter are only suitable to a limited extent for evaluating water level time series. A gravitational field model is required in order to implement these in a physical (official) level system. Within the framework of the project the GCG05 model developed by the German Federal Agency for Cartography and Geodesy (BKG) was used. Coordinates in the official coordinate system of the German National Ordnance Survey are necessary to run this model. Via simultaneously processed GREF stations (Integrated German Geodetic Reference Network) (BORJ, HELG, HOBU and HOE2), a relationship to the official realisation of the ETRS89 reference system is established, the coordinate solution is transferred to the official ETRS89 reference system, and the level anomaly of the GCG05 is applied. This results in up-to-date levels at level status 160 (DHHN92).

Owing to the short time series, it is hardly possible to derive robust prognoses of level changes within the framework of PEGASUS. Within the framework of the research programme KLIWAS (Effects of climate change on federal waterways and shipping – development of adaptation options) funded by the German Federal Ministry of Transport, Building and Urban Development (BMVBS), the path embarked on will be followed in the future. Additional tide gauge stations have been and will be equipped with GNSS systems for continuous monitoring. At the present time, GNSS systems are installed at 18 WSV tide gauge stations in the German Bight and its estuaries. Additional GREF GNSS stations operated by the GKG will be added to the 18 GNSS stations already operated by the BfG. Reference of the latter to the tide gauges will be monitored by the German Federal Waterways and Navigation Administration (WSV)/BfG. This concerns the GREF stations HELG, HOE2 and BORJ as well as tide gauges at Heligoland, Hörnum and Borkum-Südstrand.

Besides Germany, other countries (Great Britain, the Netherlands and Norway) have installed continuously-operating GNSS systems on important tide gauges. The observations of these GNSS systems will also be utilised within the framework of KLIWAS. Because the datum levels of all GNSS tide gauge stations are available in a homogeneous reference system, this permits an evaluation of water level data across country borders. In practice, this means, e.g. that the gauge datum of the Lerwick tide gauge on the Shetland Islands may be compared to the gauge datum of the Cuxhaven Steubenhöft tide gauge to an accuracy of just a few mm. Using gauge datum levels in global reference systems, it is also possible to combine locally-recorded water levels with observations obtained by satellite altimetry.

MyOcean – A project aimed at developing European Marine Core Services

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Within the framework of the GMES initiative (Global Monitoring for Environment and Security) the EU and ESA are attempting to permanently secure autonomous and independent access to reliable global monitoring information for the whole of Europe. The aim of GMES is to harmonise data from different sources and to make available high-quality data and services on a continuous and on-schedule basis. For this purpose so-called core services are presently being developed, which are intended to provide up-to-date security-relevant and environmentally-relevant information for politics, industry and commerce, citizens, authorities and science.

The project MyOcean was initiated in 2009 as part of the 7th Framework Programme of the EU for European marine areas. The aim of this project is to develop operational Marine Core Services (MCS). These are based on a combination of observed data from remote sensing and in-situ systems with model simulations. MyOcean hereby makes use of the experiences gained in earlier EU projects such as MERSEA, MarCoast, PolarView, ECOOP among others, and is based on cooperative work between the regional European GOOS alliances (NOOS, BOOS, MOON etc.). MyOcean is a three-year project comprised of 61 partners from 29 countries and is coordinated by Mercator Ocean (France). Four thematic areas are dealt with in MyOcean by meteorological and oceanographic institutions, research institutes and companies. Application examples include, among others, contributions towards safety and security in maritime shipping, support of offshore activities, preventive methods to counteract oil pollution, the management of marine resources, water quality monitoring for protecting the marine environment, climate monitoring and seasonal forecasts.

In MyOcean there are 12 production units comprised of 5 thematic centres for observation data (4 centres for remote sensing data and one in-situ data centre) as well as 7 forecasting centres (6 regional and 1 global centre). All production units are obliged to openly and continuously provide basic data concerning the physical state and ecosystem of the sea free of charge. Users of MyOcean products are European organisations (EEA, EMSA, HELCOM, OSPAR, ICES among others) as well as different institutions of the EU member states. Because the base data of MyOcean are mostly large-scale or meso-scale, these must be further processed for special end-user applications and requirements by other service providers to create so-called downstream services.

The German partners in MyOcean consist of the German Federal Maritime and Hydrographic Agency (BSH), the Leibniz Institute of Marine Sciences at the University of Kiel (IfM GEOMAR) as well as the Brockmann Consult company. The central themes dealt with in the BSH participation concern in-situ data recording as well as modelling activities in the forecasting centres for the Baltic Sea and the NW continental shelf area. In the case of the Baltic Sea forecasting centre, the BSH is directly involved in production as a partner of a consortium comprised of 4 countries bordering the Baltic Sea (DMI, BSH, SMHI, FMI). The consortium is presently developing a new physical-biogeochemical Baltic Sea model HBM (HIROMB-BOOS model), which is centrally maintained and run by the partners using different boundary conditions. By this means, it will be possible to establish the basis for an ensemble forecasting system in the Baltic Sea. The forecasting centre for the north-west continental shelf area is run by the UK Met. Office. With regard to the latter, the major activities of the BSH are focused on validation and quality control. In addition, the BSH coordinates the in-situ data management system for the north-west continental shelf area. The SMHI (Sweden) has taken on responsibility for this task in the Baltic Sea region.

In MyOcean, centralised and standardised access to services and products has been set up under ***www.myocean.eu.org.*** In the case of the 128 Version 0 - Products, however, which has existed since the project was launched, a direct download from the Web portal is only possible in a limited number of cases. In most cases it is still necessary to contact the production centres. After registering as a MyOcean user or after concluding a Service Level Agreement (SLA), it is then possible to download data from ftp or OpenDAP servers. In the next Version 1, which will be available at the end of 2010, it should be possible to receive all products directly via the MyOcean portal.

Of special importance for the MyOcean project is the integration and linking of users. In the first half of 2010, more than 600 products were already requested by over 70 users. In addition, about 20 SLAs were signed by so-called core users, also including the BSH. The further development and operational implementation of the core services is planned in a follow-up project, which is tendered in the 7th framework programme of the EU extending to November 2010 and will cover the time period 2012 to 2014. In the MyOcean follow-up project it is planned to develop new products, raise the quality of core services, and further improve access to products as well as user integration. At the present time, challenges and uncertainties still exist regarding the long-term financing of the GMES core services beyond 2014.

Imprint

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