KFKI aktuell

German Coastal Engineering Research Council - GCERC newsletter
5th year Edition Hamburg, October 2005 2/2005

Editorial

31st International Conference on Coastal Engineering

The German Society for Port Engineering (HTG) and the German Coastal Engineering Research Council (KFKI) have taken on the commitment in conjunction with other national institutions and institutes to organize the 31st International Conference on Coastal Engineering (ICCE) in Hamburg from August 31 to September 5, 2008.

The „International Conferences on Coastal Engineering“ are normally held every two years at changing locations around the world.

The conference provides and excellent opportunity for coastal engineers to discuss latest research and innovative case studies.

The target groups of ICCE conferences are research institutes, coastal authorities, consultants and contractors. The ICCE covers the whole area of coastal engineering, including:

- **Coastal processes** (waves, tidal dynamics, extreme water levels, transport processes, coastal morphodynamics, coastal erosion, scouring)
- **Coastal structures** (planning, design, performance, optimization and maintenance of coastal and estuarine structures)
- **Harbours and waterways** (planning, design and construction of harbours and deep water terminals, siltation, dredging, management und optimization of dredged material, wave structure soil-interaction, ship impacts)
- **Coastal environment** (coastal pollution, recreation, water quality, wadden seas, wetlands and estuaries, environmental impacts and compensation, coastal eco-hydraulics)
- **Coastal risks** (coastal risk sources, coastal breaching, flood risk management and strategies, assessment of coastal risks)
- **Coastal development** (coastal zone management, coastal energy, navigation and transportation, monitoring, data management, information systems, sustainability of coastal projects, coastal concepts)

In general, 500 papers on different topics of coastal engineering are presented during an ICCE in six parallel sessions. Technical excursions, short courses on special subjects, key note lectures and social events like an ice-breaker party, a welcome reception, a conference dinner and post conference tours are part of the conference programme.

Owing to its size and the large number of participating experts, the conference is also used for project meetings, discussion of new national and international research projects, information exchange and public relations. Consultants and contractors are welcomed to highlight their products, services and research activities during the technical exhibition.

The Local Organising Committee (LOC) expects international publicity for national contractors, consultants and research institutes, a broad presentation of national conference papers on applied and fundamental research results, promotion of the national relevance of research and development in coastal engineering and finally a motivation of young professionals. The LOC intends to attract all interested competencies in the field of coastal engineering in Germany for a successful and sustainable conference. Therefore, the LOC depends on a wide support from the German coastal community.

All interested colleagues are encouraged to contact Dr.-Ing. Holger Schüttrumpf for further details.

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Loading and dimensioning of wooden piles in coastal engineering

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Introduction

Groynes built of wooden piles represent an important part of coastal protection structures on the Baltic coast of Germany in order to stabilise sandy beaches. Ramming depths of wooden piles are dimensioned by an empirical approach based only on the water depth. The German Ministry for Research and Education has initiated a research programme, which aims at the development of more scientific rules for the dimensioning of wooden groyne piles.

Within the research program "Loading and dimensioning of wooden piles in coastal engineering", recommodations for the dimensioning of wooden pile constructions were developed, taking into account a larger number of parameters, such as subsoil conditions, water depth, local wave and ice conditions, and the position within the groin. The total of loading and holding forces as well as static and dynamic forces were investigated. Main subjects of investigation were wave loading and vertical ice forces. Holding forces were measured by field tests on site in different kinds of subsoil. Liquefaction effects were investigated.

Investigations were carried out from 2001 to 2005 as co-operation between the Institute for Coastal and Hydraulic Engineering of the Rostock University and the Agency for Environmental Protection of Mecklenburg-West Pommerania as governmental authority in charge of coastal protection.

Investigations

Vertical ice loads and holding forces

Besides wave impact, the most important loads acting upon piles are horizontal and vertical ice loads. Existing approaches for the calculation of vertical ice loads and holding forces of piles give largely varying results.

Vertical ice loads on piles are effected by an ice cover frozen to the piles and lifted up by water level rise. Piles can then be pulled out of the sea floor. This process known as ice-jacking can occur several times during a winter. The vertical holding forces (friction) of the pile depending on pile length and subsoil conditions have to compensate the vertical loads.

Laboratory test

Since cold winters occur only rarely on the German coast and cannot be predicted, ice loads which can be transmitted from an ice cover to wooden groyne piles need to be investigated in a laboratory. Ice-tests are performed in the climate-chamber of the Rostock University, Department of Civil Engineering. In the laboratory, temperatures down to –25°C can be produced. The maximum lifting force transmitted from ice to pile depends on ice thickness and velocity of water level rise, which can be controlled.

In the experiment, a pile is frozen into an ice sheet in a circular basin (diameter 2.5m, depth 8.0m) and then hydraulically pressed at a defined velocity until failure occurs. Load and deformation of the ice sheet are digitally registered during the test. A series of experiments with different ice thicknesses and salinities has been accomplished. Figure 1 gives an impression of the measurement device.

Fig. 1: Measurement of vertical ice loads in the climate chamber

Failure does not occur as shear failure between pile and ice, but rather happens as bending failure at the sigmoidal flexure zone in the close proximity of the pile. The measured vertical ice forces were higher than predicted according to German standards (EAU 2004). These differences are due to the physical model used in German standards. Based on the laboratory results a Russian calculation approach for vertical ice load on piles is recommended.

Holding forces (Pull-out-tests)

To investigate holding forces as a function of the type of subsoil and ramming depth of piles, pull-out-tests were performed on numerous piles under different conditions on the Baltic coast of Germany. Type of subsoil and ramming depth of the test-piles are varied.

A test apparatus was constructed, which allows the piles to be pulled with forces up to 120 kN. Pulling load and displacement of the pile are registered simultaneously. A total of 50 pull out tests were performed on the Baltic German coast during the research programme. The results were compared with different calculating methods for vertical holding forces of piles, in order to evaluate the reliability of these theoretical approaches. As a result, the holding forces of piles in different subsoil and ramming depth should be predicted by the empirical approach of Schenk and Herzog.

Pile movements and liquefaction effects

Wave attack on groyne piles results in a vibration of piles. This vibration is transferred to the surrounding subsoil, where liquefation may occur at certain frequencies. This mechanism results in a reduction of the shear strength of the soil - causing failure of the pile. Liquefaction depends on frequency and on changes in pore water pressure directly at the pile.

The response of groyne piles to wave impact was measured by acceleration sensors fixed to piles along the coast. Movements of the piles were recorded over the whole lengths of the pile. From acceleration measurements, the amplitude of pile movement and frequency of pile vibration were calculated, the latter allowing to deduce the characteristic length of the moving pile.

During the measurements of pile movements, both regional wave regime (directional waverider buoy off the coast) and local waves (pressure gauge at the pile) were recorded simultaneously. Thus, pile movements could be related to the incoming waves.

Having the results about the relation between wave attack and resulting pile movements, an experiment was performed at a beach on the Baltic Coast, aiming at the investigation of the relation between pile vibration and the development of critical pore water pressure, which is the critical parameter and cause for liquefaction.

Two piles with different lengths and ramming depths were rammed directly at the water line and forced to vibrate at defined amplitudes and frequencies. Vibration was induced by a pneumatic shaker simulating the natural vibration caused by wave impact. The changes in pore water pressure as a result of pile vibration were measured by pressure cells at different distances from the piles and in different depths. Figure 2 gives an impression of the experiment.

Fig. 2: Pore water pressure investigations

Based on the measurements, the correlation between wave load, pile movement and induced pore water pressure changes was determined, depending on soil conditions, pile length and water depth of the groyne pile. Remarkable pile movements occur as a result of breaking waves and a low water level. The pile movements effect a rising pore water pressure in the ground near the pile, but a complete loss of the shear stress of the soil can be found only till 0,5 m under ground surface. The investigation of pile movements and pore water pressure results in a prediction of wave-induced pile movements and an assessment of wave induced liquefaction around piles.

Results and acknowledgements

The investigations allow the dimensioning of ramming depth of nearshore (groyne) piles with respect to wave loads, ice forces, water depth and holding forces including liquefaction under different subsoil conditions. Guidelines for the dimensioning of piles will be published in the masterplan for coastal protection of Mecklenburg–West Pommerania, Germany.

This research was financially supported by the German Ministry for Research and Education (03KIS023) and the Agency for Environmental Affaires of Mecklenburg-West Pommerania. The authors gratefully acknowledge this support.

Simulation of morphodynamic activities due to density-effects in case of dredged matter disposal

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This paper deals with exemplary results of BMBF/KFKI project 03KIS029. It describes the extension and application of a three-dimensional morphodynamic-numerical simulation model in order to reproduce density effects and their influence on the morphodynamic behavior of natural waters. Measurements of suspended sediment concentration, salinity distribution and flow velocities in the vicinity of dredged matter disposals were provided for tidal and estuarine conditions.

The influence of density-effects on morphodynamic processes is shown in case of dredged matter disposal. Density gradients basically cause an increased damping of turbulent momentum exchange and turbulent diffusivity.

For estuarine environments, two kinds of effects can be distinguished: Density-currents in the (extended) nearfield of disposal sites due to high local gradients of suspended particulate matter concentration (SPMC) as well as salinity-induced density-effects in the lower tidal rivers and their estuaries. The latter stratification process results in a wide area variation of the flow field by means of vertical gravitational circulation. This finally leads to distinct intensification of net near-bottom sediment transport rates pointing to the upstream direction, see figure 1.

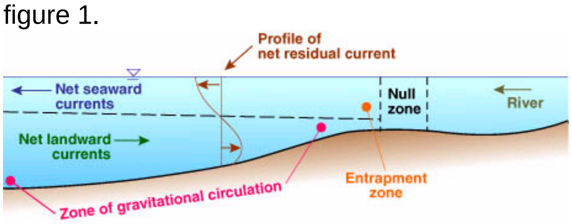

Fig. 1: Vertical gravitational circulation (Source: USGS)

In the mixing-zone of fresh and sea water both effects can appear superposed, for tidal and alluvial conditions only the first effect mentioned will occur.

Stratification due to temperature differences is negligible for the cases mentioned here.

SMOR3D is a three-dimensional time-explicit morphodynamic-numerical model. It consists of a 3D instationary flow solver, which is directly coupled with several transport models for salt, suspended and bed-load sediment at every calculational time-step.

The flow-solver calculates the instationary three-dimensional Reynolds-averaged Navier-Stokes-equations (RANS) in a time-explicit way. Spatial discretisation is done by the method of finite elements; in the time domain, a three-level leap-frog-scheme is implemented. The RANS are solved by neglecting dynamic pressure in the vertical direction. This assumption is valid for all cases, where vertical accelerations in the flow-field can be neglected, i.e. for large-scale calculations, and is used here because of its considerable saving of computational effort.

Sediment transport is balanced by a bottom evolution model, which provides bottom level changes and local resuspension properties as well as strict sediment continuity checking. Sediment is described by multiple fractions with different properties (e.g. grain size, settling velocity, cohesion). Local effects like hiding/exposure and armouring is accounted for by the bottom evolution model.

For calculations in tidal areas a robust wetting/drying-scheme is implemented to consider moving boundaries within the calculational domain. The structure of the model coupling inside SMOR3D is given by figure 2:

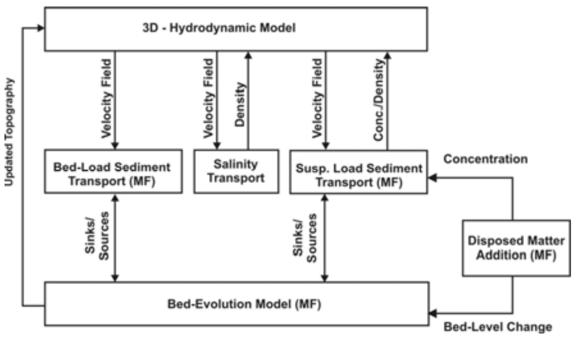

Fig. 2: Model coupling SMOR3D

The extended simulation model reproduces the measurements reasonably well as can be seen from Figure 3. It shows the spreading of disposal induced turbidity under tidal conditions. The turbidity cloud moves by means of a density current for the first minutes, for later transport phases it is confined to the near bottom area due to damping of turbulent mixing.

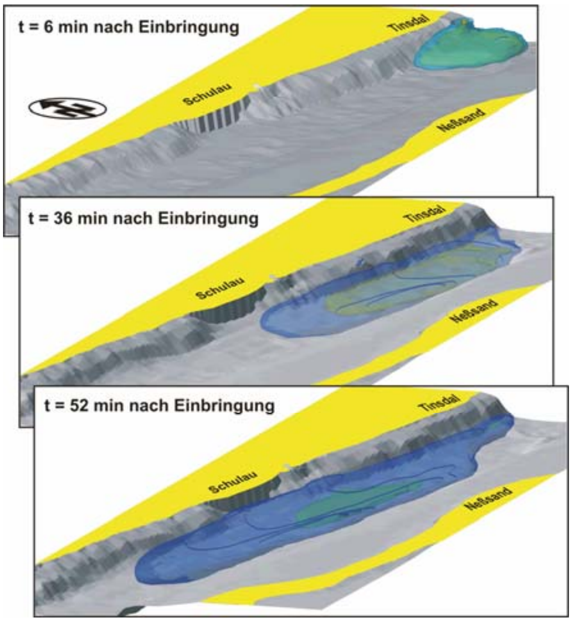

Fig. 3: Disposal induced turbidity pattern (calculated SPMC-Iso-surfaces) at three points of time.

Modelling study of storm surges with very low probabilities of occurrence in the German North Sea (MUSE)

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Introduction

MUSE (Modellgestützte Untersuchungen zu Sturmfluten mit sehr geringen Eintrittswahrscheinlichkeiten - Modelling study of storm surges with very low probabilities of occurrence in the German North Sea is a joint research project of the German Weather Service (DWD), the Federal Maritime and Hydrographic Agency (BSH), and the Research Centre for Water and Environmental Engineering (fwu) at University of Siegen, which was carried out in the period from 2002 to 2005. The project was supported by the German Coastal Engineering Research Council (KFKI).

The purpose of the project was to simulate extreme storm surge events in the German Bight (Fig. 1) and to determine their probabilities of occurrence. To achieve this goal, a modelling chain for the simulation of physically consistent storm surge weather situations was developed by the German Weather Service and the Federal Maritime and Hydrographic Agency.

Methods and results

At the beginning of the project, criteria were developed that have to be met by a wind field (near-surface horizontal wind) in order to cause a significant rise of sea level in the German Bight. Surge forcing wind events were found to be, inter alia, wind directions from WSW to NNW (247.5° - 337.5°) with a wind speed of 8 Bft (about 17 m/s) or more. This step was followed by computer-aided screening of the archived weather forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF, UK) for weather events meeting the above criteria. The events were hindcast using the ensemble prediction system (EPS) of ECMWF, and the members with the highest wind speeds were subsequently run with a higher resolution on the local model (LM) of the German Weather Service.

The modelling data of these storm surge events were then transferred via interface to the Federal Maritime and Hydrographic Agency (BSH), where water levels in the German Bight during the events were computed using a water level prediction model. Comprehensive verification analyses had to be carried out at the BSH prior to the water level computations in order to find a suitable wind stress approach for high wind speeds.

The highest modelled water levels in the German Bight were obtained using the data of the storm surge event of 1976 as initial conditions. Stochastic variation of the boundary conditions of the storm surge event of 1976 in EPS yielded one member with an extremely high maximum effective wind speed (directed toward the German Bight) of V_{max} = 29.5 m/s. By comparison, re-analysis of the actual wind field of the 1976 storm surge showed a maximum effective wind speed of $V_{max,Re}$ = 21.6 m/s. Because of the physical consistency of the meteorological models used, it is reasonable to assume that wind speeds during the storm surge event of 1976 might even have been about 8 m/s higher.

The modelled water levels in the German Bight exceeded the highest levels ever recorded (HHThw) by 0.8 to 1.4 m. The maximum modelled water level at the Cuxhaven gauge is $HW_{max.mod}$ = 651 cmNN. By comparison, the HHThw in 1976 was $HHThw_{1976}$ = 510 cmNN. The results of all simulated maximum water levels are shown in Fig. 2. These water levels represent the highest storm surge water levels modelled within the framework

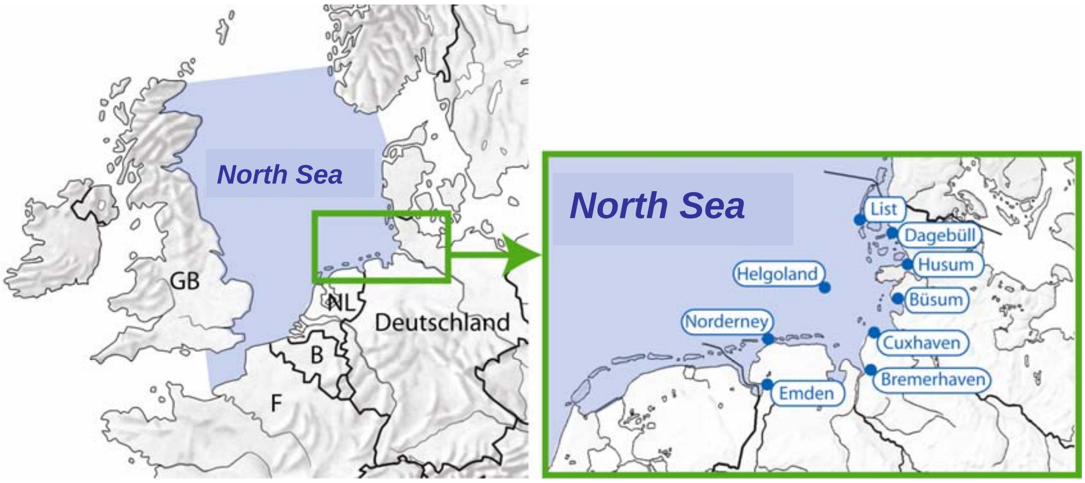

Fig. 1: Study area of the MUSE research project

of this research project. It cannot be ruled out, though, that these values can never be exceeded. That has also been taken into account in the statistic-probabilistic analysis, where a probability of $P_Ü > 0$ is allocated to these events.

The following requirements had to be met by the statistic-probabilistic analysis:

- Use of all high-quality HThw data (highest tidal levels) at a gauge
- Modelled extreme water levels had to be taken into account
- Reduction of the extrapolation variance in the range of very small probabilities ($P_Ü < 10^{-3}$)
- Water levels cannot rise indefinitely

To be able to meet these requirements, a distribution function capable of taking into account additional information in the range of very small probabilities of occurrence had to be used. To that end, the 3-parameter generalised extreme value distribution (GEV) was used which, in the range of very small probabilities, asymptotically approaches a limit value. The main task was the determination of the curvature parameter τ, which in a first approximation was computed from the maximum modelled water level and an allocated estimated probability of occurrence from the EPS ($P_{Ü,\ estimate} = 1.5 \cdot 10^{-5}$). This first approximation was improved in several iteration steps.

Fig. 2 shows the 10^{-4} events at all gauges included in the study, with their domains of uncertainty. Detailed results are presented in the final report of the research project.

Evaluation

The methods and results of the project demonstrate that, by using state-of-the-art modelling systems and adjusted mathematical-statistical methods, improved estimates of water levels in the range of very low probabilities of occurrence can be achieved, which are based not only on the mathematical properties of the distribution functions used but on additional physical data in the range of very rare probabilities of occurrence.

It is recommended to apply such methods in addition to the commonly used statistical data evaluation method in order to obtain a reliable decisionmaking basis.

Acknowledgements

We wish to thank all participants of the project for their valuable contributions and commitment. Funds for this KFKI research project were provided by the Federal Ministry of Education and Research (grant no. 03KIS039).

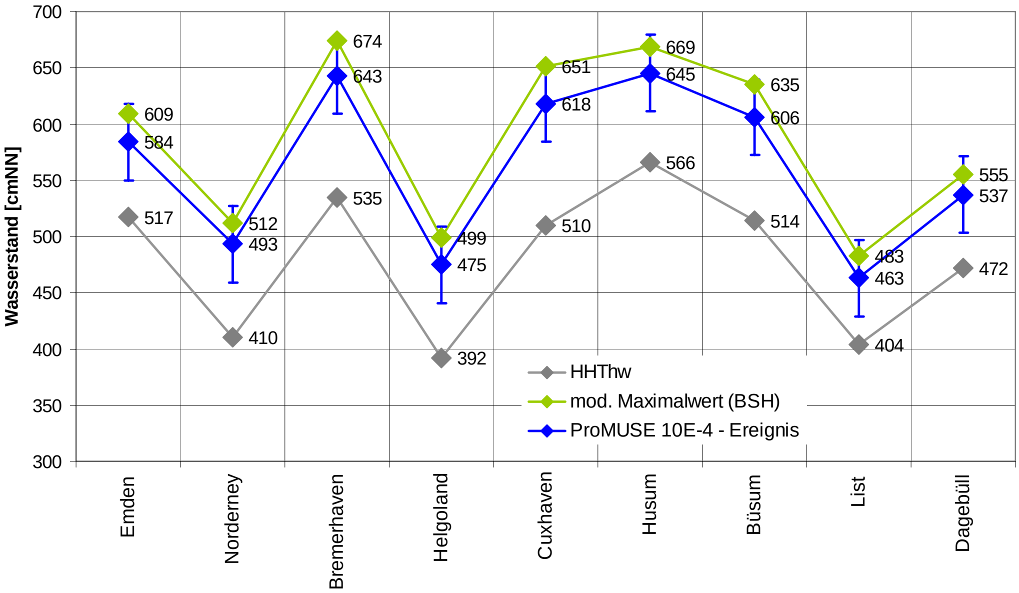

Fig. 2: Results of maximum modelled water levels and 10^{-4} events

BELAWATT – Hydrodynamic impact on Wadden areas

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The KFKI research project "Hydrodynamic impact on Wadden areas" (German acronym: BELAWATT) was funded starting in summer 2002 for a period of 3 years (research contract 03KIS038). Progress within the project was reported in 2 intermediate reports.

The previous history of the BELAWATT project: In November 2000, the project DYNAWATT was outlined (DYNAWATT = Influence of hydrodynamics on the dynamics of sediments, biogeochemistry and biology in the Wadden Sea).

The leadership for the project was with AWI (Alfred Wegener Institute for Polar and Marine Research). The proposed cost of DYNAWATT was about 5 Million Euro. However, DYNAWATT was not put into action by the German authorities. Instead the project BELAWATT was initiated by the KFKI's head of scientific research, thus putting into practice one of the basic elements of DYNAWATT, the modelling of hydrodynamics. In addition, field measurements were planned for validating the model results of BELAWATT.

It is the objective of BELAWATT to quantify the impact of currents and waves on Wadden Sea areas by using the Hörnum tidal basin (North Frisian islands, see Fig. 1) as an example. The hydrodynamic impact is quantified by means of the shear stress which is generated on the sea bottom by currents plus waves. The primary objective of BELAWATT is the search for an adequate method - the *comparison* of Wadden Sea areas, as planned in DYNAWATT, is of secondary importance.

In the sequel, we report first on the scope of field measurements, and second on the results of the model simulations.

Field measurements

During the complete funding period of BELAWATT, field measurements were carried out in cooperation (1) with the Regional Office of the Schleswig-Holstein Wadden Sea in Tönning and (2) the Authority for Rural Areas in Husum. There were both long-term measurements (several months) at fixed sites and short-term ship campaigns (10 days). The devices for the long-term measurements were a fixed monitoring pile, bottom mounted ADCPs, wave rider buoys and a wave monitoring system WaMoS (fixed land station). See Fig. 1 for the positions of the devices.

A wave gauge with a floating device and and a mechanical guidance to heave and lower the underwater unit with the sensors are mounted laterally to the monitoring pile. The pile's underwater unit is equipped with sensors for pressure, temperature, conductivity, currents (ADCP and ADV), transmittance, and turbidity. Worth mentioning is the horizontal alignment of the ADCP; in this way the currents can be measured directly at the pile, but in addition the horizontal velocity shear can be acquired at high resolution over a distance of up to 70 m.

Meteorological sensors (pressure gauge, thermometer, vane, anemometer, radiometer) are mounted on top of the pile's platform, where the data is not significantly impacted by the pile itself. In order to avoid damages by ice drift and stormy weather, the monitoring pile and the bottom mounted ADCPs were brought onshore in late autumn and relaunched in next year's spring at the previous positions. The survey vessel "Ludwig Prandtl" was used during all ship campaigns in April 2003 and August 2003. The column diagram in Fig. 2 shows the monitoring periods.

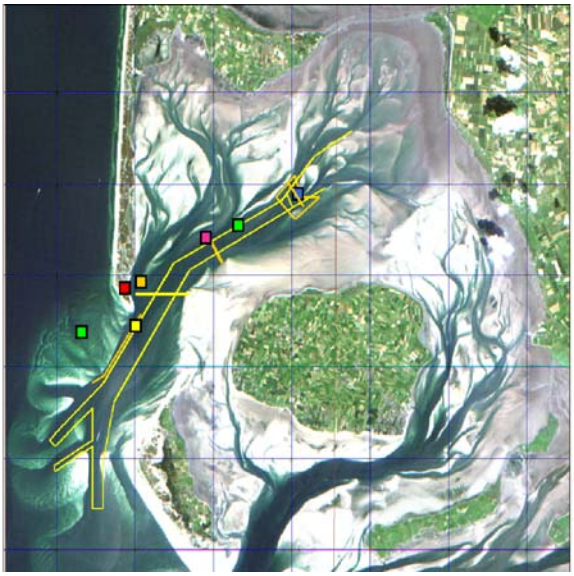


Fig. 1: The Hörnum tidal basin is located in the northern half of the map. The sites and colors of the long-term measurements: (1) monitoring pile, blue (2) bottom mounted ADCP, pink (3) wave rider buoys, green (4) WaMoS, red. The transsects of the 2003 ship campaigns are shown in yellow and in orange.

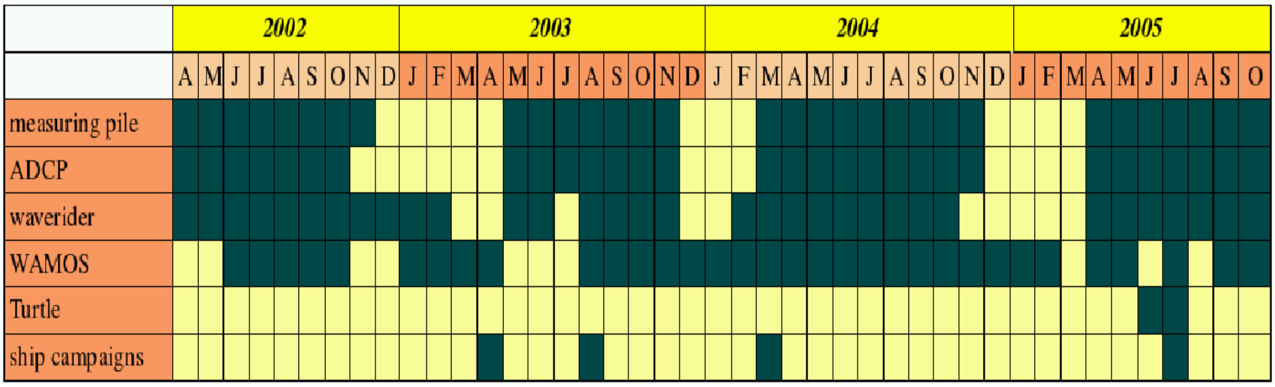


Fig. 2: Monitoring periods of long-term measurement devices and short-term ship campaigns between 2002 and 2005. Only ship campaigns longer than three days were considered. Concerning the ship campaigns, only those of April and August 2003 were carried out for BELAWATT. "Turtle" is an ADCP moored to the sea floor in deep water.

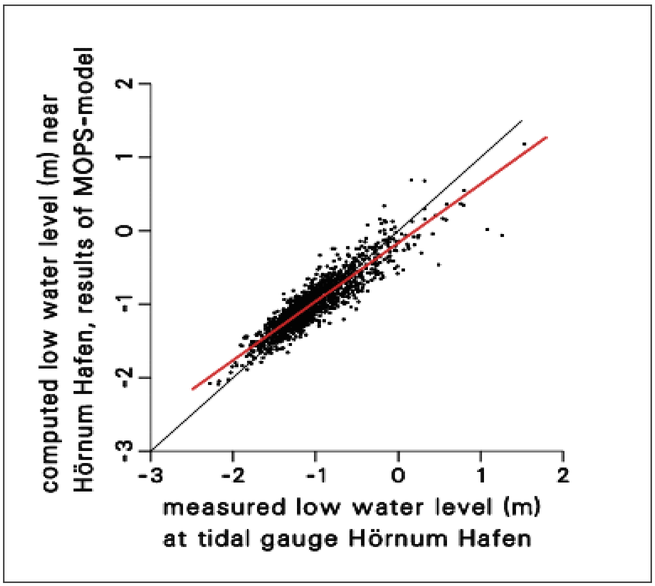
Model results

A 2-years time-series (Nov 1999 – Oct 2001) of hydrodynamics (currents, water levels, waves) was simulated for the Hörnum tidal basin. The computations use the time series of actual windspeed and wind direction.

The calculation of hydrodynamics was done with the hydrodynamic part of MOPS (Morphodynamic Prediction System), which consists of the coupled modules (1) TRIM3D (Casulli and Stelling 1995) for currents and water levels and (2) k-model (Schneggenburger et al. 2000) for waves. The coupling of the two modules means: TRIM3D provides currents and water levels to the k-model, the k-model provides radiation stresses to TRIM3D.

The model area of TRIM3D is the eastern half of the German Bight. The horizontal grid-size Δx decreases from Δx = 800 m in the seaward part of the model area stepwise via 400 m and 200 m to Δx = 100 m in the central model area, the Hörnum tidal basin (Fig. 5). The boundary conditions for TRIM3D at the seaward boundaries are provided by results (currents, water levels) of the operational BSH model (Müller-Navarra et al. 2003). The k-model calculates the waves in the central model area only. Moreover, to reduce CPU times, the k-model uses a grid-size of Δx = 400 m instead of 100 m. The wave boundary conditions for the k-model are provided by the HIPOCAS project (Weisse et al. 2003). The wind above the whole model area is the same as used in the operational BSH-model. Only above the central model area, the Hörnum tidal basin, the BSH-wind is modified by the MKW-model of the Seaweather Service Hamburg. The two-year results of the MOPS-system are archived with a time interval of 20 minutes.

Long-term validation of the MOPS results is shown in Figures 3 and 4. In Fig. 3, the computed low and high water levels at the model position "Hörnum harbour" (southern tip of Sylt island, near to the black circle in Fig. 5) are plotted against the monitored low and high water levels at tide gauge "Hörnum harbour". The gauge data was provided by the Water and Shipping Authority in Tönning. On average, the computed low water level is 4.3 cm above measured low water level, while the computed high water level is on average 6.3 cm below measured high water level. The computed mean tidal range is thus by 10 cm (or 5 %) smaller than the true tidal range which means too small current velocities by 5 %. The high water level at storm tides (high water level > 2.5 m at gauge Hörnum) are especially underestimated by the model: by 24 cm on average. Storm tides are important for the hydrodynamic impact on higher wadden areas, e.g. salt marshes.



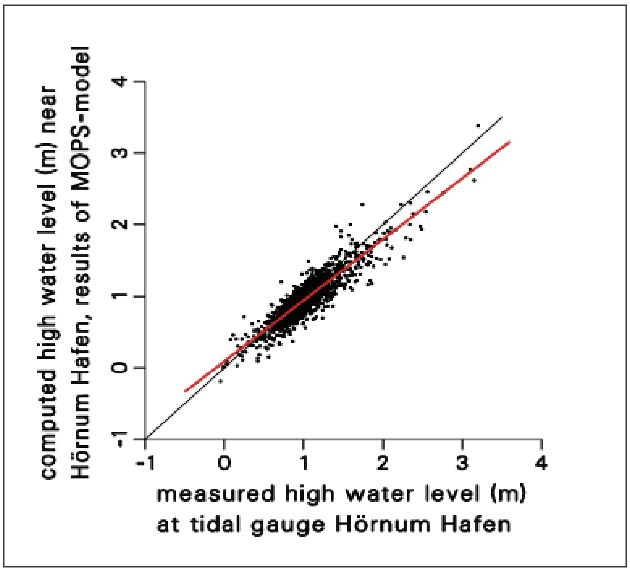


Fig. 3: Comparison of measured and simulated low water levels and high water levels at Hörnum harbour during the BELAWATT simulation period Nov 1999 – Oct 2001. The water levels refer to NN, the German ordnance level. The black lines are the 45^0 lines. The regression lines are in red.

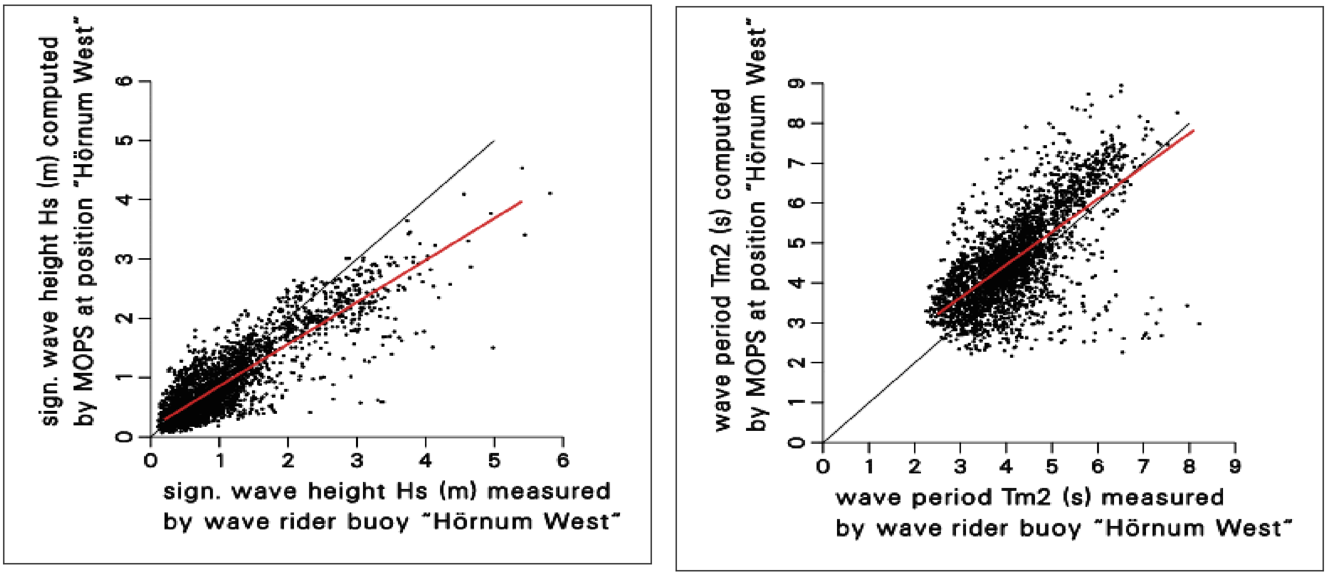


Fig. 4: Comparison of measured and simulated wave data: significant wave height HS (left plot) and mean wave period Tm2 (right plot). The measured data are from the wave rider buoy "Hörnum West" (see Fig. 5) of the Authority for Rural Areas in Husum. The water depth at the buoy's position is about 10 m. Period of comparison: Nov 1999 – Oct 2001. The black lines are the 45^0 lines. The regression lines are in red.

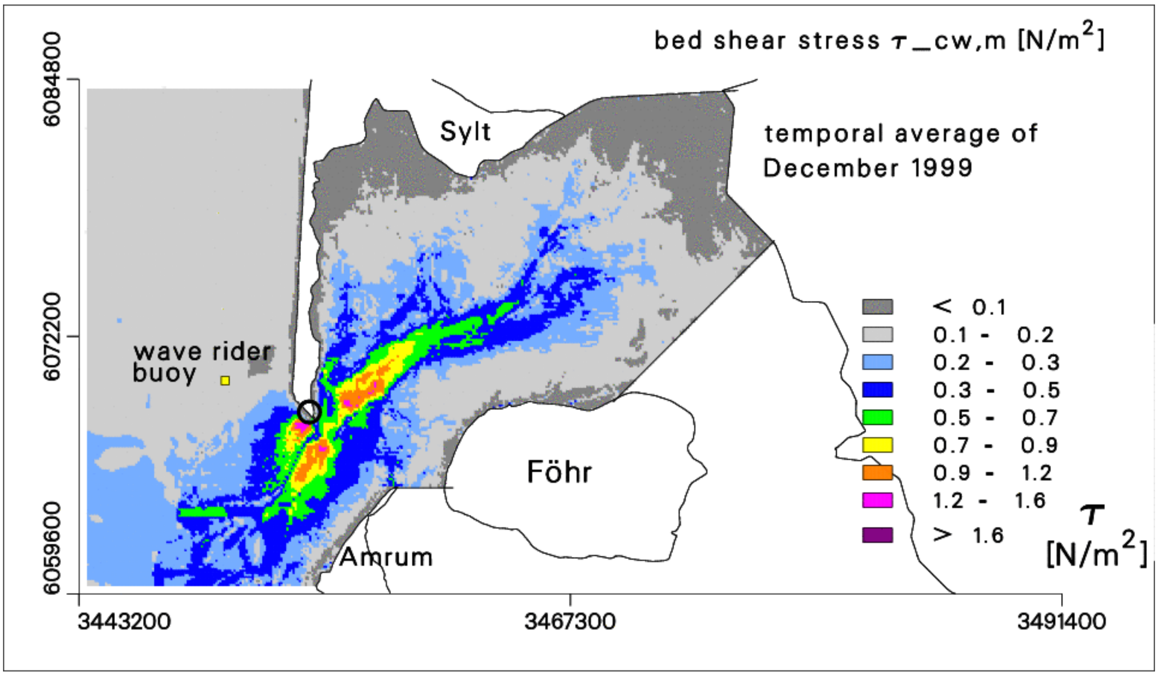


Fig. 5: Distribution of the calculated bed shear stress $\tau_{cw,m}$ in the central model area. In order to reduce the CPU time of the wave model, the wadden areas in the south and in the east of Föhr island were masked out. A spatial distribution of $\tau_{cw,m}$ is calculated every 20 minutes from the archived MOPS results (current velocities, water levels, wave parameters). This plot shows the time average of $\tau_{cw,m}$ for December 1999, a rather stormy month with the violent gale ANATOL on December 3. For each separate grid cell the time averaging of $\tau_{cw,m}$ considers only the times of flooding. The deciding factor for $\tau_{cw,m}$ is the current velocity, so $\tau_{cw,m}$ is highest in the tidal channels and smallest above the high wadden areas along the coasts. A special region with high $\tau_{cw,m}$ is just south of Hörnum Odde, the black circle in the plot at the southern tip of Sylt island. Here a strong transverse flood and ebb current ("transverse" to the main direction of the tidal channel) flows over a rather shallow bottom (water depth around 3 m). A narrow stripe with smaller $\tau_{cw,m}$ separates this area with high $\tau_{cw,m}$ from the tidal channel in the south-east with again high $\tau_{cw,m}$. The narrow stripe is due to a slowing down of the transverse current when it reaches the bank of the deep tidal channel. The co-ordinates of the map are Gauss-Krüger (German grid).

A long-term comparison of waves is given in Fig. 4. In the open sea, the model underestimates the significant wave height HS for moderate and high waves (HS > 1.5 m) by about 0.5 m. The mean wave Period Tm2, on the other hand, is computed as too high by about 0.5 s. The exception is a branch in the scatterplot with small computed Tm2 but high measured Tm2. This branch represents measured swell waves, which are obviously not adequately provided at the seaward boundaries of the k-model.

The wave data given in Fig. 4 is valid for the open sea. Most waves coming from the sea are damped or will break above the shallow ebb tidal delta between the Hörnum tidal basin and the open sea (see Fig. 1, lower left margin on the map, see also Fig. 6). In the Hörnum tidal basin itself (i.e. in the area between Sylt island and Föhr island, Fig. 5) the waves are produced by the *local* winds.

The bed shear stress τ is calculated from the near-bottom current velocity and the wave parameters HS and Tm2. The formulas used for the calculation of τ are those of Soulsby (1997). If both currents and waves act on the bed, the waves merely stir up the sediment particles, while the currents also stir up the sediment, but in addition produce a net transport of particles.

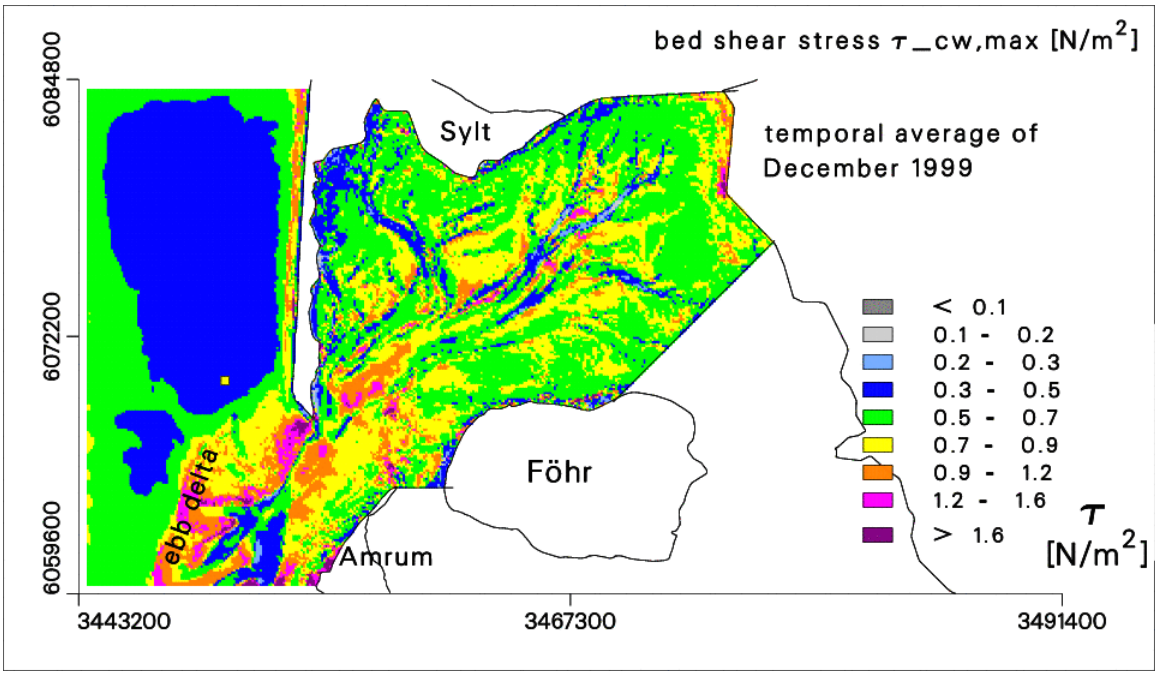


Fig. 6: Distribution of the calculated bed shear stress $\tau_{cw,max}$ in the central model area. To understand the plot see also the caption of Fig. 5. $\tau_{cw,max}$ is highest in areas where waves travel from deep water into shallow water, e.g. above the tidal ebb delta. $\tau_{cw,max}$ is also high above the higher wadden areas (salt marshes) along the coast in the eastern part of the basin. It must be kept in mind, however, that the temporal averaging of $\tau_{cw,max}$ takes into account the times of flooding only. Salt marshes are only flooded during storm tides, just when waves are comparatively high. In the tidal channels, the waves do hardly reach the bottom. So in the tidal channels $\tau_{cw,max}$ is only slightly increased compared with $\tau_{cw,m}$ shown in Fig. 5. In general, the distribution of $\tau_{cw,max}$ shows higher values above the tidal flats and smaller values in the tidal channels. This is just opposite to the distribution of $\tau_{cw,m}$ in Fig. 5. The incoming waves (HIPOCAS data) along the seaward boundaries are not fully "supported" by the k-model: the wave height decreases when the waves travel away from the boundaries. This results in higher $\tau_{cw,max}$ along the boundaries than in the areas away from the boundaries

Figures 5 and 6 show the bed shear stresses $\tau_{cw,m}$ and $\tau_{cw,max}$ which are both calculated from the combined action of currents and waves.

$\tau_{cw,m}$ is the *mean* bed shear stress during a wave cycle. It has the same direction as τ_c (which is the bed shear stress due to the current alone), but $\tau_{cw,m}$ is larger than τ_c (by a factor of 2.2 at most).

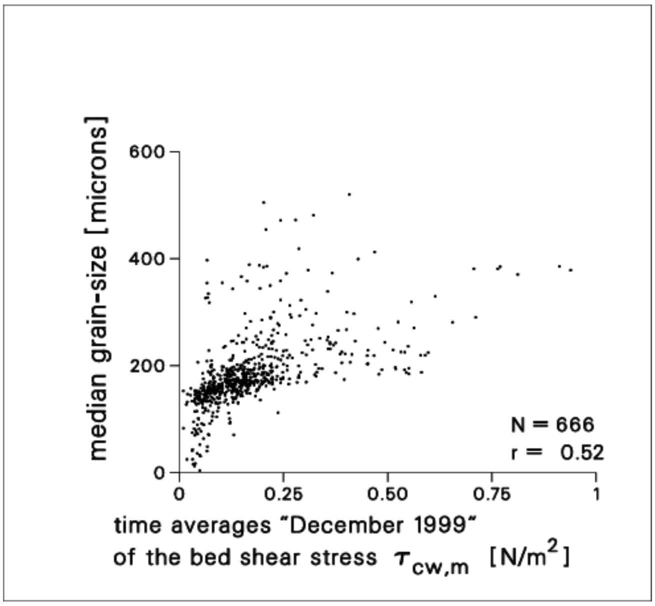
The reason for $\tau_{cw,m} > \tau_c$: The additional turbulence produced by the waves very near to the bed lets the mean current "reach" the bottom more intensely than without waves. In Soulsby's bed load formula, $\tau_{cw,m}$ is responsible for the transport (the drift) of the sediment. $\tau_{cw,max}$ is the *maximum* bed shear stress during a wave cycle. $\tau_{cw,max}$ shown in Fig. 6 is (in Soulsby's bedload formula) "only" responsible for answering the question whether sediment transport takes place at all: in case $\tau_{cw,max} < \tau_{cr}$, sediment transport is zero. τ_{cr} is the threshold bed shear stress for motion of sediment.

The central question in the BELAWATT project is: Is the bed shear stress τ a relevant parameter for describing the impact of hydrodynamics on the Wadden Sea? If yes, which kind of τ is mostly relevant? To answer those questions, spatial distrubutions of τ (as shown in figures 5 and 6) are compared with the spatial distributions of grain-sizes and bottom fauna in the Hörnum tidal basin.

One of those comparisons is shown in Fig. 7: the median grain-size of sediments is plotted against $\tau_{cw,m}$ and $\tau_{cw,max}$.

Obviously $\tau_{cw,m}$ is more relevant for the spatial sediment distribution than $\tau_{cw,max}$. This means that the distribution of sediment in the Hörnum tidal basin is more influenced by the (transporting) current than by the (stirring) waves.

It must be concluded that not the impact, but the transportive action of hydrodynamics is relevant for the sediment distribution.



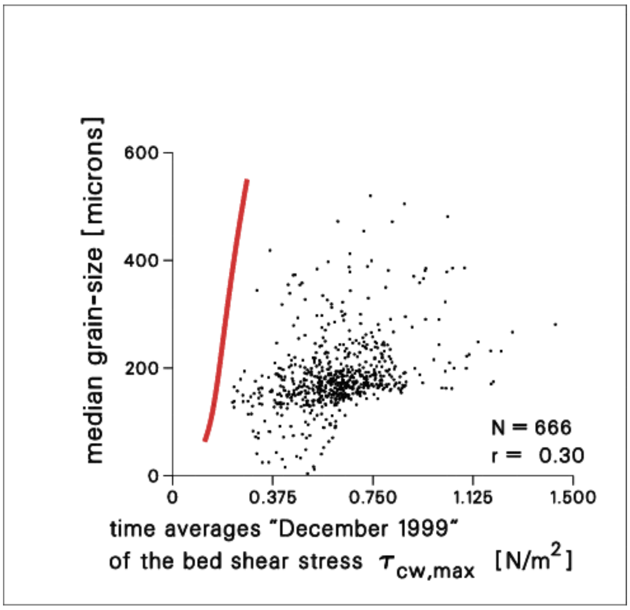


Fig. 7: Two scatter plots: the median grain-size of the bottom sediments in the Hörnum tidal basin is plotted against the bed shear stress τ (temporal average of December 1999). Left plot: $\tau_{cw,m}$ as shown in Fig. 5. Right plot: $\tau_{cw,max}$ as shown in Fig. 6. "N" is the number of data points (= number of sediment samples), "r" is the correlation coefficient. Sediment samples influenced by wind-blown sand from the land dunes of Sylt island are not taken into account. The grain-size data are from BSH (Figge) and GKSS (van Bernem). In the right plot the Shields curve is added (in red). The Shields curve gives the threshold bed shear stress τ_{cr} for the begin of sediment motion, depending on the grain-size. Field measurements (e.g. by GKSS) indicate that τ_{cr} is rather in the order of 0.5 – 1 N/m².

In addition to the investigation of the actual conditions, BELAWATT also investigates 3 scenarios: water level increases (a) by 25 cm, (b) by 50 cm and (c) by 50 cm *plus* an increase of windspeed by 10 %. As an example, we present a result of scenario (b) for the stormy December 1999. We regard only the Hörnum tidal basin proper, i.e. the area east of the tidal inlet between Sylt island and Amrum island (see Fig. 5).

Due to scenario (b), the time averaged current velocity in the tidal channels (sea bottom deeper than NN-10 m, NN=German ordnance level) increases by only 1 to 2 %. The corresponding increase of $\tau_{cw,m}$ is thus also small in the tidal channels.

Above the high wadden areas (sea bottom > NN+1 m), $\tau_{cw,max}$ decreases by 10 %, though the significant wave height HS increases in that area by 7 %. The deciding factor is: the wave impact on the bottom is decreased due to the increased water depth.

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Wind atlas for German coastal areas in the North Sea

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A digital wind atlas, covering the three areas Southern North Sea, Norderney and Bight of Dithmarschen (see Fig. 1), was developed in the context of the KFKI-project MOSES (03KIS040), as input for models of coastal engineering.

The wind atlas is composed of a large number of wind speed fields, depending on given wind directions and mean water levels of the respective sea area. Wind fields were calculated with the mass-consistent wind model MKW, which has already been used successfully for numerous analyses of comparable problems.

Wind fields in the area Southern North Sea were calculated on a numerical grid with a mesh size of 1000 m. They provide the boundary conditions for the calculation of the nested fields Norderney and Bight of Dithmarschen with mesh sizes of 250 m. Each wind field is determined by given values of wind speed direction in a height of 800 m above ground and a representative water level. An example of a wind field covering the area Bight of Dithmarschen is shown in Fig. 2.

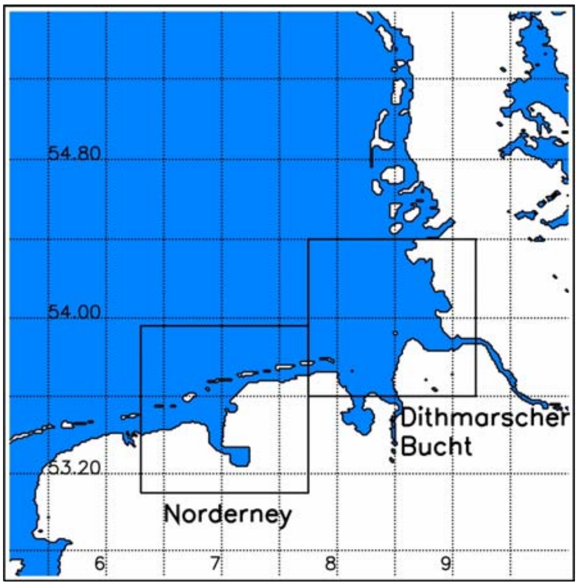

Fig. 1: Area Southern North Sea and nested areas Norderney and Bight of Dithmarschen.

For the calculation of the wind atlas, wind speed, direction and water level are varied with defined class ranges. Thus it is possible to interpolate every desired wind field with sufficient accuracy.

Altogether the wind atlas consists of 534 wind fields for each of the two nested areas.

For the application of the wind atlas, hourly mean values of wind speed and direction and water level, corresponding in time, must be given at a user-defined point, lying in one of the two areas. With the wind atlas, the meteorologically consistent wind field is calculated for the chosen region, by means of an interpolation program. Values at all grid points or the wind speeds at a given point can be stored in ASCII-format. It allows also fitting wind fields for complete time series of wind speed, which e.g. have been measured at a distinct site. Afterwards these wind fields can be used as meteorological input for numerical models of swell and current.

In order to verify the wind atlas for single measuring stations, the closest grid points were determined and a comparison of calculated wind speeds and measurements performed.

Furthermore, time series of many years of measurements and hindcast results of HIPOCAS (Weiss, R., Feser, F. and Günther, H. (2003): Wind- und Seegangsklimatologie 1958 – 2001 für die südliche Nordsee basierend auf Modellrechnungen. GKSS 2003/10, ISSN 0344-9629) and PRISMA (Luthardt, H. (1987): Analyse der wassernahen Druck- und Windfelder über der Nordsee aus Routinebeobachtungen. Dissertation, Universität Hamburg. Hamburger Geophysikalische Einzelschriften, Reihe A, Heft 83) were used as input. Both statistics based on a large number of years and short time series for special weather situations were verified.

Independent of the origin of data, coincidence was satisfying or even good. However, individual storm events should not be calculated with the wind atlas.

Online access to this data base is available at http: // windatlas. hosted-by-kfki. baw.de/windatlasvisu.php and through search interfaces provided by NOKIS (www.nokis.org) in conjunction with an OGC conform web service (wms 1.1.1).

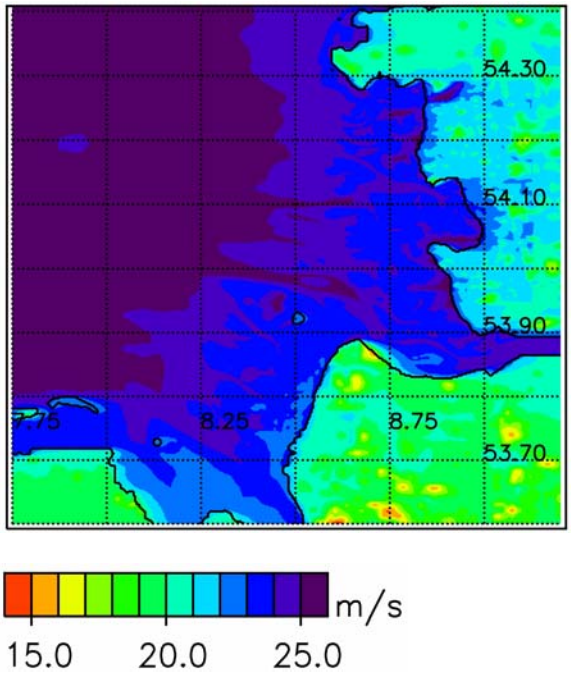

Fig. 2: Wind speed in 10 m height (above ground or sea level, respectively) in the area Bight of Dithmarschen, calculated with the MKW for 40 m/s wind speed and 270° wind direction in 800 m height, and a representative sea level of 0 m.

Medium-term wave modelling in the MOSES project - approach, goals and first results

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Introduction

One of the main purposes of the research project MOSES ("Modelling of the medium-term wave climatology at the German North Sea coast"; 03 KIS 041) is the investigation of the medium-term wave climate in three chosen coastal areas – based on wind, water level, current and wave data produced in the EU project HIPOCAS (Weisse et al., 2003).

The medium-term time series for the coastal zone enable to estimate the occurrence frequency of significant wave parameters in the study areas and the constant load onto coastal structures. Further reconstructions of hydrodynamic and wave climate during past storm events at the coast are possible. Furthermore, the data are applicable to investigations concerning the morphologically representative wave climate.

Validation of HIPOCAS boundary conditions

One task of the FTZ Westkueste within MOSES is the validation of the lateral boundary conditions for water levels and currents. Thereby water levels of the HIPOCAS data set are, e.g., compared with computed water levels from a continental shelf model (CSM). Further a validation is performed by comparing HIPOCAS data with measurements from the tidal gauges Huibertgat, Helgoland and Grosser Vogelsand for the period 1997–2000. A mean absolute error is determined from the differences of the tidal peak water levels. A good agreement between the mean high water levels in connection with relatively low values for the standard deviation of the errors, as well as a rather low mean absolute error demonstrates the good reproduction of the high water levels by the HIPOCAS data. Less good are the agreements concerning the low water peaks.

The computed mean flood and ebb durations show small differences at the gauges Helgoland and Grosser Vogelsand. Bigger are these differences at Huibertgat. The comparison with water level data from CSM shows a similar pattern. The errors with regard to the high water levels turn out to be slightly smaller than the HIPOCAS data (Fig. 1); in contrast to the errors for the low water levels which are higher. Both data sets, HIPOCAS and CSM, have in common that the mean low water levels at all three gauges are significantly higher than the measured water levels.

Averaging the mean absolute errors over a shorter period than the four years, e.g., a lunar cycle reveals that the errors fluctuate quite periodically, especially with regard to high water levels. Compared to the winter months the mean absolute errors in the summer months are significantly smaller.

It is important to keep in mind that the temporal resolution from the different data sources is not the same. HIPOCAS data are provided hourly, CSM data every twelve minutes, and gauge data every minute / ten minutes. Moreover, different datasets were used for the meteorological boundary conditions (wind vector, atmospheric pressure).

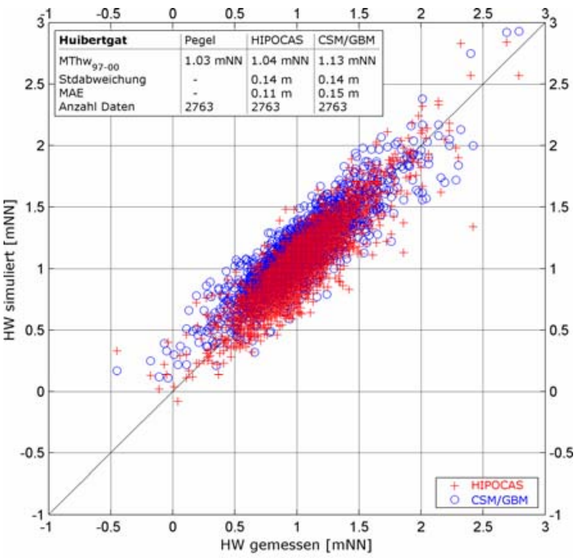

Fig. 1: Correlation between measured and modelled (HIPOCAS: red; CSM: blue) high water at Huibertgat (Ems).

Another task will be the setup of the regional coastal area models. For this purpose, HIPOCAS data and data from a new wind atlas, provided by the German Weather Service (DWD) within a task of the MOSES project, are integrated into the models. A comparison of water levels out of the coastal area models computed with different meteorological boundary conditions will highlight the size of influence.

Wave modelling in the Elbe estuary

For the Elbe estuary the hydrodynamic model TRIM-3D (Casulli and Gattani, 1994) and the shallow-water wave model developed at GKSS, called “k-Model” (Schneggenburger, 1997), are applied. For this area a medium-term hind cast is performed resulting, for the first time, in a complete hydrodynamic and sea-state data base in an inhomogeneous coastal area with strong tidal influence.

The results show that there is not a simple relationship between the off-shore wave climate and the on-shore climate in particular regions. The bathymetry, tidal change, near-shore currents, or the incident wave-propagation direction are important complicating factors. They lead to high spatial and temporal variation in the amount of energy dissipated in the coastal area.

The medium-term Elbe Estuary data basis is directly used for estimating the occurring frequency of certain sea state parameters in coastal areas, and to come to conclusions regarding the long-period loads on marine structures for their assessment to withstand such probable loads. This is done by performing extreme-value statistics in the Elbe Estuary area. Thereby for each location within the Elbe Estuary two-dimensional frequency-direction spectra (hourly over 10 years) are analyzed. They are utilized, e.g. regarding the interaction of wind sea and swell or regarding the duration of extreme sea state events.

Further summarizing seasonal or monthly tables and maps of statistical parameters including interrelationships between them are gathered.

With the given position, durability and hazard probability of a planned coastal construction, the calculation parameters for the assessment of the construction are determined.

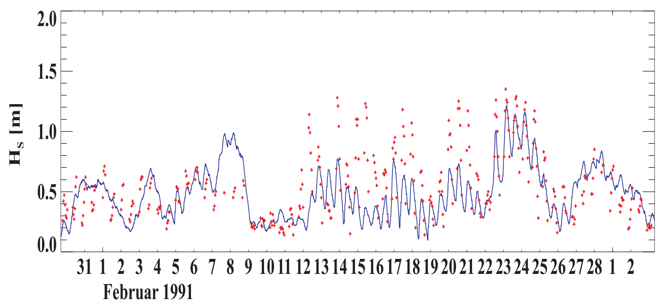

Fig. 2: Measured (red) and modelled (k-Model: blue) significant wave heights at the station Vogelsand (Elbe estuary) in February 1991.

Wave modelling in the Norderney inlet

The wave and current modelling in the catchment area of the tidal inlet Norderneyer Seegat is done at the CRS by means of the hydrodynamic model Delft-3D (Delft Hydraulics, 2003) and the spectral wave model SWAN (Booij et al., 1999). In the initial phase of the project, the code of the new, parallel version of SWAN (TU-Delft, 2004) has been modified, e.g. regarding optimization of output routines, to reach computational efficiency required for the medium-term modelling.

During the test period 09–11/2002 the model results have been compared with measured data (Fig. 3) and with the results of the k-Model simulations obtained by GKSS. The comparisons enabled to show that both models are capable of reliably reproducing the important characteristics of wave propagation and transformation in the investigation area.

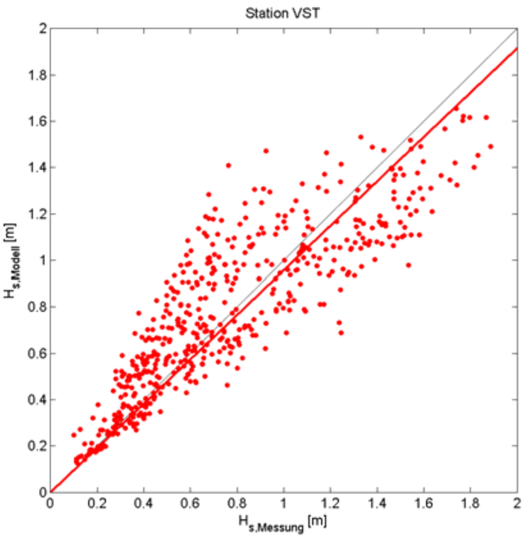

Fig. 3: Scatter plot of measured and simulated (with SWAN) significant wave heights at the station VST by Norderney (Sep.-Nov. 2002).

The results of the hydrodynamic modelling provide an insight into the overall volume transport through the boundaries of the catchment area of the Norderneyer Seegat and into the influence of wind and bottom topography on the temporal and spatial variations of water levels and currents. The results show that the local deviations from the well known overall water exchange processes in the investigation area can be – under certain circumstances – statistically significant. The wave modelling results show a similar picture. Through "filtering" of the wave energy the influence of the boundary conditions decreases from the outer model boundary to the region to the south of the islands, where the influence of the bottom topography and wind is dominant.

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Sediment distribution and the post-glacial sediment accumulation in the North Frisian Wadden Sea

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The sediment distribution and the post glacial sediment accumulation in the North Frisian Wadden Sea were analysed. The last 8000 years of the geological development was lighted on base of 6000 (18000 complete) corings in high resolution. The geometry of the Holocene accumulation wedge was reconstructed. This large amount of corings allowed an estimation of the amount of eroded and resettled sediment in quality (grain size) and quantity. Using modern ict-techniques, a balance of eroded/accumulated sediments was calculated. In addition, the granulometric sediment distribution of the upper 3 meters, in 1 m intervals, was determined. Based on morphological stability criteria the amount of discharged material and the amount of required sediment for the maintenance of the stability of different units in the Wadden Sea (i. e. sand flat, mixed sediment mudflat, intertidal estuarine mudflat) in the case of sea level rise were estimated and the availability was calculated. Different sea level rises were considered.

The results are:
- the Holocene volumetric development follows a logarithmic trend, with the exception of the region between –10m NN and –8m NN (German datum)
- at most 10% of the Holocene sediments come from internal erosion, 90% came from outside (mostly from the North Sea)
- the dewatering South of a border Amrum-Föhr-mainland up to –6m NN (approx. 5.000 BC) follows a Westerly direction. After 5.000 BC the dewatering is North-West bonded
- no hint of a barrier in the area Amrum-Süderoog-Eiderstedt was found
- approx. 33% of the Holocene sediments are diked and not available for remobilisation
- there is enough sediment inside the system for a growing of the higher part of the Wadden sea following a rising sea level. This leads to a steepening of the relief and to coarser sediment
- no appreciable import of sediment from the North Sea is expected because there is no available sediment
- in the non-diked areas, a coarsening from the lower to the upper region (first meter) can be identified

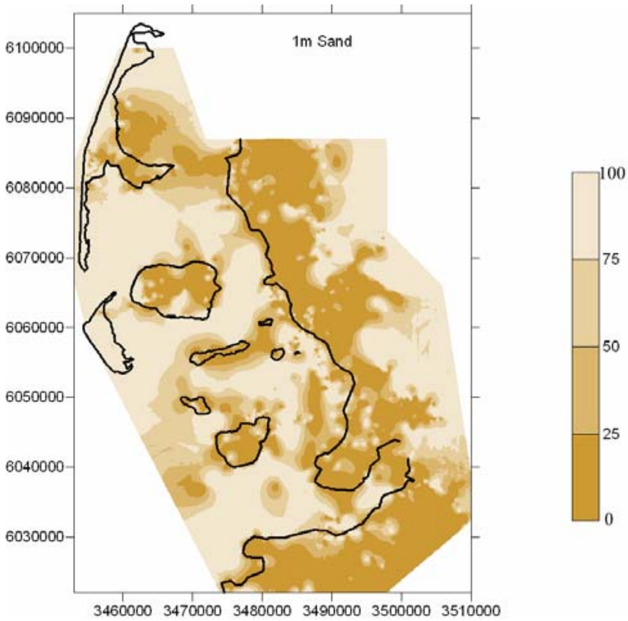

Fig. 2: Sand fraction (%) with grain size > 63 μ m in the upper meter.

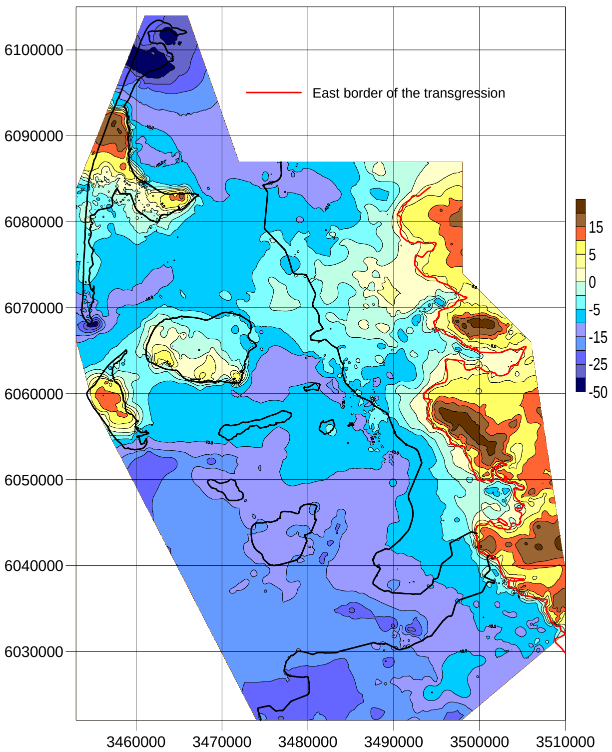

Fig. 1: Depth contours (m NN) of the current Holocene basis according to approx. 18000 corings. The areas lying above the maximum marine extent are generated from the current topographical data of the State Office for Surveying (Landesvermessungsamt).

As raw data served the official topographic data from Schleswig-Holstein, topographic data of the Wadden Sea from the LANU and the ALR. The topographical data where available in digital format. A 50 X 50 m grid was calculated on basis of this data. Geological information was available only on paper. 6000 of 18000 corings were digitised and recorded by the GeoDin 4 software package.

Metadata concerning the digital maps of this project will be provided by NOKIS including links to the final report.

Die Küste

This year, two volumes of "Die Küste" appear in English. Volume 70 contains the final report of the transnational INTERREG IIIB project "COMRISK – Joint Strategies to Reduce the Risk of Storm Floods in Coastal Lowlands" with chapters devoted to each of the sub-projects. In Volume 69 you will find papers relating to the research project "PROMORPH - Predictions of medium-scale morphodynamics".

Contents of Volume 70

Contents of Volume 69

Internal News

KFKI workshop on morphodynamics

A KFKI workshop on morphodynamics held at the Research and Technology Centre, FTZ, Büsum from September 21 to 22 was attended by 48 participants from various administrations and research institutes. Important points of discussion were the prospects for morphodynamic modelling, current modelling potentials, future perspectives for applied research, and the necessary framework conditions. The aim of the workshop was to sound out basic ideas for detailing the KFKI research agenda.

On the first day, open questions of high priority from the **user** point of view were presented in the areas of harbour, waterways and coastal protection management by way of short lectures. **Model developers** and **model users** summarized the state-of-the-art of numerical modelling as well as conceptual problems.

During the second day, four parallel working groups addressed the issues of **data** inventories and data availability, the performance, reliability and prognostic capabilities of **models**, the level of understanding and modelling of **processes**, and future prospects regarding modelling **techniques** and model coupling.

The outcome of the workshop was rounded up in a closing plenary discussion. Owing to the fact that this workshop provided a unique forum for wide-ranging discussions between participants from different disciplines, the response was extremely positive. The results of the workshop will form an important basis for defining the focal point of future research needs in this field, explained Frank Thorenz, KFKI Head of Coastal Research, in his résumé of the event.

KRING 2005 in Hamburg

The **Kring van Zeewerende Ingenieurs** was established in 1954 by Dutch coastal engineers and meets annually at different locations for exchange of experiences and discussions of current issues. Normally, a number of lectures are given referring to projects, which are visited during the following excursions.

Participation numbers of the KRING range between 80 and 100 representatives from England, Belgium, The Netherlands, Germany, Denmark and Poland. In Germany, KRING events have taken place in the years 1962, 1965, 1967, 1970, 1974, 1977, 1980, 1987, 1990, 1993, 1998, and 2005. Since its establishment in 1972, the German Coastal Engineering Research Council KFKI organizes these meetings in cooperation with the responsible Federal State authorities and arranges appropriate social programs.

This year's KRING meeting themed **Storm Surge Protection in a Harbour Metropolis** was held in Hamburg on September 25 to 27. It was organized by the State office of Urban Development and Environment in conjunction with Hamburg Port Authority. Introductory presentations concerning the inner city flood protection, the particular situation of flood gates at Fischmarkt and the planning for Galerie Landungsbrücken prepared the participants for the excursions on foot and by barge. The 90 participants from 6 countries took particular interest in the emerging Hafencity and the barrage at Billwerder Bucht.

A visit at Airbus Industries with lectures on the site extension into the Elbe river, a walkabout through the assembly plants and a bus tour on the Airbus site plus a short visit to METHA (Mechanische Trennung von Hafensedimenten - Mecanical separation of harbor sediments) completed the program.

Events in 2005 and 2006

17.- 18.10. 2005	**GIS-Küste** - Schwerpunktthema Naturschutz, Insel Vilm Website: http://www.gis-kueste.de/
03.- 04.11. 2005	CEDA **Dredging Days 2005,** Rotterdam, Niederlande Website: www.dredging.org/
10.11. 2005	**Fachliche Grundlagen zur Begutachtung wasserbaulicher Maßnahmen an Seeschifffahrtsstraßen**, Hamburg-Rissen Website: http://www.baw.de/vip/programm.php?veranstaltung=60
03.- 08.09. 2006	**ICCE 2006** 30th International Conference on Coastal Engineering, San Diego, Kalifornien, USA Website: http://www.icce2006.com/
10.- 13. 09. 2006	**ICHE 2006** 7th International Conference on Hydroscience and Engineering, Philadelphia, USA Website: http://thor.cae.drexel.edu/ICHE2006/intro.html
18. - 20. 09. 2006	**Littoral 2006** Conference "Costal Innovation and Initiatives", Gdansk, Polen Website: http://www.littoral2006.gda.pl