Evaluation of simulation models used for morphodynamic studies

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INTRODUCTION

Large scale morphodynamic studies in the Southern Baltic Sea have been carried out with a number of numerical modeling systems based on different conceptual models. For a severe storm event of 10 days duration, the evolution of the bathymetry due to littoral transport driven by currents and waves has been computed with DHI's Mike21 modeling suite [1]. Comparison with results of a holistic model developed at Hannover University [2], which treats all physical processes within a single system of partial differential equations shows good qualitative agreement with respect to magnitudes and spatial distributions of simulated sediment transport. The models could be validated on the basis of a set of field data collected during this period.

Extreme care is necessary in providing consistent boundary conditions for morphodynamic simulations, in particular with regard to the transformation of offshore waves towards the coast. The data base for initial and boundary conditions was compiled from extensive field data and large scale operational circulation models. All data available together with the corresponding meta information are provided through a web portal [3] especially set up for the comparison exercise.

A second model comparison is carried out for long shore sediment transport in a micro-tidal coastal region between the one-dimensional littoral transport models COSMOS [4] of HR Wallingford and CRAST [5] of the University of Latvia. Again, results show good qualitative and quantitative agreement. Once more, it must be noted that all solutions are extremely sensitive to the applied wave boundary conditions.

MODELING TECHNIQUES

A variety of simulation tools for coastal and offshore processes has been developed during the last decades. Essentially, they differ in dimensionality, in the complexity of the considered physical processes [6], and in solution algorithms based on finite differences or finite elements. A small number of well documented and validated commercial models are available for coastal engineering applications.

Following the concept of treating the principle physical processes of currents, waves and (sediment) transport within stand-alone models, the most common approach to morphodynamic modeling consists of coupling pre-existing tools into modeling suites. Interaction of waves and currents is accounted for by passing radiation stress fields from the wave to the flow model. In contrast to this kind of alternating computation of individual processes is the holistic approach with a system of nine time dependent partial differential equations which are solved simultaneously. An advantage of this method lies in the immediate interaction of different processes without parameters being passed between different simulation modules. However, the runtimes of this approach are considerably higher since the overall time step is dependent on the smallest element of the computational grid.

The chosen solution methods sometimes pose severe constraints on the solution procedures. Working with finite differences in complex coastal regions often puts limits on possible spatial resolution because of runtime considerations. Finite element methods on triangular grids are a more flexible alternative. The grid structure easily adapts to intricate geometries and can be refined for specific bathymetries.Furthermore, certain classes of wave models require the computational grid to be aligned with the major direction of wave attack. Thus, for regions with high directional variability it becomes necessary to discretize time series according to wave direction and solve the equations on several grids for principal directions. The resulting quasi-stationary states are reassembled for a complete temporal coverage of the domain. Boundary conditions stemming from single-point offshore field measurements need to be transferred to the model domain.

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Examples for different FD and FEM solution procedures will be presented and the effort regarding model set up and operation will be assessed. We will also discuss results of one-dimensional long-shore models covering the same areain order to show the embedding of 1D results along selected cross sections in 2D area simulations [6].

SCENARIOS

Often, the compilation of consistent boundary conditions for regional coastal models has to deal with conflicting information from large-scale low-resolution circulation models which may lack significant local effects. In the case of barrier islands, for instance, important small-scale current patterns could be missing, or wind and wave fields may not consider shielding effects. Such inconsistencies need be addressed and corrected. Either refined models or transfer functions can be used to provide the unavailable data.

Longshore models have been compared for the 5 year period 1993 – 1997 with several extreme storm events. Intercomparison of 2D morphodynamic modeling is carried out for a storm period in January 2000.

CONCLUSIONS

Reliable consistent boundary conditions are essential for meaningful morphodynamic modeling. In particular, wave data from single-point measuring devices need suitable spatial interpolation (model, transfer function) to accomodate the sensitivity of sediment transport in terms of driving forces.

Intercomparison of cumulative sediment transport along selected cross sections in the vicinity of a coastal inlet shows that long-shore models are particularly sensitive to the applied wave conditions.Results may differ by a factor of 1.5 between the models under identical conditions.

Two 2D model systems based on different philosphies have been successfully applied to reproduce natural scenarios. The commercial Mike21 system and the holistic research tool produce similar and plausible results. The performance of Mike21 strongly depends on the experience of the operator with respect to selection of time step, number of computational grids, etc. Effective execution of a project depends on optimal parameter selection. The holistic approach has less options for tuning and is focussed on reproducibility of results on a single computational grid. Being primarily a research tool, runtime considerations are of secondary importance.

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