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Accounting for a High Resolution Bathymetry in Shallow Water Simulations on a Coarse Grid

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Estuaries are characterized by a wide range of spatial scales, from small gullies to complete channel-shoal systems. High resolution hydrodynamic models are needed to take the effect of these local variations into account. Although these models have been improved significantly during the last decades and computation power of computers is still growing, one is still to find a balance between accuracy and computation time.

In order to cope with the multi-scale problem of flow (and morphology) in estuaries, a subgrid approach is used, which was first introduced by Casulli [1]. In this study, we propose a new formulation for the bed friction bases on this subgrid approach. The friction force is determined by taking the small scale bathymetry information and local variations in bed roughness into account.

The concept of a model with subgrid resolution was developed to use detailed bathymetry information in order to model the wetting and drying of areas accurately [1]. Using two grids, a coarse grid and a fine one (subgrid), makes it possible to take detailed bathymetry information into account, without the high computational costs of simulation on a complete high resolution grid. Water levels and velocities are computed on coarse grid level ensuring the efficiency of the model. The subgrid is used to determine wet volumes and cross-sectional areas of a coarse grid cell each time step again.

We extend the use of the high resolution bathymetry information on subgrid level by using it to determine the friction term. Traditionally, the velocity is assumed to be constant within a computation cell, while it can highly vary due to bathymetry variations within the cell. Instead, the subgrid approach assumes the friction slope to be constant. This allows the velocity field to vary within a coarse grid cell. As the friction term is highly non-linear, determination of the friction term before integrating it over the full cell gives a different averaged value than when the friction term is based on the cell-averaged velocity and friction coefficient.

The method has first been tested for simple geometries: a straight channel and a channel bend, both with non-uniform bed levels. In addition, the model is applied to the Western Scheldt, a two-channel estuary in the South-West of The Netherlands. Initial results indicate that the run-time for simulations is accelerated by more than a factor ten, with less than 1% deviation in accuracy.

A subgrid velocity field can be constructed accurately, as well. This offers the possibility to compute the bed shear stress at subgrid level, which can be used as input for sediment transport models. Therefore, the near-future development is a morphological model based on the subgrid approach.

In conclusion, the subgrid approach is a promising technique for the multi-scale problem in estuaries (but also for rivers and coastal seas). The proposed improvement of the bed friction term increases the accuracy strongly, with only a small increase in computation time.

References

[1] Vincenzo Casulli, *A High-Resolution Wetting and Drying Algorithm for Free-Surface Hydrodynamics*, International Journal for Numerical Methods in Fluids **60** (2009), no. 4, 391–408.