Modelling of hydrodynamic and morphological processes in the Scheldt Estuary with a new bed roughness model

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Modelling of hydrodynamic and morphological processes in estuaries is very important in coastal research. The development of sophisticated numerical models requires appropriate theoretical models which can accurately describe physical processes in coastal areas. However, the existing morphological models always have over-simplified assumptions in physics, for example, the constant bed roughness, which usually leads to wrong predictions in sediment flux. For this reason, a physics-based bed roughness model is developed by Toorman (2012) as a general approach to improve the predictive accuracy of morphological models.

This new bed roughness model is derived from Generalized Mixing Length (GML) Theory (Toorman, 2012), in which a new viscous damping function is proposed for extending its validity into the low-Reynolds layer where the traditional high-Reynolds turbulence model usually leaves it unresolved, and a roughness factor that represents subgrid-scale turbulence generated in the vortex between the roughness elements is introduced for rough walls. The analysis of the flume experiments with sand of Cellino (1998) with this new GML model suggests that the corresponding apparent increase in roughness is proportional to the sediment concentration, which means that the roughness factor can be linked to concentration and extendable to high concentration effects near the bottom as well. By integrating the velocity profile given in the GML theory, a physics-based roughness model is obtained as the superposition of two parts, the turbulent part and the laminar part, which allow both transient conditions and the transition during drying or wetting of tidal flats.

A numerical experiment is conducted in order to demonstrate the effects of this new bed roughness model. The Scheldt Estuary is selected as the research domain and a 2-D hydrodynamic-morphological model is built by using the Open TELEMAC Modelling System. For engineering applications, the above theory has been converted into the depth & concentration-dependent friction factor and implemented into the TELEMAC code. The sediment flux through the estuary in one spring-neap tidal cycle is calculated for both the constant roughness case and the depth & concentration-dependent roughness case. The results show that the sediment flux reduces by 60% with the help of the new bed roughness model. This value is closer to the observations (Van Alphen, 1990) than the constant roughness case.

The new bed roughness model considerably alters the sediment transport in our numerical models although further calibration and validation is still needed. It is easy to implement and flexible for different cases. The roughness factor is adjustable thus it can increase the bed roughness for non-cohesive sediment transport and it is also expected to reproduce the drag reduction for cohesive sediment transport near the bed, which will be performed in the future.

References

Toorman E.A. 2012. A Generalized Mixing-Length model for flow over rough surfaces. (in preparation).

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