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BOOK OF ABSTRACTS

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A well-posed model for 2D mixed-size sediment morphodynamics

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1. Introduction

The active layer model (Hirano, 1971) is the most widely applied model to account for mixed-size sediment in morphodynamic simulations. In this model, the bed is discretized into two parts: the active layer and the substrate. The sediment in the active layer is assumed to be perfectly mixed, whereas the substrate may be stratified. Sediment entrainment and deposition occurs within the active layer only. A flux of sediment from and to the substrate occurs in case of lowering or increase in the elevation of the interface between the active layer and the substrate.

Using this simplified view of the mixing processes, one is able to reproduce, up to a certain extent, a large amount of physical processes such as armoring, tracer propagation, downstream fining, and the formation of a gravel-sand transition. However, the model suffers from an important limitation: under certain conditions (specially under degradational conditions when the active layer is coarse with respect to the substrate) it may be ill-posed. An ill-posed model is incapable of representing any physical process, as the solution is unstable to short wave perturbations (e.g., noise in the initial condition and numerical truncation errors) and does not converge when the numerical grid is refined (Chavarrías et al., 2019). Ill-posedness indicates that a key physical process is missing in the model description.

Chavarrías et al. (2017) devised a regularization strategy that prevents the one-dimensional active layer model from being ill-posed. By increasing the time scale of the mixing processes, the regularized model is guaranteed to be well-posed. The strategy was tested against laboratory data. In the laboratory experiment, degradation into a fine substrate was imposed, which led to periodic entrainment cycles of fine sediment. The regularized model captures the mixing processes averaged over a time scale that includes several cycles of sudden entrainment of fine sediment. Although the strategy was shown to be successful, it has been applied under one-dimensional conditions only. Here we extend the strategy to two-dimensional conditions.

2. Regularization Strategy

Our first attempt is to modify the two-dimensional version of the active layer model in the same manner as Chavarrías et al. (2017) modified the one-dimensional version of the model. Interestingly, this straightforward extension of the one-dimensional solution to two dimensions does not regularize the model. We prove this fact conducting a perturbation analysis of the two-dimensional model accounting for the modification of the time scale.

We propose a new strategy for regularizing the two-dimensional model. As an increase of the time scale of the mixing processes appears to be the key element to regularize the one-dimensional model, we devise a different strategy that has similar physical implications. Diffusion accounts for the mixing processes on a short time scale not resolved by the model. The new strategy consists of adding a diffusive component to the active layer equation only (i.e., the Exner equation for bed elevation changes remains intact). By means of a perturbation analysis, we prove that a certain amount of diffusion guarantees that the active layer model is well-posed under two-dimensional conditions.

3. Application

The regularized two-dimensional model is guaranteed to be well-posed. Yet, well-posedness does not guarantee that mixing-processes are well represented. In testing whether diffusion accounts for the mixing processes occurring on a short time scale, we compare the results of the regularized model to laboratory and field data.

We implement the strategy in the software package Delft3D. We model the laboratory experiment conducted by Chavarrías et al. (2017) while considering the transverse direction and compare the results to the laboratory data. In this way, we not only compare results to laboratory data but also to the results of the regularization strategy of the one-dimensional model. A second test is to model the experiment conducted by Blom et al. (2003). In this second experiment fine sediment initially part of the substrate was entrained due to dune growth. This process is represented in the active layer model by an increase in the active layer thickness. Finally, we asses the consequences of ill-posedness and the regularization strategy in a field case. To this end, we use a two-dimensional schematization of the Rhine branches in the Netherlands that accounts for mixed-size sediment processes.

References

Blom, A., Ribberink, J. S., and de Vriend, H. J. (2003). Vertical sorting in bed forms: Flume experiments with a natural and a trimodal sediment mixture. *Water Resour. Res.*, 39(2):1025.

Chavarrías, V., Schielen, R., Ottevanger, W., and Blom, A. (2019). Ill posedness in modelling 2d morphodynamic problems: Effects of bed slope and secondary flow. *J. Fluid Mech.* (in press).

Chavarrías, V., Stecca, G., Labeur, R. J., and Blom, A. (2017). A strategy to avoid ill-posedness in mixed sediment morphodynamics. In Lanzoni, S., Redolfi, M., and Zolezzi, G., editors, *10th Symposium on River, Coastal and Estuarine Morphodynamics, Trento-Padova, Italy 15–22 September*, page 166.

Hirano, M. (1971). River bed degradation with armoring. *Proc. Jpn. Soc. Civ. Eng.*, 195:55–65.