Irregular dunes, sediment sorting, and river orphodynamics

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Abstract
This research project focuses on modelling the large-scale morphodynamics of low-slope rivers dominated by mixed sediment, such as the Dutch part of the Rhine River. Usually we simply neglect the effects of sorting and variability in dune dimensions on the large-scale morphodynamics. This paper shows that these effects are not negligible.

Introduction
Existing bed layer-type sediment continuity models (e.g., Hirano, 1971) suffer from a number of shortcomings (effects of sorting neglected; elliptic equations; problematic definition active layer). Instead of using discrete bed layers, the sediment continuity framework by Parker et al. (2000), offers the possibility to describe the active part of the bed using a probability density function (PDF) of bed surface elevations. Blom and Parker (2004) have extended this model to conditions with dunes, and we now extend the model to conditions with net aggradation or degradation.

Material and methods
In the case study described in the present paper, the aggradational flume experiment by Ribberink (1987) is simulated using three sediment continuity models (Fig 1):

A. the **Hirano active layer model**;
B. the sorting evolution model with **regular dunes**;
C. the sorting evolution model with **irregular dunes**.

Flow is described using the formulation for a backwater curve, and the sub-model of sediment transport is a simple power-based relation (Ribberink, 1987).

The Ribberink (1987) experiment E8-E9 was conducted under conditions dominated by dunes and bed load transport. The mixture was well sorted and consisted of two sand fractions (0.78mm, 1.29mm). The experiment started from the final state of experiment E8, in which a common downward coarsening profile had developed. Over 30h, the feed rate of fines was decreased from 0.5 to 0, while the total feed rate was maintained steady. The measured PDF of trough elevations serves as input to Model C.

Results
Due to the increase of coarse sediment fed to the flume, the active part of the bed starts to coarsen at the upstream end of the flume. As a result, the sediment transport capacity decreases and a small degradation wave migrates in downward direction. As the total feed rate is maintained steady, an aggradation wave follows (Fig. 2)

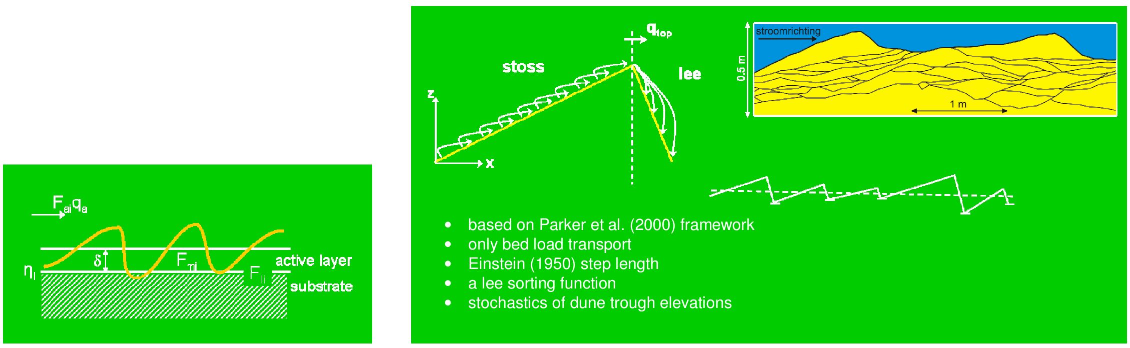

Figure 1. (a) The Hirano (1971) active layer model, and (b) The Blom & Parker (2004) probabilistic sediment continuity model for conditions with dunes.

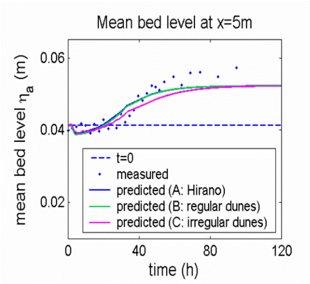

Figure 2. Mean bed level.

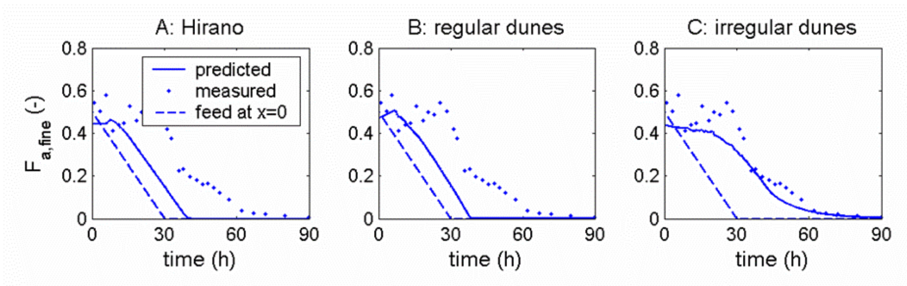

Figure 3. Volume fraction content of fines in bed load transport at the downstream end of the flume.

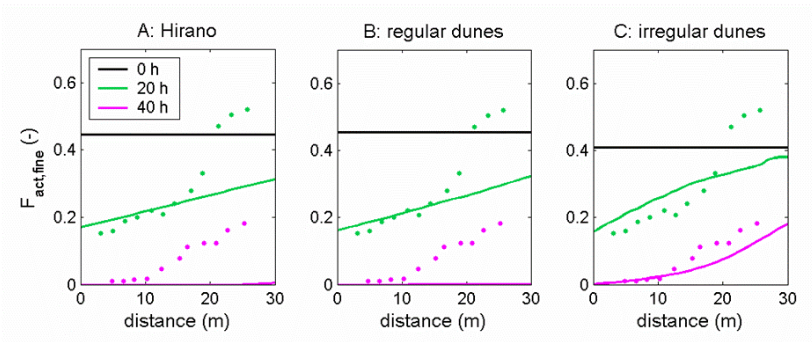

Figure 4. Volume fraction content of fines in the active part of the bed.

Taking into account the variability in dune dimensions allows sediment to be 'stored' at lower elevations. It therefore improves the predicted adaptation time scales of the composition of both the bed load transport (Fig. 3) and the active part of the bed (Fig. 4). It also significantly improves the predicted sorting profile.

Conclusion

The present study shows that incorporating the variability in dune dimensions significantly improves the predicted adaptation time scales of the composition of both the bed load transport and the active part of the bed, as well as the predicted sorting profile. However, application of the sorting evolution model appears cumbersome and future application to field cases asks for a simplification of the model.

Acknowledgements

This research project (VENI project TCB.6286) is supported by (1) the Technology Foundation STW, applied science division of NWO and the technology programme of the Ministry of Economic Affairs, (2) the University of Twente, and (3) the US National Center for Earth-surface Dynamics (NCED).

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