A FINITE-AMPLITUDE MORPHODYNAMIC MODEL OF TIDALLY GENERATED BED FORMS BASED ON SWASH

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INTRODUCTION

Tidal sand waves are prominent bed forms occurring in coastal seas characterized by non-cohesive sediment deposits and relatively strong tidal currents (0.3 - 1.0 m/s). These bed features have a crest-to-crest distance between 100 and 500 m and are oriented approximately orthogonal to the main direction of the tidal current. Typical amplitudes are of the order of 1 to 10 m. Due to the ability of the bed forms to migrate, tidal sand waves pose serious hazards to many coastal structures such as pipe lines, monopiles and shipping lanes. Insight in the dynamics of these bed forms therefore is crucial for the long-term management of the coastal zone. Here, we describe the development of a new generic numerical morphodynamic model to simulate the finite amplitude of tidal sand waves.

MODEL

Since the crests of tidal sand waves are almost perpendicular to the main direction of the tidal current, we adopt a two-dimensional model in the horizontal and vertical directions, respectively *x* and *z*-axes; assuming that the crests of the waves are aligned with the *x*-axis. The tidal flow field is simulated using a modified version of the numerical non-hydrostatic free surface flow solver SWASH (Zijlema *et al.*, 2011). In particular, an additional forcing *F(t)* is added to the horizontal momentum balance, resembling the gradient in the tidal potential. For details on the properties of the numerical solution procedure, we refer to (Zijlema *et al.*, 2011). Once the flow field is evaluated, we compute the bed shear stress and determine the sediment transport *Q(t)*. The latter is calculated by means of the bedload transport formula proposed by van Rijn (1991), accounting also for slope effects. Considering that the changes in the bed during the tidal cycle are very small, the evolution of the bed can be described by

$$\frac{\partial d}{\partial T} = \frac{1}{1-n}\frac{\partial}{\partial x}\left(\int_0^T Q(t')d'\right)$$

with n the porosity, d the bed level and T the period of the tide. When the adjusted bed elevation is known, a new step in the morphodynamic loop is performed by reevaluating the flow field, bed shear stresses and corresponding sediment transport. Here, it worth to point out that, to speed up the calculations, this step is only taken when the changes in the bed elevation are larger than a percentage α of the depth.

RESULTS

Figure 1 (top panel) presents the evolution in time of a tidal sand wave considering a mean depth of 15 m and the maximum of the depth-averaged tidal velocity equal to 0.4 m/s. The mean grain size of the bed is set 0.3 mm. Initially a sand wave with a wavelength of 390 m is considered with an amplitude of 0.15 m. We considered a wavelength of 390 m based on a linear stability analysis of the bed using the model of Blondeaux and Vittori (2005).
Figure 1 shows that the sand wave growth slows down and eventually stops after approximately 500 years when the amplitude of the bed form is about 7.5 meter.

DISCUSSION AND CONCLUSION

Comparing the obtained finite amplitude with field observations, it appears that the model overestimates the final amplitude of the sand waves. Also, the growth of the bed forms is found to occur over much longer time scales than suggested by linear stability analysis. Taken together, we conclude that further work is still needed before the morphodynamic model can be confidentially used as a modelling tool.

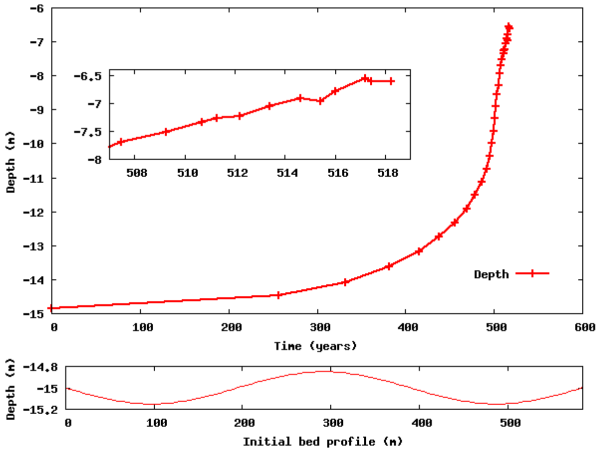

Figure 1 - Top: evolution in time of the depth at the crest of the sand wave. Bottom: profile of the initially considered sand wave.

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