A NUMERICAL MODEL TO COMPUTE THE MORPHODYNAMIC IMPACT OF A HUMAN INTERVENTION

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ABSTRACT

In this contribution, a method, named "concurrent correction method" (CCM) is described which uses the parallel computing technique and evaluates only the morphological impact of a human intervention, assuming that the hydrodynamics and morphodynamics are in equilibrium before the intervention. The morphological evolution is computed based on the change of the sediment flux induced by the human intervention. The advantage of the CCM model is that it can avoid the computational demanding spin-up period, usually employed in numerical modeling, to reach equilibrium conditions.

Keywords: Numerical modeling, morphological model, sediment transport, sand pit.

1. THE METHOD

The long-term seabed evolution in the inner continental shelf is driven by a multi-scale hydrodynamics. The seabed changes due to the long time-scale driving forces are usually slow and the system can considered to be in equilibrium or quasi-equilibrium state, if short-term events are considered. On the other hand, some short-term events, such as storms or offshore sand extraction, may break the equilibrium and cause relatively faster morphological changes.

In numerical modeling, for a given seabed geometry, the system may not be in equilibrium relative to the hydrodynamic conditions at the beginning of a simulation due to poor knowledge of initial data and/or approximations introduced by the model.

To estimate the bed evolution due to short-term events such as an offshore sand extraction, we propose a reduced model, which allows to avoid the preliminary speed-up period, necessary to obtain initial equilibrium conditions. The proposed model, named "concurrent correction method" (CCM), computes the bed evolution due to a single factor, e.g. the dredging of a pit. Specifically, for the application to the morphological evolution influenced by a sandpit, this method is implemented by conducting two scenarios concurrently on two separate processors of a parallel computer. One scenario (Model 1) is a simulation of a seabed without the pit. The other (Model 2) is a simulation with the pit. The two models share the same hydrodynamic boundary conditions, sediment characteristics, and numerical parameters.

The equation providing the seabed evolution for Model 1 is written as:

$$(1-s)\frac{\partial h_1}{\partial t} = -\nabla \cdot Q_1 + \epsilon_1 \qquad [1]$$

where h_1 is sea bed elevation, t is time, s is bed porosity and Q_1 represents the sediment transport rate calculated by means of the model for the given hydrodynamic conditions. Since the bed is assumed to be in equilibrium and the seabed not to change under the given hydrodynamic conditions ($\partial h_1/\partial t = 0$), ϵ_1 represents the mismatch between the value of $\nabla \cdot Q_1$ provided by the model and its actual value.

For Model 2, the equation providing the seabed evolution is written in the form

$$(1-s)\frac{\partial h_2}{\partial t} = -\nabla \cdot Q_2 + \epsilon_2 \qquad [2]$$

where h_2 is the bed elevation for Model 2 and $\nabla \cdot Q_2$ is the sediment transport rate for the given hydrodynamic conditions and the sandpit geometry. In equation [2], the time development of the bottom profile is assumed to be caused by two different contributions. One contribution is due to the short term event which should be modeled (e.g. dredging of the pit). The other contribution is induced by the mismatch between the actual initial bottom profile and the equilibrium bottom profile. Assuming that the influence of the pit on the evolution of the bottom profile toward equilibrium is small, the latter contribution, named ϵ_2 in [2], can be assumed equal to ϵ_1. This linearization procedure is certainly reasonable in the far-field region. Its applicability in the nearfield region depends both on pit geometry and on flow and sediment characteristics. Using [1] and $\epsilon_1 = \epsilon_2$, [2] can be rewritten as

$$(1-s)\frac{\partial h_2}{\partial t} = -\nabla \cdot (Q_2 - Q_1) \qquad [3]$$

Then equation [3] is used to calculate the seabed change due to the presence of the sandpit in Model 2. The equation indicates that the seabed is updated using the difference of the sediment fluxes computed with and without the pit, rather than solely the sediment flux computed for the case with the pit. Hence, the method only takes into account the morphological differences from a reference situation, which is assumed to be in equilibrium. In other words, the sediment flux used to update the seabed is corrected at each time step with respect to the reference sediment flux calculated without the pit. The CCM was implemented in the current version of NearCoM code (Chen et al., 2014, Shi et al., 2013). The CCM can be used in conjunction with any kind of sediment transport model. In this study, we used the sediment transport formulation proposed by van Rijn (1991) which allows to evaluate the amount of sediment transport and its direction, due to both waves and currents. A slope term was added to the original formula of van Rijn (1991) to take into account the effect of slope on sediment transport. More details on the model are given in Shi et al (2015).

2. RESULTS AND DISCUSSION

In this contribution, we present a CCM simulation of the morphological evolution of an area around a pit dredged offshore of Cane South, SC, as shown in Figure 1. A preliminary analysis of the available data offshore the South Carolina coast (Ramsey et al., 2014), showed that sediment transport is basically dominated by the action of waves during storms.
The seabed bathymetry at Cane South was measured before dredging, after dredging and one-year after dredging in January 2009, April 2009 and March 2010, respectively. A comprehensive morphological study, which used different morphodynamic models, was carried out with the aim of looking at the near-field seabed evolution of the dredged area (Ramsey et al., 2014). In order to get the boundary conditions driving the hydrodynamics of the CCM model, we applied the Coupled Ocean-Atmosphere-Wave-Sediment Transport Modeling System (COAWST, Warner et al., 2010) with three nested computational grids, the US east coast grid, the North and South Carolina grid, and Long Bay grid. The Long Bay grid covers Cane South borrow site and provides the CCM model with wave and current boundary conditions. COAWST is computational expensive for a run of one year period associated with the 2009-2010 bathymetric surveys. Therefore, we selected a representative one-month time period during 2009-2010 which was found to be the best candidate to represent the annual average wave energy based on wave spectral analysis of the data recorded by NOAA's Buoy 41043 over the year period (Ramsey et al., 2014). Sediment with median grain size equal to 0.27 mm was adopted, based on the size analysis of sediment from the dredging material. Models 1 and 2 in the CCM model simulation used the bathymetry without the sandpit, obtained from the survey before dredging, and the bathymetry with the sandpit, respectively. Wave and current boundary conditions were the same in the two processes. A run using the original model without CCM was also carried out for the model-model comparison.

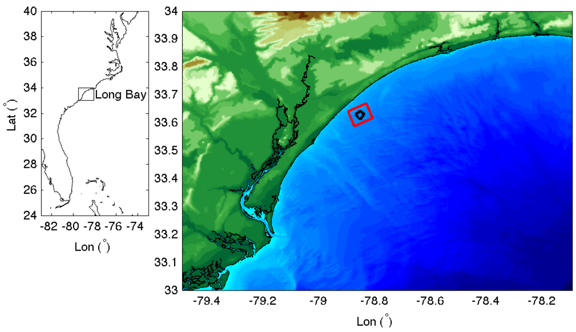

Figure 1. Left: Cane South, South Carolina (USA), red rectangle indicates the computational domain for NearCoM, black block: borrow pit. Right:

Figure 2 (left panel) shows the measured bed elevation change over the one year period. The dredging area is located in the rectangular box. The solid lines represent contours of the post-dredged bathymetry which denote the small-scale dredging signature. The figure shows the small-scale infilling process which is exhibited by the local erosion/deposition patterns associated with the dredging prints. The figure also shows a general deposition at the North-East region and erosion at the South-West region.

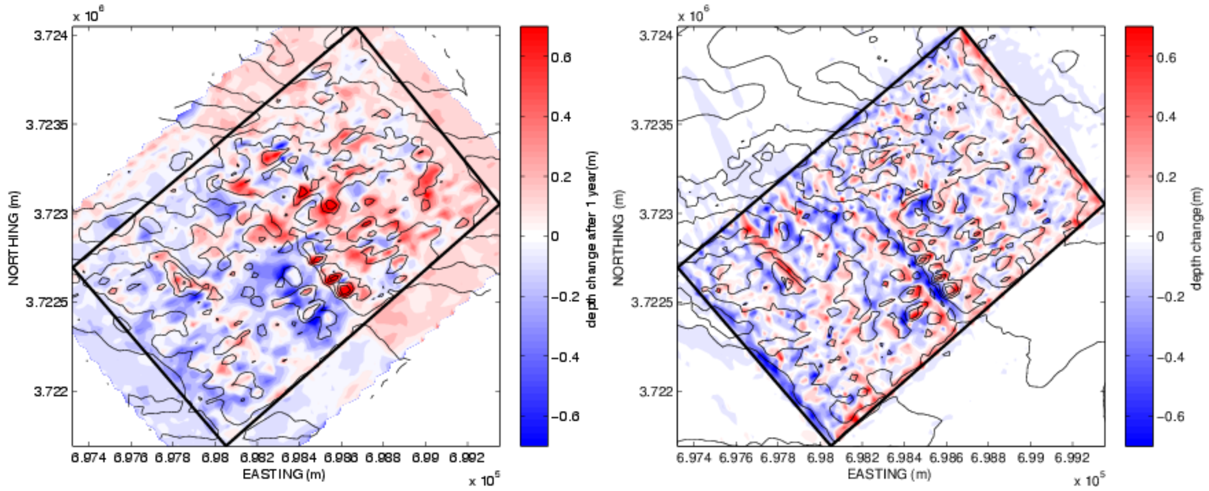

Figure 2. Left panel: measured bed elevation change one year post dredging (color). Right panel: computed bed elevation change from 01/01/2010 to 03/03/2010 with a morphological factor equal to 12. Solid lines represent contours of bed elevation measured after dredging.

The right panel of Figure 2 shows depth changes modeled by the CCM model in a one-month time period with a morphological factor of 12. The model predicts the small-scale erosion/deposition pattern consistent with the measurements. The general deposition pattern in the northeast region is not obvious compared with the field observation, due to the predominant small-scale filling of the dredging prints . A comparison of the results obtained by using the original NearCoM model has shown that NearCoM model with CCM predicts qualitatively similar erosion and deposition patterns . However, the CCM simulation predicts smaller morphological changes outside the dredge area compared to the result from the NearCoM simulation without CCM. This finding is expected because of the reduction in the simulated morphological change outside of the borrow site. The comparison of the computed and measured eroded and deposited volumes one year after dredging (see Table 1) showed that CCM provides quantitative predictions closer to measurements with respect to the original model. More applications to CCM to idealized cases can be found in Shi et al. (2015).

Table 1. Eroded and deposited volumes from measurements, the original NearCoM model and CCM.

	EROSION (M^3)	DEPOSITION (M^3)
MEASURED	-139734	245070
ORIGINAL NEARCOM	-351915	322756
CCM MODEL	-213182	218517

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