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Enhancing the morphodynamical data assimilation process

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For complex non-linear models the implementation of data assimilation techniques is usually cumbersome and challenging. Here, the problem of parameter optimization of wave characteristics for a small test case of near shore morphodynamics is studied. The model reduced variational assimilation technique is implemented to avoid the estimation of the adjoint model of the morphodynamical model and ease the assimilation process implementation.

First a Reduced Order Model (ROM) is constructed based on the dynamical behavior of the morphodynamical model. This requires several model runs: one background run and two extra runs for each parameter of interest. The background run shows the behavior of the model with the initial guess of the parameter values. The other runs are for snapshots generation and sensitivity assessments. The snapshots matrix contains the value of the state vector at different stages in time and for particular perturbations of the parameters of interest, it shows the dynamical behavior of the model. Solving a Singular Value Problem (SVP) on this matrix will provide the most important dynamical modes of the model for the given perturbations and background. The ROM is a projection of the dynamics and sensitivities of the model to a reduced rank space. This space is constituted by a limited number of modes selected from the solution of the SVP. Since the ROM is linear, a 4DVar assimilation technique may be implemented easily.

Previous studies have shown that morphodynamical models are very sensitive to the wave characteristics: wave incidence direction, wave significant height, wave peak period and directional spreading. The morphodynamical model that is being used is Delft3D, which is a physically based model that combines hydrodynamics, sediment transport and morphology. In Delft3D, a wave model provides the necessary boundary conditions for the solution of a flow model. The flow model provides the velocity vector field for the assessment of sediments transport which is done with a morphology module. An iterative approach is necessary since changes in bathymetry affect the flow conditions of the system. Since assessing an accurate velocity vector field, especially in the nearshore area, is challenging and the interaction between models is troublesome, modeling these processes is complex and extremely expensive.

One of the setbacks of the model reduced variational assimilation is that its efficiency relies on the quality of the ROM. Appropriate snapshots that represent the dynamical behavior of the full model should be taken into account. Here, we study different approaches to select an appropriate set of snapshots with the aim to enhance the performance of the model reduced variational assimilation. Given the assumption that the new snapshots provide new details of the model; as the number of snapshots used increases, so does the quality of the ROM. On the other hand, the higher the number of snapshots the higher the number of model runs that is required. The aim then is to be able to select appropriate snapshots based on the prior knowledge of the modeler.

The system under study is Palm Beach, which is a microtidal swell dominated beach located to the south of Sydney. To minimize the execution times small part of the beach is being analyzed which constitutes a grid 59 by 15 cells, each of 15 by 15 meters. No forcings different to the wave are being considered. A set twin experiments are presented of a model reduced 4DVar scheme that optimizes the parameters of interest. The different experiments show the performance of the technique for different choices of snapshots.