ASSIMILATION OF SHORELINE DATA INTO MORPHODYNAMIC MODEL PREDICTIONS

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ABSTRACT

A new method to assimilate shoreline data extracted from satellite images into coastal morphodynamic simulations is introduced. The verification of the assimilation method in a preliminary application to the Caparica coast beaches shows encouraging results.

Keywords: SCHISM; WORSICA; Caparica coast.

1. INTRODUCTION

The ability of coastal area morphodynamic models to reproduce the long-term evolution of the coastal bathymetry remains limited by the inadequate representation of some physical processes. Errors can accumulate over time, progressively degrading the quality of the predictions. While these limitations should ideally be overcome through a better representation of the physics, data assimilation appears as an attractive alternative, given the availability of bathymetric data derived from satellite imagery. A new approach for the assimilation of shoreline data into a morphodynamic modeling system (SCHISM) is introduced herein, and preliminary results from an application to the Caparica beaches are discussed. Shoreline data are extracted from the WORSICA platform (worsica.incd.pt/).

2. METHODS

Numerical morphodynamic models predict future bathymetries by computing circulation, waves, sediment fluxes and bathymetric changes. In general, the predicted bathymetry (hf) can be written as $h_f = h_i + \Delta h_m + \Delta h_d$, where h_i is the initial bathymetry, Δh_m is the model-predicted bottom evolution between times *i* and *f* and Δh_d is a correction associated with data assimilation, if any. Here, we focus on determining the assimilation term Dhd in a user-specified portion of the model domain (Ω), containing Na grid nodes. The primary inputs are shorelines determined from satellite images along the wet-dry interface, using the WORSICA platform. The terrain elevation along the wet-dry interface can be obtained using results from the circulation model at the time of the satellite images, and then interpolated using an inverse distance weighed method to provide the observed bathymetry (h_o) at N_o grid nodes.

Three sets of equations are used to determine Δh_d: 1) model predictions are valid, *i.e.* $\Delta h_d = 0$ (N_a equations); 2) observations are valid, *i.e.* $\Delta h_d = h_o - \Delta h_m - h_i$ (No equations); 3) data assimilation does not introduce or remove mass, *i.e.* $\int_{\Omega}^{\square} \Delta h_d dx dy = 0$ (1 equation). Because there are more equations than unknowns (*i.e.*, Na+No+1>Na), the system of equations is solved using a least squares method.

The shoreline is determined on the WORSICA service by extracting and processing Sentinel-2 images and their corresponding water indexes (*e.g.*, NDWI, MNDWI, AWEI). The terrain elevation along the shoreline is estimated from predictions from hydrodynamic models, considering that the total water depth at the shoreline is zero.

3. PRELIMINARY TESTS

Tests were performed at the Caparica beaches for October-December 2021 based on a previous model application without data assimilation (Fortunato *et al.*, 2021). Results along the Caparica beach indicate that the model accumulates sand in the upper beach, particularly in the intertidal area (red areas in Fig. 1b). This behavior is attributed to the lack of representation of undertow in the 2DH version of the model, which prevents the reproduction of the seaward-directed cross-shore transport. Because the intertidal area is where shoreline data can be determined from satellite images, the potential for the exploitation of these data for assimilation is high. As a preliminary verification, the initial bathymetry was used as surrogate data and assimilated along the shoreline at low tide (end of October), mean sea level (end of November) and high tide (end of December). The assimilation procedure preserves the volume with negligible errors and significantly reduces the discrepancy between model results and the initial bathymetry (Fig. 1c). These preliminary results show that the method is effective.

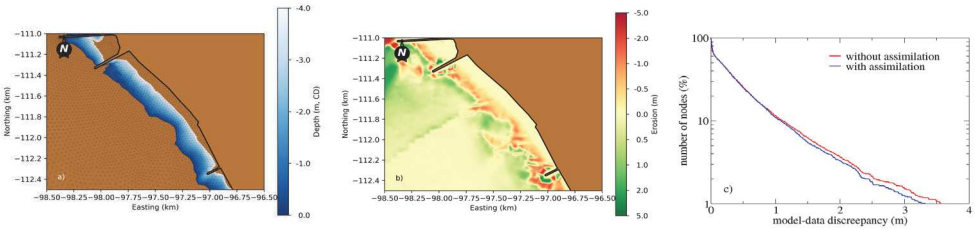

Figure 1. Result details in the S. João beach: a) grid and intertidal bathymetry; b) erosion without data assimilation; c) method assessment for the December 31st results

4. DISCUSSION AND CONCLUSIONS

The slow deterioration of morphodynamic model predictions along the coast remains a limitation for the automatic forecasting of beach evolution and coastal inundation. Preliminary tests indicate that data assimilation can improve the model results near the shoreline, where improvement is most needed. Further tests are underway to assess the dependency of the results on the frequency of assimilation, and the importance of assimilating real data.

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