

MODELING RAPID BEACH CHANGE SURROUNDING A COASTAL STRUCTURE IN OBLIQUE WAVES

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INTRODUCTION

Sandy beaches are typically in equilibrium with the wave climate, and changes occur when the system is perturbed. This can occur in the case of a major storm with large waves and therefore higher energy that drives wave setup and alongshore currents. However, changes to nearshore morphology can also occur when coastal structures are built and the system adjusts to a new equilibrium. An example of this is the construction of a shore-perpendicular groin that is designed to trap sediment by reducing the alongshore flow. The strength of the current is a function of the wave energy, and also the wave angle. Therefore, on beaches with low wave energy but an oblique angle, the alongshore current and the potential to transport sediment can be significant. We investigate the capability of Delft3D model (Deltares,2014; Deltares,2018) to simulate wave transformation, nearshore circulation and morphology change around a structure, driven by relatively small breaking waves at a very high incident angle. This is accomplished by comparing the numerical model results with high resolution field observations on a sandy micro-tidal sea breeze dominated beach (Medellín et al., 2018), to best simulate the rapid and small-scale morphological changes.

FIELD EXPERIMENT

The field site is located at Sisal beach, on the north coast of the Yucatan Peninsula in Mexico. A temporary 14-m long groin made of plywood sheets was deployed for 24-hours during intense sea-breeze conditions on May, 2015 (Fig. 1). High-resolution beach surveys were undertaken every 2 hours using DGPS-RTK. Winds, waves outside and inside the surf zone, and surf zone currents were measured during the experiment. After the structure deployment, rapid morphological change occurred, consisting of the accumulation of sand on the updrift side, and erosion on the downdrift side of the structure, shown in Fig. 1. Observations indicate that locally generated small waves ($H_s = 0.4$ m) approach the coast with a very high incident angle ($\alpha = 45^\circ$) which drive the strong alongshore current ($v = 0.6$ m/s) (Fig. 2). Furthermore, nearshore bathymetry of the study area was acquired up to 3 m water depth using an echo sounder. Offshore wave conditions at 10 m water depth, approximately 10 km offshore, were measured using an ADCP on a bottom mount. Moreover, mean sea level was recorded every 5 minutes by means of a tidal gauge installed inside the Port of Sisal.

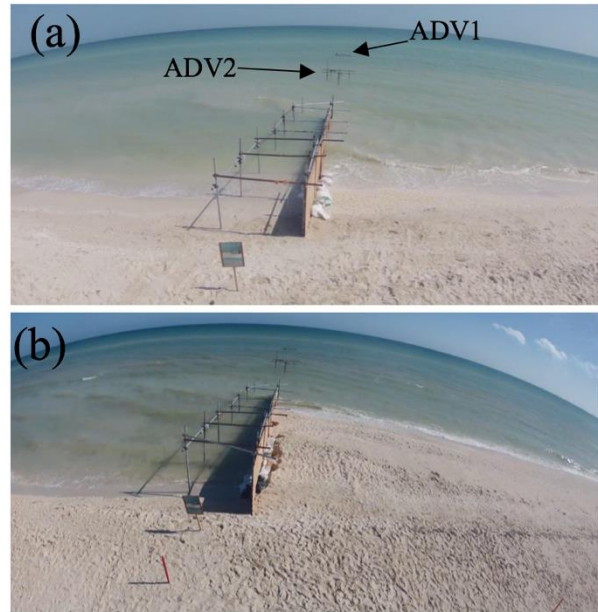


Figure 1 - Beach shoreline during the experiment at: (a) the beginning and (b) the end of the 24-hour experiment. The ADCVs locations are shown in (a). The alongshore flow is right to left.

NUMERICAL MODEL

We employed the Delft3D model (Deltares, 2014; Deltares, 2018) to simulate waves, currents, and beach morphology changes during the field experiment. The initial bed conditions for Delft3D are developed from measured bathymetry and topographic surveys conducted before the groin deployment. Offshore wave conditions and water levels at the 4 m water depth are used to drive the model. A series of nested grids with uniform mesh size with a minimum resolution of 8x4 m on the coarser grid and a maximum resolution of 2x1 m inside the surf zone are employed. Simulations were run on 2DH in stationary mode by an online coupling of WAVE and FLOW modules. In order to match results to observations in the surf zone, several parameters from both modules were tuned. The WAVE module is set with a breaking index equal to 0.6 and a Jonswap type bottom friction of 0.35. The FLOW module is run with time step of 1.5 s, a Chezy roughness coefficient of 100, and an eddy viscosity and diffusivity of 0.1 and 0.001 respectively. The groin is specified within the model as a 'thin dam'. MORFAC is set equal to 1 to simulate the sediment transport and morphology change in real time. Only suspended transport from currents is considered, bedload and wave-

related transport are neglected. FLOW module results (bathymetry, currents and water level) were shared and extended to the WAVE module every 60 minutes to accurately represent hydrodynamics and morpho dynamics.

RESULTS

Model-data comparison of the mean water level inside the surf zone (Fig. 2a) show significant differences, which might be caused by other processes not being accounted in the model that might contribute to the set-up (e.g. wind). The model predicts accurately low wave heights and underestimates high waves conditions in the outer surf zone (Fig. 2b). The diurnal variation of the significant wave height is ascribed to local sea breezes. Such diurnal variability is also found for the alongshore currents that reached 0.5 m/s during the peak of the sea breeze (Fig. 2c-d). The cross-shore currents remained smaller and were qualitatively reproduced at the offshore sensor (Fig. 2e-f).

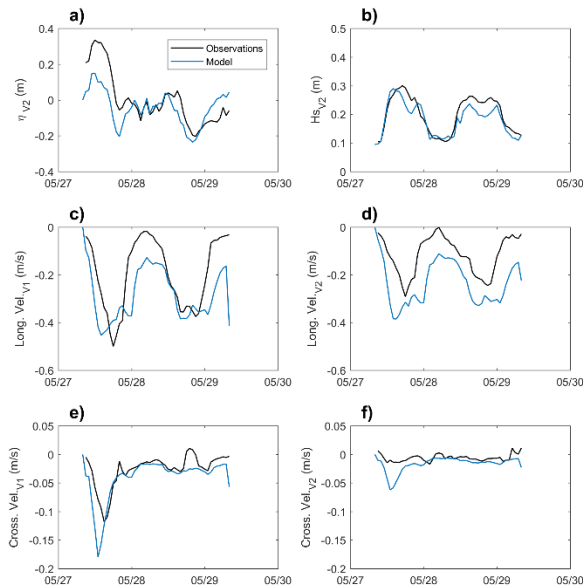


Figure 2 - Model-data comparison of: a) mean water level; b) significant wave height in the outer surf zone; c) alongshore velocity in the outer and (d) the inner surf zone. Cross-shore velocity in the outer (e) and (f) the inner surf zone.

Beach surveys show rapid morphological change occurred over only 24-hours (Fig. 3a), with beach accretion exceeding 60 m³ on the updrift side of the structure due to sediment impoundment and 40 m³ loss on the downdrift side. Preliminary model results qualitatively and quantitatively reproduce the rapid evolution of the beach over the updrift side (Fig. 3b) with an accretion of 40 m³. Field observations show that the updrift side reaches quasi-equilibrium conditions 12-hour after the structure deployment, reaching an accumulation of 50 m³ and a 5 m shoreline seaward displacement. For the numerical model this occurred after 10-hours, with 40

m³ and a 5 m contour displacement (Fig. 3c-d). However, the numerical model was not able to reproduce the downdrift erosion measured in the field (Fig. 3a). The latter can be ascribed to wave diffraction effects that are not well reproduced in the numerical model simulations.

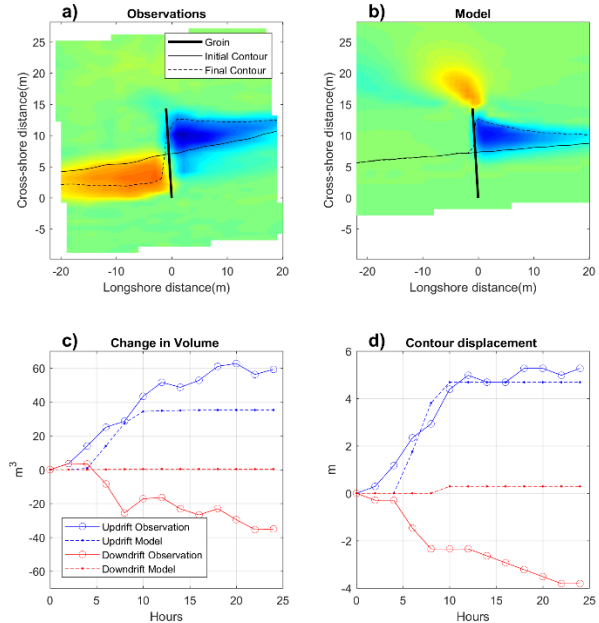


Figure 3 - Morphological changes comparison for 24 hours after groin placement: a) Measured changes on field (blue is accretion, red is erosion); b) Modelled changes; c) Volume changes for accretion (updrift) and erosion (downdrift) every 2 hours; d) Maximum displacement of contour 0.25m for updrift and downdrift region.

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REFERENCES

- Deltares (2014). Delft3D-WAVE. Simulation of short-crested waves with SWAN. Delft.
- Deltares (2018). Delft3D-FLOW. Simulation of multi-dimensional hydrodynamic flows and transport phenomena, including sediments. Delft.
- Medellín, Torres-Freyermuth, Tomasicchio, Francone, Tereszkievicz, Lusito, Palemón-Arcos, López (2018). Field and numerical study of resistance and resilience on a sea breeze dominated beach in Yucatan (Mexico), Water, vol. 10(12), p.1806.