Combined Wave and Tidal Effects on Sandy Beaches at a Short-Term Time Scale

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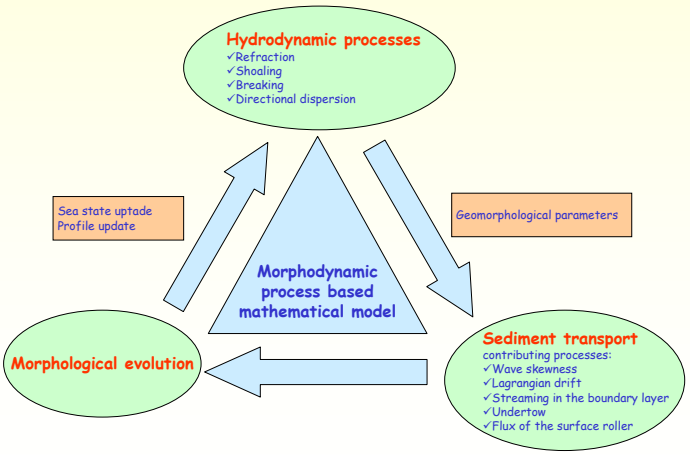
Abstract

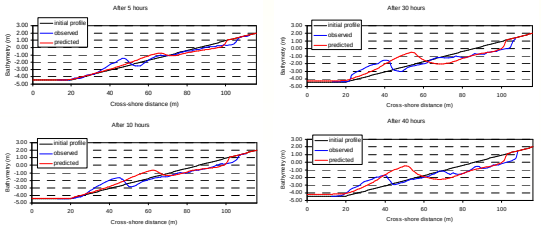
The sediment dynamics and morphological evolution of a sandy beach profile, subjected to the combined action of wave and tide, was analysed, during a tidal cycle, through process based mathematical modelling. The model was calibrated and verified with results of laboratory experimentation. Since the numerical results were in good agreement with the experimental data, the model was applied, for different scenarios of combined tidal regime and wave conditions, to assess the cross-shore beach evolution. The sediment transport, induced by the hydrodynamic conditions on the initial equilibrium profile, generates the formation of a cut in the beach face and upper part of the shoreface and a bar in the surf zone, which are, in the present work, characterized as function of the wave energy and the tidal range. The results show that the tide smears the morphology of the beach profile and that the volume of eroded sand slightly decreases as the tidal range increases, independently of the wave field. The analysis of the results also allowed to conclude on the relationship between the characteristics of the beach morphology (bar and swale geometry) developed during the tidal cycle and the combined action of wave and tide: the bar shoreward face slope decreases with the increase of the wave height and with the increase of the tidal range; the increase of the tidal range also pushes the bar offshore and simultaneously widens the cut at the beach face and decreases its depth.

Theme: (4) Living with erosion

Methodology



Model verification



Results

Effect of the wave energy on the beach evolution

For each tidal regime, the intensity of the cross-shore sediment transport rate increases with the wave height (Figure 4). As result, the sand volume eroded and the extension of the area eroded within the breaker zone increase with the wave height, as can be seen in Figures 5 and 6, respectively. The inshore sediment transport (positive values) that occurs before wave breaking, increases significantly with the wave height and gives a reasonable contribution to the formation of the bar for the highest incident wave height cases, of 3.0 and 5.0 m (Figure 4).

The differences on the integrated cross-shore transport (Figure 7), and consequently on the morphology of the bar (Figure 6), for the three tidal ranges, tends to decrease as the wave height increases, meaning that, in the presence of a severe storm, the sea level variation plays a minor role on the cross-shore evolution of the beach profile when compared with wave action.

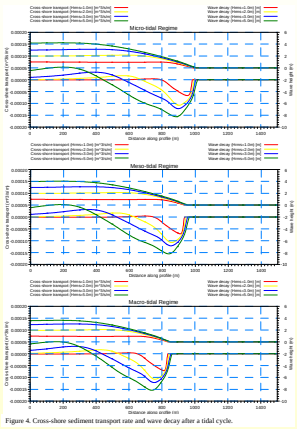


Figure 4. Cross-shore sediment transport rate and wave decay after a tidal cycle.

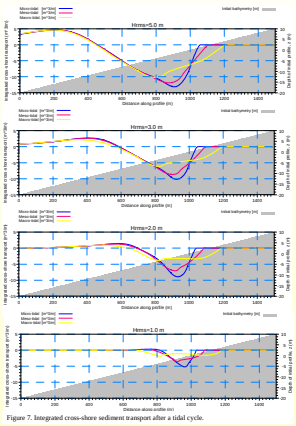


Figure 7. Integrated cross-shore sediment transport after a tidal cycle.

Effect of the tide on the offshore transport

The results show that, for all the incident waves, despite the slight decrease of the offshore sediment transport with the increase of the tidal range, the volume of sediment mobilized is of the same order of magnitude for the three tidal regimes independently of the wave height (Figure 5). This means that the effect of the sea level variation on the volume of sediment eroded from the beach face and upper shoreface is not relevant in the presence of storm waves. However, the tidal range affects the morphology of the beach, i.e., the bar and cut geometry, particularly under the action of the less energetic wave fields.

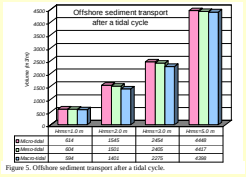


Figure 5. Offshore sediment transport after a tidal cycle.

Relationship between the bar form and the combined action of wave and tide

Two geometrical characterization parameters were analysed in order to investigate the relationship between the bar form and the combined action of wave and tide. These parameters are the bar shoreward face slope and the total cross-shore extension of the bar. The results show that the bar shoreward face slope decreases with the wave height, for the all the tidal regimes, and for each wave height decreases with the tidal range (Figure 8). In what concerns the cross-shore extension of the bar, it increases significantly, towards offshore, as the wave height increases. The increase of the tidal range decreases slightly the total width of the bar, however, its effect is more significant for the most energetic waves (Figure 9).

The maximum height of the bar (at the bar crest) decreases as the tidal range increases. The depth of the cut at the beach face is shortened with the increase of the tidal range, which widens the cut.

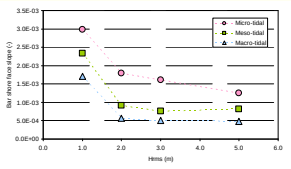


Figure 8. Bar shoreward face slope after a tidal cycle.

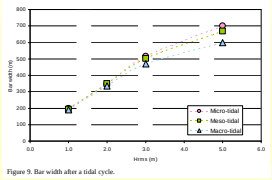


Figure 9. Bar width after a tidal cycle.

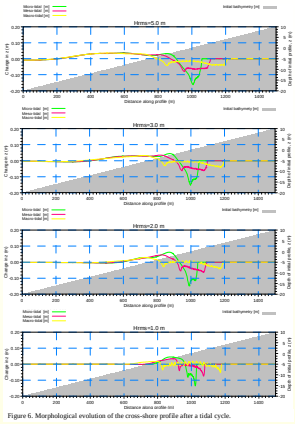


Figure 6. Morphological evolution of the cross-shore profile after a tidal cycle.

Profile changes during flood and ebb

Since the swash process is not considered in the model applied, the profile changes observed during flood and ebb are only due to wave action at a varying sea level (Figure 10). During flood, in the first half of the tidal cycle, it can be observed a slightly higher gradient, at the lower extreme of the cut for the micro-tidal regime, and at the upper extreme of the cut for the meso- and macro-tidal regimes. However, there are no distinctive morphological characteristics of the profile evolution during flood and ebb.

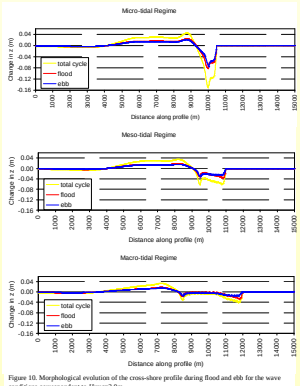


Figure 10. Morphological evolution of the cross-shore profile during flood and ebb for the wave conditions correspondent to *Hrms*=3.0m.