A COMPREHENSIVE ONE-LINE MODEL FOR SHORELINE EVOLUTION ESTIMATION

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INTRODUCTION

The prediction of sandy shoreline evolution, over both short/medium- and long-term temporal scales for small and large spatial scales, remains a challenge for coastal researchers and engineers. Basically, the configuration of sandy beaches, which are characterized by high complexity, are influenced by waves-sediment interaction. Coastal zones, which have a significant environmental, tourist, and economic value, are constantly exposed to natural (e.g., waves, tides, climate change) and human (e.g., over-exploitation by the construction of railways, roads, and private buildings close to the beach) pressures. The need for robust planning and management tools is essential, to preserve the environmental, economic, and social resources represented by coastal areas. Then, predicting the future morphodynamic state of sandy beaches is crucial to quantify their vulnerability. To address this issue, various approaches, including 2D coastal morphodynamic numerical models and simple one-line models, have been developed so far. The latter are often preferred due to their ability to assess coastal changes across extensive spatial scales (tens of kilometers) and extended temporal scales (tens of years) and for several scenarios at a reasonable computational time cost. Recently, such models have undergone continuous improvements in their capability to reproduce physical phenomena and complex shoreline configurations. One-line models, with a particular focus on the study of curved shorelines, and the development of coastal shoreline features, such as spits, cups, and rhythmic shoreline undulations (Ashton and Murray, 2006a, b; Kaergaard and Fredsoe, 2013a; Hurst et al., 2015; Robinet et al., 2018, 2020) have been developed. Other one-line models (Vitousek et al., 2017; Antolinez et al., 2019) have explored the impact of the cross-shore sediment transport on long-term shoreline dynamics, accounting not only for river inputs, beach nourishments, sand-bypassing (Pelnard-Considère, 1956), but also cross-shore transport due to wave action (Yates et al., 2009) and water level variation due to sea level rise (Bruun,1962), storm surge, and monthly sea level anomalies. In this context, the work described hereinafter is aimed to provide the scientific and technical communities with a comprehensive one-line tool, covering hydrodynamics and morphodynamics processes.

METHODOLOGY

The proposed model is provided as Python classes, which allows to read and process input and output data files. The model (named morfRESTORE) belongs to the class of one-line models. As most of the one-line models, morfRESTORE includes two main sub-models, a hydrodynamics module and a morphological one.

As far as the hydrodynamics module is concerned, depending on the complexity of the case under study, the proposed tool allows for two options to compute wave propagation: (i) a simple one-dimensional wave transformation model; (ii) the spectral wave model SWAN (Booij et al., 1997; Ris et al., 1999). Particularly, the former has been formulated in order to be at the same time simple, quick, and accurate. The model reproduces the main physical processes of shoaling, refraction, breaking, and wave energy dissipation (Batties and Stive, 1985). The method relies on the model proposed by Dally et al. (1985), accounting for the phenomenon of wave height stabilization. Wave propagation is computed by solving the steady-state wave energy flux conservation equation combined with a generalized Snell's law. The latter can be applied only to straight and parallel bathymetric contours. However, submerged contours are usually weakly curved. Since in coastal processes, such as longshore sediment transport, shoreline evolution, nearshore wave height, and direction play a main role, a new methodology for determining nearshore wave angle for curvilinear (rather than straight) and parallel bathymetry has been formulated. The nearshore wave angle is estimated by using a correction factor which depends on shoreline orientation. The correction factor is defined within the frame of a simplified analytical model accounting for refraction phenomenon.

The morphodynamics tool concerns the effects of the defense coastal structures, such as groins and breakwaters, which cause pronounced changes in shoreline position. The implementation of both hard and soft defense measures can be essential to protect beach from loss of sediment (Shore Protection Manual, 1984). One-line models provide a valuable tool for examining defense structures-beach interaction, even with limitations due to their simplified capability to represent all governing processes. However, one-line models are decision support tools designed to assist in decision-making related to the management of long-term coastal planning.

Although groins are simple structures typically deployed perpendicular to the shoreline, their interaction with the beach system is influenced by a range of factors, including wave parameters, currents, diffraction, sand size, cross-shore beach profiles, and groin geometrical and physical parameters (e.g., length, construction materials, elevation relative to mean sea level, porosity). Groins act on shoreline changes trapping sand in coastal areas where sediment transport is predominantly induced along the long-shore direction. Many one-line models typically estimate groin bypassing in a straightforward manner, assuming a linear distribution of longshore sediment transport along the surf zone or neglecting the temporal variability of relevant factors. A novel approach is proposed herein. In brief, the rationale of the approach is to assume cross-shore distribution of the long-shore sediment transport proportional to the wave-breaking dissipation function, calculated applying the Battjes and Janssen (1978)'s formula. Moreover, groin length and permeability are considered time-dependent variables (see Figure 1).

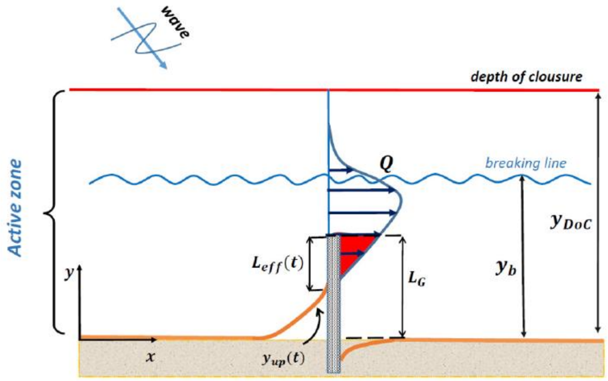

Figure 1 – Example of groin impact on longshore sand transport at a generical instant t. The red area of Q represents the longshore sand transport trapped by the groin.

Detached breakwaters, which are usually parallel to coast orientation, act on wave propagation, modifying nearshore parameters (i.e., wave height and direction) of incident waves, and reducing wave energy reaching the protected area. In turn, this phenomenon generates reduced longshore sediment transport and creates a sheltered area that promotes shoreline advance. Most of the studies focused on the prediction of the shoreline response behind breakwaters. Efforts have been made to reproduce in a simple but effective way diffraction phenomenon behind a breakwater, in shoreline models (Hanson and Kraus, 1990; Dabees, 2000; Hurst et al., 2015; Roelvink et al., 2020). The tool proposed in this work aimed to evaluate the effect of both offshore (i.e., breakwaters located outside the surf zone) and nearshore breakwaters (i.e., breakwaters located inside the surf zone) on medium- and long-term cross-shore beach profile. In one-line models, the main assumption is that the cross-shore beach profile shape remains constant (average profile) and moves parallel to itself seaward or landward as a result of accretion or erosion conditions, respectively. This average profile is usually assumed equal to the equilibrium profile (Dean, 1977), which extends from the shoreline to the depth of closure (Hallermeier, 1978, 1980). For offshore breakwaters, the profile shape is assumed not to be altered by the presence of the structure. Whereas a breakwater is located inside the active zone, the natural cross-shore profile is interrupted. Therefore, the proposed tool allows to compute the long-term changes of the shoreline by employing two compound beach profiles. The first one, behind the breakwater, represents the "real" shoreline and moves due to physical processes that happen in the band between the coast and structure. The second profile is related to the location of a "dummy" shoreline and moves due to the physical processes that act into the band between the structure and the end of the active zone.

A series of ideal and real-world applications of the model will be presented during the conference.

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