MODELLING THE DECADAL EVOLUTION OF A DELTAIC COAST UNDER DIFFERENT SOFT INTERVENTIONS FOR CLIMATE CHANGE ADAPTATION

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INTRODUCTION

Deltaic coasts are among the most dynamic terrestrial environments, hosting important ecosystems and being intensively used by humans. Their low-altitude makes them especially vulnerable to mean sea level rise (MSLR) and extreme sea levels related to climate change (CC), which worsens the local subsidence effect.
A potential protection strategy to reduce CC impacts are hard protections (e.g., groins). In some cases, they are simply the only possible protection but their cost, adverse effects and unpopularity make their use increasingly limited. Alternatively, soft options such as beach and shoreface nourishments and groin partial deconstruction are adaptation measures that protect coastal systems while providing social and environmental benefits.
The morphodynamic evolution of the coastal zone of wave-dominated deltas is extremely-complex and highly-dynamic at a wide range of spatio-temporal scales. In essence, sediment supply from the river is reworked and redistributed by waves and currents, producing sand transport and topo-bathymetric changes. The modelling of these morphological changes requires considering the inherent feedbacks between these changes and water flows. Such modelling at a decadal scale provides crucial information for the design of potential interventions.
This contribution aims at characterizing the effect of different potential soft interventions for CC adaptation on the decadal evolution of a wave-dominated deltaic coast. The study site is the Llobregat delta (Barcelona, Spain). Projections with different interventions will be modelled and compared, with emphasis on performing a sensitivity analysis and understanding the involved physical processes. The Q2Dmorfo model will be used for its good compromise between accuracy and computational speed (Arriaga et al., 2017).

AVAILABLE DATA AND MODEL

Llobregat delta is a microtidal coast south of Barcelona, about 17.7 km long and bounded by groins of 530 m in the east part (separating the beaches from the Llobregat river mouth) and 100 m in the west side (next to a small marina, Fig. 1). It is a continuous sandy stretch with D_{50} $\approx$ 0.3 mm at the dry beach and a curvilinear shoreline facing to the south-southeast. It hosts the Barcelona airport, significant natural areas and four large cities. Bathymetric data was obtained from several LIDAR campaigns (2012-2017), a deep water bathymetry and several nearshore topo-bathymetries along 1 km. The wave conditions from the Barcelona buoy (65 m depth) were propagated using SWAN to the offshore model domain. Sea level data was obtained from the Barcelona harbour gauge. Dominant waves come from east and south (Fig. 1) and the maximum sea-level variations are about 50 cm.
Q2Dmorfo describes the full topo-bathymetric evolution by computing sediment fluxes parametrically from the wave field without resolving the currents. It thus filters out the complex dynamics of the surf zone and it is suited to long term and large-scale modeling. The geometry and initial bathymetry of the Llobregat delta have been adapted to the rectangular model domain, coordinates and mesh. The lateral groins are represented by rectilinear walls of the appropriate length. The model has been calibrated with available data (2012-2017) by tuning the main parameters (related with sediment transport) to minimize the difference between final observed and modelled shorelines.
Preliminary long-term runs are being performed from 2012 to 2070. The future wave and sea-level forcing has been built by repeating 12 times the 5-yr wave conditions and baseline sea level (more realistic projections will be also considered). When needed, decadal values of MSLR applicable to the area (RCP2.6, 4.5 and 8.5) have been added to the sea-level baseline. The 58-yr simulations are being undertaken for different MSLR scenarios and interventions, including the partial deconstruction of the Llobregat river jetty and different types of sand nourishments and borrow areas.

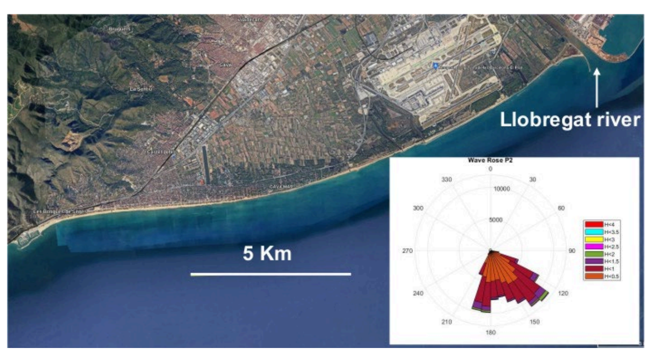

Figure 1 - Llobregat river delta (Google image) and wave rose at 11 m depth. North points up.

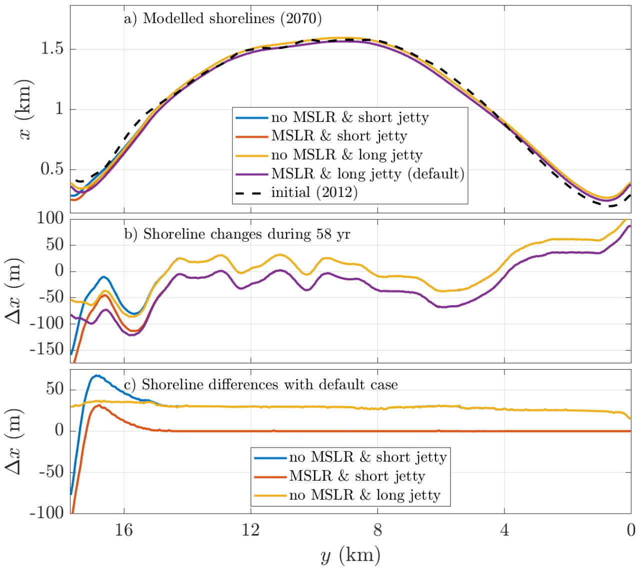

Figure 2 - Q2Dmorfo results without and with MSLR (RCP8.5) and with either a 100 m or a 530 m long jetty (purple lines being the default run). We show initial (in 2012) and final (in 2070) shorelines (panel a), shoreline changes during 58 yr (panel b) and shoreline differences with the default one (panel c). The right side (y=0) corresponds to the west (small marina) and the left side (y=17.7 km) is at the east (jetty).

PRELIMINARY RESULTS AND DISCUSSION

The default run simulates the delta evolution during 58 yr (2012-2070) with the real jetty of 530 m and the MSLR of the RCP8.5 scenario (business as usual), which induces an overall increase in mean sea level of 40 cm. Panel a of Fig. 2 shows the initial (black dashed) and final (purple for the default case) position of the shoreline. It recedes some 85 m on average along the 3 km next to the jetty (east, y=14.5-17.7 km) and accretes 35 m on average along the 4 km next to the small marina (west, y=0.0-4.0 km). Regarding the central part of the domain, there is a small mean recession of about 10 m at the eastern side, in El Prat and Viladecans areas (y=8.5-14.5 km), and a stronger mean recession of 45 m at the western part, approximately in the area of Gavà city (y=4.0-8.5 km). This morphological evolution can be explained by the interplay of different processes: the natural behaviour related with the shoreline curvature and the dominant oblique wave conditions (from the east), the effect of the jetty at the east and the small marina at the west, and the role of MSLR.

The latter has been characterized by running the model for four scenarios: no MSLR and MSLR according to RCP2.6, 4.5 and 8.5 (default case). Results in 2070 are very similar for the three MSLR scenarios, with recession being smaller by < 8 m in the more “optimistic” case. The run without MSLR (yellow line in Fig. 2) gives a significantly different result compared with the default one, shoreline recession being between 35 m (at east) and 25 m (at west) smaller than the default case (panels b and c).

A potential intervention that could be applied in this area is a partial deconstruction of the Llobregat long jetty and we have run simulations with lengths of 100 m, 200 m, 300 m, 400 m and the original 530 m. As an example, Fig. 2 shows the case of a 100 m jetty with MSLR (orange lines) and without MSLR (blue lines). The jetty effect is restricted to the 3 km near it (see panels b and c). When the jetty is shortened, the 0.5 km beach right next to it recedes much more than in the default case (protection effect of the jetty shadow) whilst the following 2.5 km experience a smaller recession due to the sediment arriving from the eroded area.

Finally, model simulations with soft interventions based on nourishments are also being performed. A first set has been based on superimposing to the initial bathymetry alongshore uniform perturbations that have Gaussian shapes in the cross-shore. For example, we have imposed Gaussian bumps of 1.5 m amplitude and 15 m width (simulating small man-made dunes or berms) at two locations of the dry beach (30 m and at 10 m shoreward from the shoreline). The resulting shoreline in 2070 is the same for the two locations, with less recession than the default (but the effect is small, of 6 m maximum, figure not shown). We have also played with a Gaussian hole of 1.5 m amplitude and 15 m width located 100 m seaward form the shore (at 2.5 m depth), simulating a borrow area. The 2070 shoreline shows more recession (5 m maximum). When both interventions (bump and hole) are included at the same time the shoreline remains approximately the same as in the default run.

CONCLUSIONS AND FURTHER WORK

The Q2Dmorfo model, which has been successfully validated in different sites (e.g., in the Sand Engine mega-nourishment, Ribas et al., 2023), also reproduces reasonably well the dynamics of the Llobregat delta beaches during 5 yr (2012-2017). Validation with a longer time period is in process, and more realistic forcing projections will also be used based on this extended historic data set.

The modelled 58-yr modelled morphodynamic evolution including MSLR provides insights in the fate of the delta coast. According to the preliminary results, two hot spots develop, along 3 km next to the east jetty and along 4.5 km of Gavà city area. The rest of the domain is either rather stable (area of El Prat and Viladecans) or shows accretion (along 4 km next to the small marina). MSLR is responsible for an overall recession of about 30 m and the effect of the jetty is restricted to the closest 3 km area. Further work will include testing a wide range of different potential interventions (nourishments and borrow areas) of different sizes and located at different positions. Alongshore variable perturbations will also be tested: for example, setting borrow areas in the accreting areas and dumping the sand in the hot spots. The possibility of building mega-nourishments will also be modelled.

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