

SEDIMENT TRANSPORT AND DISPERSAL IN THE NEARSHORE OF “FLASH-FLOOD” RIVERS

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River sediment dispersal on the near-shore of “flash-flood” rivers is investigated using a coupled wave-current-sediment transport model. Besòs and Llobregat rivers (short and mountainous rivers in NW Mediterranean Sea, near to Barcelona City) are used as examples to study the sediment transport under “flash-flood” regime. The modeling system COWAST which includes the coupling between the water circulation model ROMS and the wave model SWAN, is applied to assess the sediment dispersal mechanisms and deposition in the coastal area off the two river mouths. Preferential depositional areas such as mud-belts were identified from the simulations. The sediment dispersal pattern obtained by the model agrees with observational measurements. Complementary numerical simulations revealed sorting of sediment grain size in the cross-shelf direction.

Keywords: sediment transport; river dispersal; mud-belt; coupling

INTRODUCTION

The river-borne sediment dispersal and the interface between the river and the shelf involve physical and geological mechanisms acting at different temporal and spatial scales (Wright and Nittrouer 1995). Observational studies have revealed that, in many coastal environments, episodic storms dominate sediment fluxes and subsequent dispersal patterns (Sherwood et al. 1994, Warner et al. 2008a, Bever et al. 2011, Grifoll et al. 2013a). The sediment flux during storm events can be several orders of magnitude larger than during calm conditions (Guillén et al. 2006, Ulses et al. 2008, Bever et al. 2011). In consequence, preferential depositional patterns during river floods can partially explain long-term fine deposits observed on the sea floor (Ogston et al. 2000). On longer time-scales, advection of sediment by shelf currents can redistribute sediment and determine final deposition patterns (Sherwood et al. 1994, Harris et al. 2008, Bever et al. 2009, Xu et al., 2011, Xue et al. 2013).

River sediment dispersal on the shallow continental shelf is investigated using a coupled wave-current-sediment transport model. Besòs and Llobregat rivers (short and mountainous rivers in NW Mediterranean Sea, near to Barcelona City) are used as examples to study the sediment transport under “flash-flood” regime. River “flash-flood” regime is characterized by sudden river freshwater peaks after rainy events and is typical for the Mediterranean Climate. The modeling system COWAST (Warner et al. 2010) which includes the coupling between the circulation model ROMS and the wave model SWAN, is applied to assess the sediment dispersal mechanisms in the coastal area off the two river mouths (see Figure 1). The sediment balance calculations consider river source, bed-load and suspended transport, and sedimentation/re-suspension processes due to waves and currents.

Preliminary computations have been performed in order to identify the cross-shelf sorting of sediment grain-size observed in the D50 measurements (Grifoll et al. 2014). In this case the model was initialized with 4 homogenous sediment classes (D50 in mm): 0.125, 0.063, 0.06 and 0.015mm. Characteristic hydrodynamic conditions were applied monitoring the time-evolution of the class percentages.

In a second step, the COAWST code has been used to simulate the hydrodynamics and sediment dispersal patterns for a one-year period. Open boundary conditions for currents were obtained from a nested system fed by the MyOcean system (see details in Grifoll et al. 2013b). Wave information at numerical boundaries was obtained from buoy measurements in the study area (see Figure 1.b). Hydrodynamics (currents, waves and sea-level) and sediment (suspended sediment concentrations) variables were recorded during two specific field campaigns and used to assess the skill of the code (see details in Grifoll et al. 2013b, Grifoll et al. 2014). Numerical computations agree reasonably well

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in comparison to observations (Grifoll et al. 2013b, Grifoll et al. 2014). Results obtained from numerical experiments reveal that the water circulation in the inner-shelf is controlled by a prevalent along-shelf direction current forced by local wind on short time scales and by remote pressure gradients on synoptic time scales (Grifoll et al. 2013b).

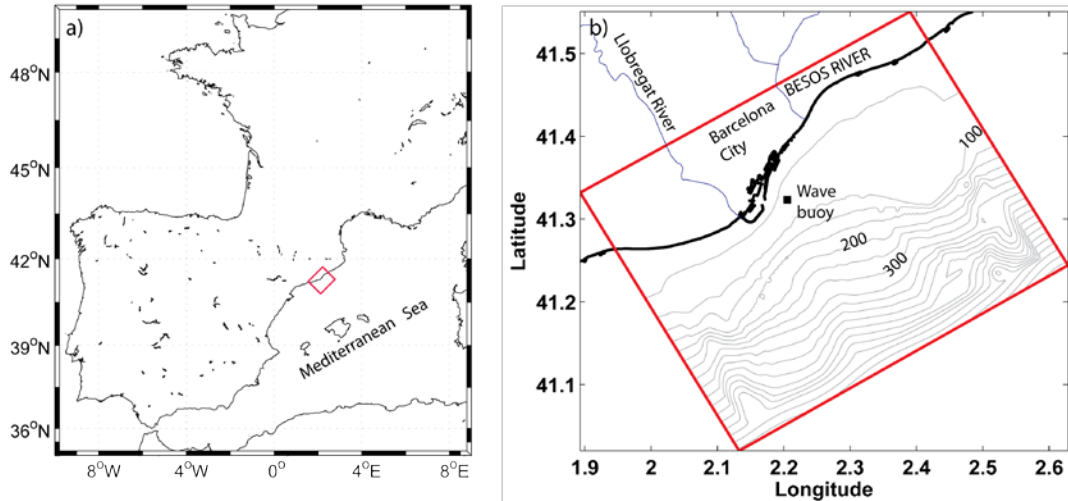


Figure 1. (a) Location of the study area in the NW Mediterranean Sea. (b) Bathymetry and mesh boundary (in red) of the simulations. The square in Figure 1.b shows the position of the wave buoy used to obtain the wave boundary conditions for the simulations.

RESULTS

Cross-shelf sorting

Sediment grain size used to show a seaward fining trend on the inner-shelf (Galparsoro et al. 2010; Grifoll et al. 2014; Guillén and Jimenez 2009). Sediment transport numerical experiments were conducted without considering the effect of the river load. Characteristic hydrodynamic conditions (significant wave height and period) are presented in Figures 2.a and 2.b. A typical energetic event with two significant wave height peaks (about 1.5 m) was introduced in the model. The wave peak period oscillates between 6 and 8 seconds during the energetic event. The sediment fraction was initialized at 25% for each class of sediment (D50 equals to 0.125 mm, 0.063 mm, 0.060 mm and 0.015 mm). Different control points following a cross-shelf transect were used to determine the time evolution of the percentage of the sediment fraction. Figure 2.d, 2.e and 2.f show the time-evolution of the percentage of the sediment fraction for -10 m, -25 m and -50 m contours respectively. According to Figure 2.d the coarser sediment fraction prevails after the energetic event at the shallower areas (~10 m). At -25 m, the intermediate sediment fraction prevails at the end of the simulation. Within the deepest area the mud fraction is larger than the coarser ones. According to the results it seems evident that a net transport offshore for the fine fraction occurs. This transport is consistent with the near-bottom cross-shelf fluxes shown in Figure 2.c. The near-bottom water velocity is well correlated with the increase of the significant wave height. In consequence, a mass fluxes offshore balance the onshore mass flux that occurs in the sub-surface layers due to the wave action. In the inner and mid-shelf, seaward fluxes may respond to Eulerian-mass transport or undertow that extends offshore of the surf zone (Lentz et al. 2008, Scandura and Foti 2011). The numerical results shown are consistent with theoretical considerations (Harris and Wiberg, 2002) and with observed sorting of material in the shelf (Galparsoro et al. 2010, Guillén and Jiménez, 2009).

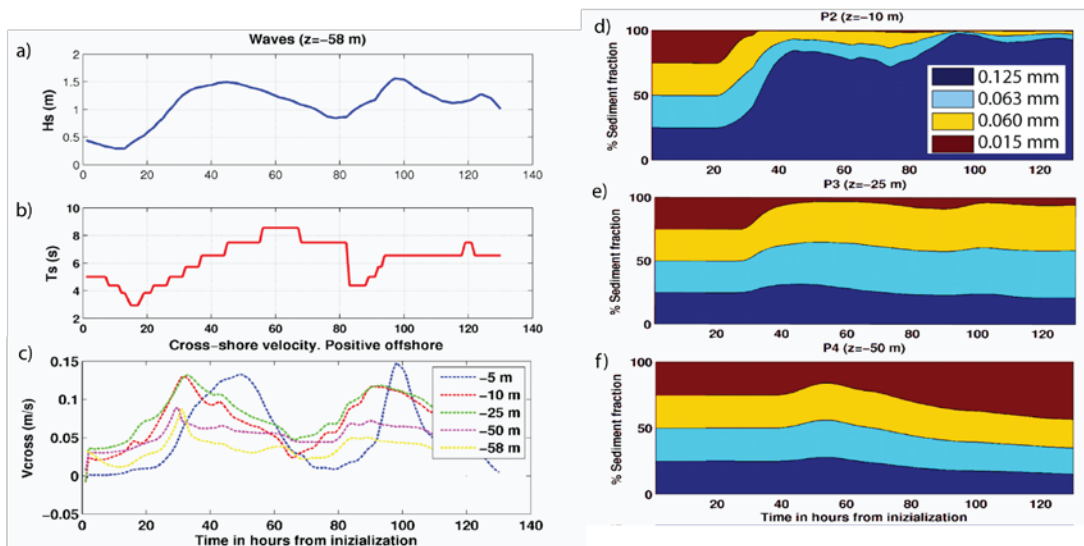


Figure 2. Hydrodynamic conditions for the sediment transport simulations to investigate the cross-shelf sorting: (a) significant wave height (m) and (b) peak period (seconds). The obtained cross-shelf velocities near-bottom is shown in (c). (d, e, f) Time-evolution of the four classes of sediment fraction initially considered in the sea bed at three different control points (10 m, 25 m and 50 m water depth). Note that initially the percentage of each fraction is equal to 25%. Coarser sediment dominates the shallow point (P2) and the depth areas (P4) are dominated by the finer fraction at end of the simulation.

Mud-belt formation

A one-year period was modelled to reproduce the sediment transport and preferential deposition from river load to the inner shelf and within the Barcelona harbour basins (Figure 1). Silt fractions from the buoyant plume were transported and deposited offshore due to near bottom fluxes rather than fluxes in the surface plume (Grifoll et al. 2014). Sediment data reveals preferential mud deposition between 20 m and 50 m water depth (Figure 3) consistent with seismic data presented by Lique et al. (2007). Two fine deposits were formed shifted southwestwards from the river mouth. This is related with the prevalent along-shelf flow in the inner-shelf which is southwestward according to the seasonal characterization presented by Grifoll et al. (2013). Topographic effects results in an energetic area in front of the south mouth of the Barcelona harbor (see Figure 3). This is consistent with an area without significant deposition due to an increase of the bottom stress (Grifoll et al. 2014).

The sediment transport follows a multi-step process with 4 stages (Wright and Nittrouer 1995, Grifoll et al. 2014): buoyant river plume due to the “flash-flood event”, initial deposition after the energetic event, reworking due to the subsequent wave action and long-term transport. Numerical simulations revealed that the deposition rates were controlled by the “flash-flood” events due to the sudden increase of the suspended sediment availability. Approximately, one third of the sediment from river load is deposited in the mud-belts or fine deposits.

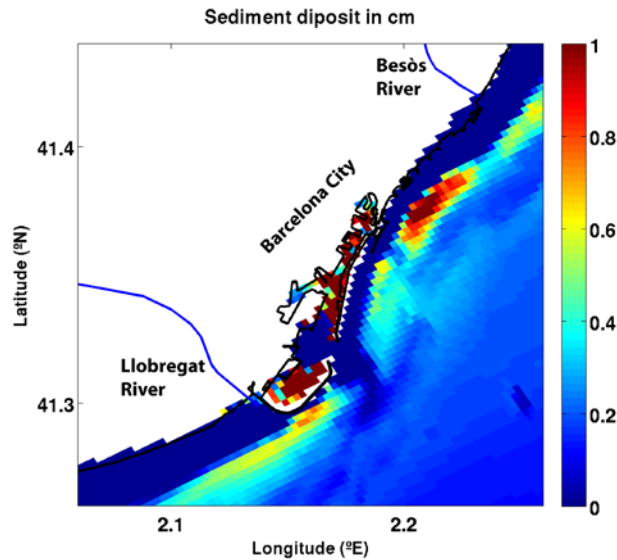


Figure 3. Simulated sediment deposition (in cm) after one-year modelling of dispersal sediment of the Besòs and Llobregat rivers. The Figure show also the Besòs and Llobregat river mouths and the Barcelona harbor lay-out.

FINAL REMARKS

Preferential depositional areas (i.e. mud-belts) from “flash-flood” rivers were identified from the simulations. The sediment dispersal obtained by the model agrees with observations. The depositional mechanisms is based on a multi-step pattern where the offshore cross-shelf flows near bottom occurs. This is due to the Eulerian mass-transport that plays an important role in the fine sediment dispersion. This means that, in shallow water depths, coarser sediment accumulate, whilst the finer ones are easily resuspended by wave action and deposited in deeper water areas. As future work there will be additional simulations including flocculation and anthropogenic effects, cohesive behavior of the sediment or mesh refinement.

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