Near-bottom sediment dynamics on highly-protected beaches

The Coastal Ocean Observatory of Barcelona

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Abstract—. **This article presents some preliminary results of the sedimentary dynamics measured during 5 months in Barcelona city beaches (NW Mediterranean). Wave storms, resuspension events and near-bottom sediment fluxes are analyzed in order to characterize the sedimentary behavior of highly-protected beaches.**

Keywords-component; coastal zone, sediment transport; currents; storms

I. INTRODUCTION

Pocket beaches limited by rocky headlands or artificial structures are singular littoral systems constrained in their cross-shore and longshore sediment flux. They are frequent elements in many coasts and their study is mainly focused on the modification of the platform shape depending on wave conditions. On the contrary, nearshore sediment dynamics is usually oriented to open beaches and previous studies in embayed beaches are scarce. In the framework of the Coastal Ocean Observatory (ICM-CSIC) we plan to develop a long-term measuring program of sediment dynamics in the artificial pocket beaches of Barcelona city in order to unravel specific sediment transport conditions of these beaches and to apply this knowledge to improve the management of this kind of beaches.

II. THE MONITORING SYSTEM

The city of Barcelona is located at the Catalan coast (Spain) in the north-western Mediterranean. It is a micro-tidal zone (range about of 20 cm) in which waves is the main stirring mechanism controlling coastal evolution. The most energetic storms approach from the east, have a typical duration of a few days, and are often associated with the cyclonic activity in the western Mediterranean. The study site is located in front of the Somorrostro beach, close to the Port Olimpic harbor of the Barcelona city (Fig. 1). A Nortek ADCP AWAC 1MHz equipped with pressure and temperature sensors, coupled with an OBS (D&A) turbidity sensor were deployed on a bottom tripod in an upward-looking configuration. The ADCP measured the current speed and direction in 0.5m thick layers from the bottom (0.9 mab) to the surface. Waves were measured hourly with bursts of 8.5 minutes at 2 Hz, and currents and turbidity were measured every 10 minutes averaging bursts of 1 minute at 1 Hz. The OBS turbidimeter was located 0.5 mab and it was coupled with an anti-fouling wiper (Hydro-wiper, Zebra-Tech LTD). The tripod was deployed near the pole marking the entrance to the Port Olimpic harbor at 10 m water depth (Fig. 1). The system was powered from a solar panel installed on the top of the pole. The median grain size of the bottom sediment at the study site is about 225 µm, with a content of fine sediment (< 63 µm) lower than 5%.

III. MEASUREMENTS

Tripod measurements took place from November 10th, 2010 to April 30th, 2011. The time series allowed us to extract information about wave and current conditions and sediment fluxes during the study in the aforementioned period.

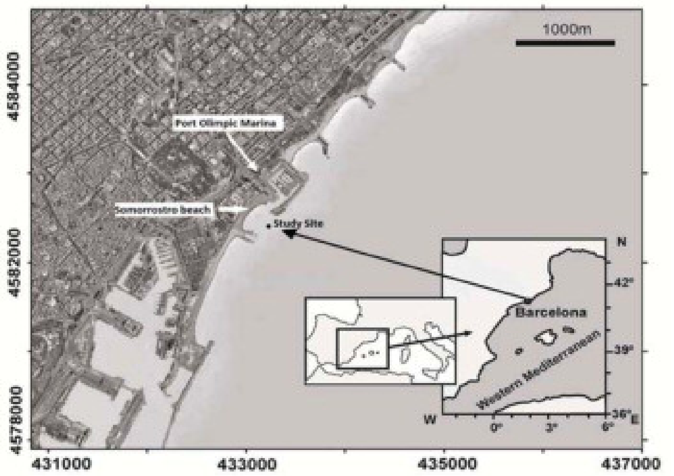

Fig. 1. Map of the western Mediterranean and detailed map of the coastal area in front of Barcelona showing the location of the Somorrostro beach.

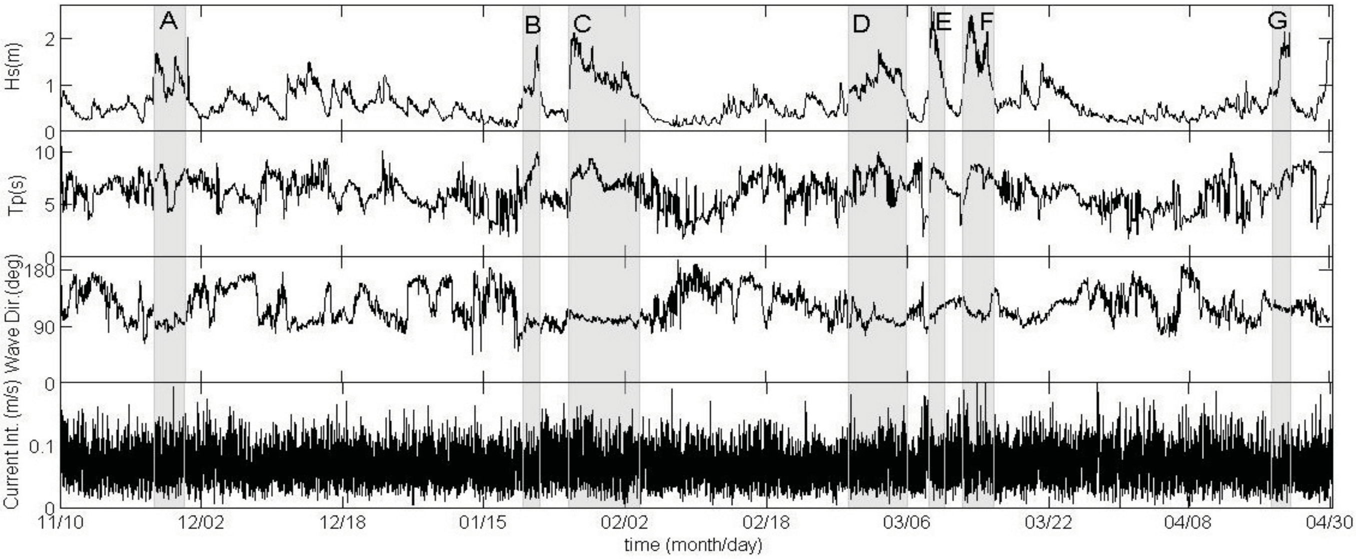

Fig. 2. Wave and current conditions during the study period. From top to bottom: significant wave height, wave peak period, wave mean direction and current intensity at 0.9 m above the bottom. Shaded regions are the storm events (from A to G).

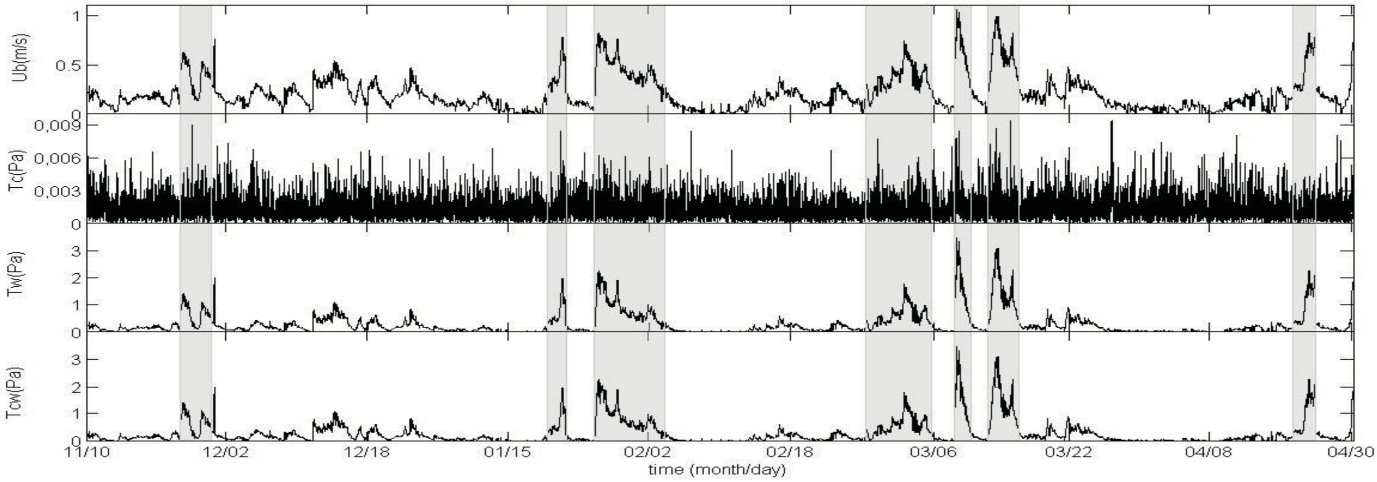

Fig. 3. From top to bottom: Bottom orbital velocity (Ub), current bed shear stress (Tc), wave shear stress (Tw) and combined wave-current bed shear stress (Tcw). (Note the different scale for current bed shear stress)

Seven easterly storms with significant wave height, Hs, over 1.5 m were identified (see Fig. 2 and Table I). Shaded regions in Fig. 2 show these storms bounded by Hs > 0.75 m. The event with highest wave (2.64 m) was the storm beginning on March 8th (storm E in Fig. 2). The wave peak periods reached 9.96 s and their mean values do not differ significantly between the different storm events.

Interactions between surface waves and the seabed are most conveniently expressed in terms of the wave-induced motion close to the bed (see, e.g., [1]). Near bottom orbital velocities and the components of bed shear stress (current component, T_c, wave component, T_w, and total stress, T_{cw}) are shown in Fig. 3. The bed shear stress was calculated following the methods described in [2] and [3] so as to evaluate sediment resuspension. The total combined wave-current shear stress, T_{cw}, is well correlated with the near bed orbital velocity, and thus with wave height, since the bottom boundary is dominated by waves ($T_c << T_w \sim T_{cw}$). The total stress T_{cw} reached its maximum value, 3.451 Pa, on March 8th (storm E).

Using progressive vectors to represent flow conditions during the survey period, a northeast circulation pattern is stressed at 0.9 m from seabed (see Fig. 4). In some periods it can be observed reversals in current direction, which happen to match in some cases with storms events. For instance, a longshore current component towards the south is observed at the storm beginning on March 2th (storm D). The progressive vector at 8.9 m from seabed presents a northeast circulation pattern

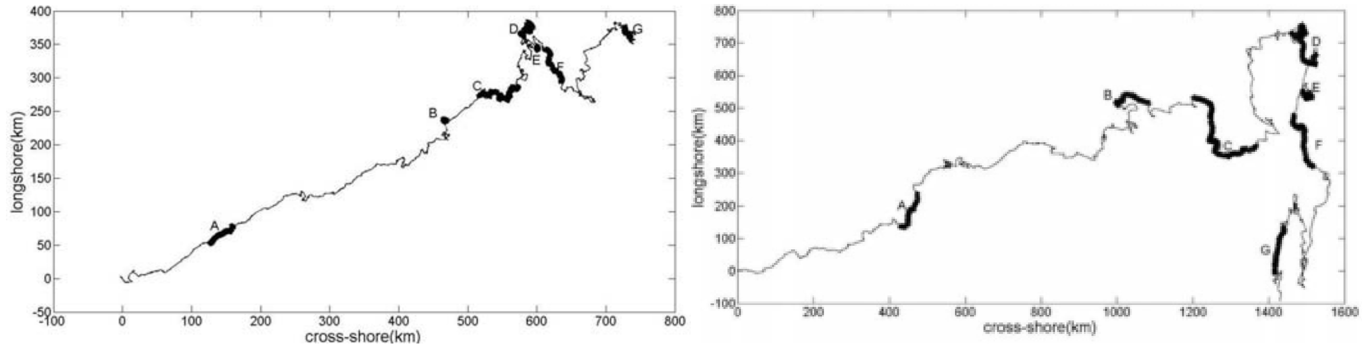

Fig. 4. Progressive vector diagram obtained during the study period at 0.9 m (left) and 8.9 m (right) distance from seabed. Starting points are (0, 0) corresponding to their real relative locations. Storms events A to G are in thicker line.

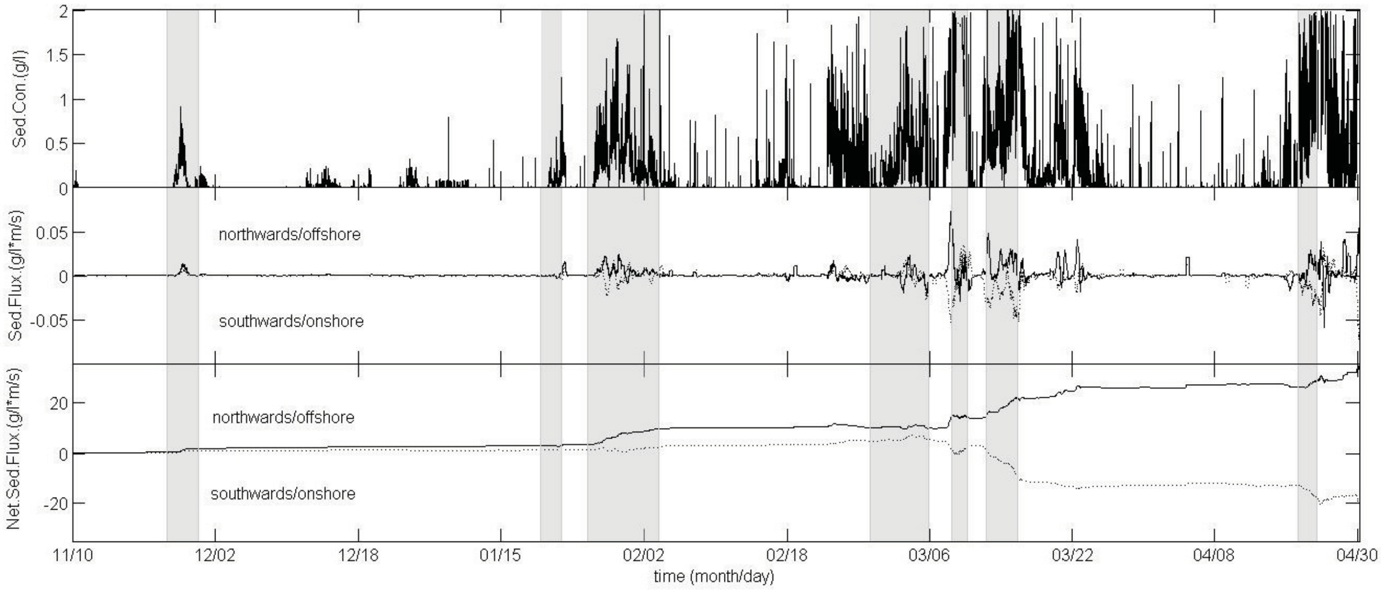

Fig. 5. From top to bottom: Suspended sediment concentration (Sed. Con.); sediment fluxes (Sed Flux) (across-shore in continuous line and alongshore in dotted line) and cumulative net sediment fluxes (Net Sed Flux) (across-shore in continuous line and alongshore in dotted line).

until the end of January (see Fig. 4). From March to April the flow was direct mainly south and parallel to the coast (alongshore).

The measuring range of the turbidimeter was 0-2000 FTU and the transformation to suspended sediment concentration (SSC) was carried out based on an adaptation of the general fit proposed in [4] for the western Mediterranean:

$$\text{SSC (mg/l)} = 1.74\ \text{FTU} - 1.32 \qquad (1)$$

The peaks in SSC (Fig. 5) are clearly related to the occurrence of storm events, although some of the highest concentration were reached after the peak of the storm (on March 18th SSC = 1.56 g/l, on April 27 SSC = 1.90 g/l). These concentration peaks suggest a combination of sediment resuspension and advection processes during and after the storm, respectively.

The suspended sediment fluxes can be expressed as the product of the velocity vector (decomposed here into across- and along-shore components) and the suspended sediment concentration. Fig. 5 shows also the sediment fluxes associated with the flow at 0.9 mab. The maximum alongshore and cross-shore transport rates are related to storm activity. If alongshore and across-shore fluxes are integrated over the survey period, they give a cumulative transport (net flux) which presents abrupt changes for both fluxes when storms events took place. During storm events the across-shore flux component comes offshore and the alongshore component is towards the south. Furthermore, the cumulative across-shore component is nearly twice than that alongshore.

Storm event	A	B	C	D	E	F	G
Date (month-day-year)	11-28-10	01-21-11	01-28-11	03-02-11	03-08-11	03-12-11	04-21-11
Duration (h)	81	46	179	166	45	79	55
Mean significant wave height (m)	1.13	1.06	1.22	1.03	1.59	1.61	1.3
Maximum significant wave height (m)	1.67	1.85	2.1	1.74	2.64	2.47	2.12
Mean wave peak period (s)	6.85	7.77	7.27	7.03	7.4	7.5	6.93
Maximum wave peak period (s)	8.8	9.96	9.34	9.91	8.86	8.82	8.36
Mean wave direction (deg.)	94	92	100	102	112	114	119
Maximum wave direction (deg.)	112	110	116	146	124	142	131
Mean bottom wave orbital velocity (m/s)	0.39	0.44	0.45	0.36	0.6	0.59	0.47
Maximum bottom wave orbital velocity (m/s)	0.63	0.78	0.82	0.73	1.05	0.99	0.82
Maximum alongshore velocity at 0.9 mab (m/s)	0.20	0.14	0.16	0.2	0.14	0.15	0.12
Maximum across-shore velocity at 0.9 mab (m/s)	0.19	0.17	0.2	0.17	0.2	0.22	0.18
Mean suspended sediment concentration (g/l)	0.12	0,14	0.35	0.28	0.65	0.64	0.89
Maximum suspended sediment concentration (g/l)	0.9	1.24	1.98	1.81	2	1.99	1.98

Table I. Characteristics of storm events at the study site.

IV. CONCLUDING REMARKS

Long-term monitoring of sediment dynamics on a highly-protected beach reveals frequent resuspension of bottom sediment caused by waves during storms and a dominant nearbottom sediment transport towards offshore. The magnitude of the across-shore sediment transport is higher than alongshore and this could be a differential behavior relative to open beaches.

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