Measurements of Cross-Shore Sand fluxes on a Macrotidal Pocket Beach (Saint-Georges Beach, Atlantic Coast, SW France)

Authors: Corbau, Corinne, Ciavola, Paolo, Gonzalez, Ramon, and Ferreira, Óscar

Source: Journal of Coastal Research, 36(sp1) : 182-189

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/1551-5036-36.sp1.182

Journal of Coastal Research	SI 36	182-189	(ICS 2002 Proceedings)	Northern Ireland	ISSN 0749-0208

Measurements of Cross-Shore Sand fluxes on a Macrotidal Pocket Beach (Saint-Georges Beach, Atlantic Coast, SW France)

Corinne Corbau†, Paolo Ciavola†, Ramon Gonzalez‡ and Óscar Ferreira‡

†Dipartimento di Scienze della Terra,
Università degli Studi di Ferrara,
C.so Ercole I d'Este 32, 44100 Ferrara, Italia
corinne.corbau@unife.it
cvp@unife.it

‡CIACOMAR - Universidade do Algarve,
Avenida das Forças Armadas s/n, 8700 - 311
Olhão, Portugal
rgonzale@mozart.si.ualg.pt
oferreir@ualg.pt

ABSTRACT

Data on cross-shore sand transport were obtained during two tidal cycles on a dissipative macrotidal pocket beach in the outer Gironde Estuary (SW France). Sediment samples were collected, using streamer traps, at different elevations above the bed across the surf zone whilst measuring nearshore waves and cross-shore currents on the beach. During the experiment the tidal range reached 3.8 m and the current speeds on the beach were up to 0.5 m s^{-1}. Wave activity was characterised by a variable significant height, ranging from 0.3 m at low to 0.94 m at high tide, due to the sheltering effect of a nearshore sand bank.

The study found that the median grain size of the transported sediment ranged from 0.207 mm to 0.333 mm, decreasing slightly away from the bed, with less than 0.056 mm variation throughout the water column. This vertical distribution was assumed to be related to a near uniform mixing by saturation of turbulence and to large scale vertical eddies under breaking and/or broken waves.

The fluxes calculated using the sediment captured in the streamer traps increased exponentially or linearly towards the bottom, whilst some curves had an S-shaped profile. These results confirm the general theory of a decrease in sediment transport rate away from the bed. However, the S-shaped profile may be due to coherent vortex structures which led to strongly irregular patterns. Finally, the sediment fluxes appeared to be higher during the ebb than during the flood tide, indicating a tidal influence on sediment transport.

ADDITIONALINDEXWORDS: *Surf zone, streamer trap, grain size distribution, plunging breakers.*

INTRODUCTION

Surf zones represent areas where the most intense sediment transport occurs, because of the magnitude of turbulence. A good knowledge of these processes of sediment transport is useful to coastal engineers when modelling coastal processes. Several workers have focused their attention on measuring sediment transport in the surf zone (e.g. KANA, 1976, 1977; KENNEDY *et al.*, 1981; LARSON and KRAUS, 1995; BEACH and STERNBERG, 1996; OSBORNE and VINCENT, 1996; WANG *et al.*, 1998; WILLIAMS *et al.*, 2000). While the bed load transport has been well studied and can be estimated from shear stress computations, the behaviour of suspended sediment in the water column appears more complicated, due to the periodic decrease and increase in turbulent activity. In order to better understand these processes, it is of crucial importance to measure correctly suspended sediment fluxes. Commonly two kinds of methods are available for measuring the suspended sediment concentration: optical and acoustic sensors (e.g. GREENWOOD *et al.*, 1990; BEACH and STERNBERG, 1996; OSBORNE and VINCENT, 1996; CIAVOLA *et al*., 1999; WILLIAMS *et al*., 2000), that measure instantaneous values of sediment concentration; time-averaged sampling methods, such as sediment traps (KANA, 1976, KRAUS, 1987) and pump sediment samplers (NIELSEN, 1984).

Different kinds of sediment traps and samplers have been used to measure short-term transport rate, KANA (1976, 1977), for instance, sampled suspended-sediment simultaneously at different elevations above the bed, using diver-operated arrays of bulk water samplers. The transport rate was determined by measuring the sediment concentration, needing extensive sample handling and time to separate and weight trapped sediment and water. In a similar manner, the "close-interval water sampler" collects suspended sediment at multiple heights, between 0.2 m and 1.8 m above the bed (ROSA *et al.,* 1991). This apparatus was specifically developed to aid in the interpretation and understanding of sediment resuspension in the Laurentian Great Lakes. A shortcoming of such study was that the transport rate was not directly measured, because the transport direction and the time of deployment were not well defined.

Portable traps provide more reliable data that may be directly related to waves and currents. As an example, ALLEN (1985) used a canister trap deployed in the trough of a wave for the duration of a wave period. The apparatus sampled at three elevations and the sediment collected in the lower trap was assumed to entrap bed load, while the other two traps corresponded to the suspended sediment transport.

KRAUS (1987) used a streamer trap to measure the longshore sand transport rate in the surf zone. The streamer trap concept was based on a Helley-Smith trap. He concluded that the streamer trap gives a nearly direct measurement of the transport rate and can be used to measure longshore and cross-shore transport in the surf zone. The streamer trap has also been modified by Katori (in KRAUS, 1987) to measure the cross-shore transport near the bed.

Multidirectional sediment traps were especially conceived for the macrotidal environment of the western coast of Cotentin, France (LEVOY *et al*., 1994). The traps sampled for different directions and at three levels: near the bed for bed load transport, at 70 and 140 cm above the bed for suspended transport.

In the present study, the streamer trap was chosen because it appeared suitable to analyse the vertical grain size distribution in the water column during transport and time variations in onshore sediment fluxes.

STUDYAREA

Morphological and Sedimentological Characteristics

The data analysed in this paper were collected on the Saint-Georges Beach in the Gironde Estuary from the 15th to the 18th of May 2000 (Figure 1a). St. Georges Beach is a dissipative sandy pocket beach, 2.5 km long and 200-600 m wide. The beach profile, with a gradient of tan β of 0.037, at the time of the experiment was slightly convex, without well-developed berms or ridges and runnels (Figure 1b). The beach was composed of moderately well-sorted fine sand with a medium grain size of 0.23 mm. A linear bank is present offshore, the Saint-George bank, nearly attached to the headland of Suzac (Figure 1a). The bank is elongated, 5 km long, 1.2 km wide, rises up to 1 m above the level of mean Low Water Springs and is delimited by two channels, with depths of 25-30 m. The sandbar is asymmetric: the southeastern part is steeper than the northeastern flank, due

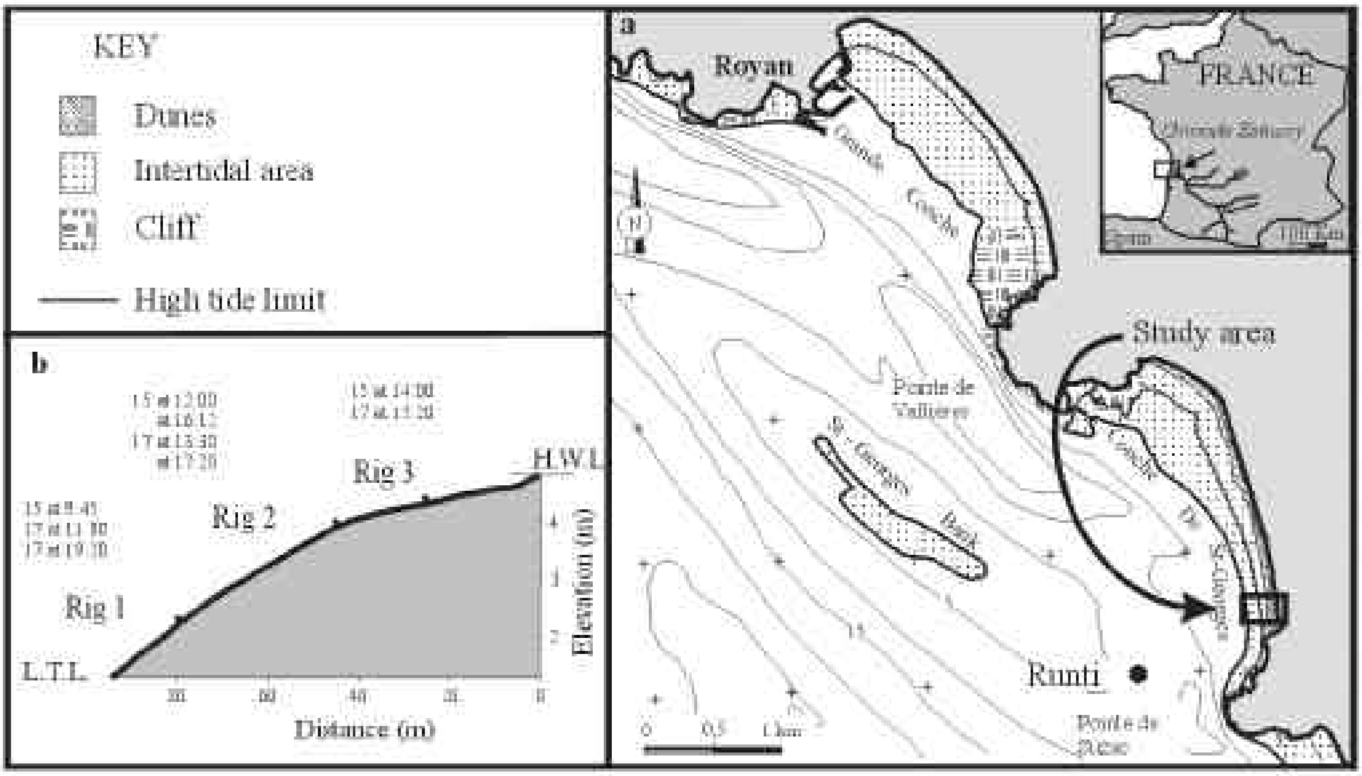

Figure 1: a)Study area after the map 1332 ETTOP25 of the French National Geographic Institute (1990), positions are referred to Lambert kilometric grid of the extended zone II; b) Beach profile, RIG positions and the relative trap deployments. The indicated water depths refer to the French Hydrographic Zero. HWL = High Water Limit, LTD = Low Tide Limit.

to its up-estuary migration during the years. The dominant process responsible for the maintenance of the sandbar seems to be the depth-averaged main tidal flow (see MALLET *et al.*, 2000a). The surficial sediments of the bank consist of fairly well-sorted medium sized sand being related to the longshore drift driven by tidal currents and waves (LEGIGAN and CASTAING, 1981).

Hydrodynamic Characteristics

The Gironde Estuary is characterised by a mean annual fresh water discharge of about 900 $m^3 s^{-1}$ and presents strong seasonal variations of the mean monthly water flow (CASTAING, 1981). Swell waves generally come inside the mouth from the west and the northwest (MALLET *et al.*, 2000a). Inside the estuary the average swell heights are less than 1 m, while the mean wave periods are of 5-6 s (HOWA, 1993). In the study area wave refraction generates a longshore up-estuary drift along the right margin.

The tidal regime in the study area is semi-diurnal, with a spring tidal range that exceeds 5 m. The main central channel is ebb-dominated, whereas the Saint-Georges Channel is flood dominated, with maximum surface currents of about 2 m s^{-1} (Figure 1a). Sediment flux vectors converge at the crest of the Saint-Georges Bank. Longshore countercurrents have been observed downstream of the Suzac and La Vallière headlands, penetrating into the pocket beaches and circulating trough the Saint-Georges Channel (PORT AUTONOME de BORDEAUX, 1980; MALLET *et al.*, 2000a). As a consequence, anticlockwise current vortices are observed during flood and clockwise current vortices occur during the ebb tide (PORT AUTONOME de BORDEAUX, 1980).

METHODS

Instrumentation

Figure 1b shows the positions of the instrumented stations deployed during the campaign. Offshore, on the eastern flank of Saint Georges Bank, the University of Ferrara's benthic lander RUNTI (Remote Unit for Nearshore Transport Investigation, see CIAVOLA *et al*., 2000) was deployed at a mean depth of 11 m, to measure a 20 min data burst at 4 Hz every hour, generating time series of current speed and direction, water level, turbidity. Processing of the time series was carried out using a suite of Matlab routines, which included the computation of the characteristics of surface waves using spectral analysis.

The breaker index was calculated using the following formula:

$$Hb = g\, s / T \tag{1}$$

where g is the acceleration due to gravity, s is the beach slope and T is the wave period (GALVIN, 1968). Caviglia's numerical model (1994) was used to obtain wave characteristics in the surf zone (width of the surf zone), transferring the measured deep water data and assuming linear-wave theory.

Along a shore-normal transect on the beach, three instrumented rigs were deployed from the 16th to the 18th of May 2000 (Figure 1b). Each instrument set consisted of a Valeport electromagnetic current meter, a pressure transducer and a flux-gate compass. All sensors continuously gathered data at 2 s intervals.

Streamer Traps

Sediment traps, similar to the ones designed by KRAUS (1987), were used on the 15th and 17th of May 2000. Four streamer bags were mounted on a rack at the following levels above the bed: 0.08, 0.19, 0.27 and 0.35 m. The mesh size of the streamer bag was 59 µm. The traps were deployed next to the rigs (Figure 1b) at a position in the surf zone where all four bags would always be completely covered by water at the beginning of each deployment, with the trap mouth (30 cm wide and 4 cm high) facing offshore. Deployments facing onshore were not possible because of the difficulties to maintain the streamer horizontal. The duration of the measurements ranged from 2 to 15 min, depending on the magnitude of the transport rate and the amount of sand retained in the traps. Grain size distributions of the sediment collected by the traps were obtained by dry-sieving at 0.5 Ø interval.

The sediment transport rates from the traps were calculated using the equation of CERC (1987). The sediment flux F(I), in g m^{-2} s^{-1}, at streamer (I) is equivalent to:

$$F(I) = \frac{S(I)}{h\,w\,t} \tag{2}$$

where S(I) is the dry weight of sediment collected in the streamer (I), h is the height of the streamer opening (0.04 m), w is the streamer width (0.30 m), and t is the sampling period.

The sediment flux between neighbouring streamers FE(I) corresponds to the linear interpolation between two adjacent traps:

$$FE(I) = 0.5\,(F(I) + F(I+1)) \tag{3}$$

The total transport rate RTRAP(g m^{-2} s^{-1}) is equivalent to:

$$RTRAP = h \sum_{I=1}^{N} F(I) + \sum_{I=1}^{N-1} a(I)\, FE(I) \tag{4}$$

where a(I) is the distance between neighbouring streamers, and N is the total number of streamers. The conversion from RTRAP expressed as kg m^{-1} s^{-1} to m^3 m^{-1} s^{-1} was done assuming that 1 kg of dry quartz sand occupies a volume of about 6.3 10^{-4} m^3 (CERC, 1987).

RESULTS AND DISCUSSION

Hydrodynamic Conditions

Table I presents a summary of the wave conditions recorded offshore and those calculated for the surf zone. The waves were observed parallel to the beach. Strong variations of the root-mean-square wave height (Hrms) were observed throughout the experiment: on the 15th of May 2000 they ranged from 0.32 to 0.61 m and on the 17th of May 2000 varied from 0.23 to 0.63 m (Figure 2). Similarly, the mean wave period ranged from 6.9 to 9.9 s on the 15th of May and from 5.8 to 8.2 s on the 17th of May. At the breaker line, Hrms ranged from 0.45 to 0.79 m on the 15th of May and from 0.33 to 0.76 m on the 17th of May. Visual observations of wave height at the breaking point show good agreement with the prediction of the model. The reduction in wave height at low tide was probably caused by wave energy dissipation on the Saint-Georges Bank. MALLET *et al*. (2000b) pointed out the influence of the bank on the wave height, with higher waves occurring at high water. In this context, the bank acts as a natural offshore breakwater that protects the beach behind. The breaker zone width varied with the tide, from 70 m during low tide to 177 m during high tide. Field observations indicate that waves were of plunging type, which is also in agreement with the calculated breaker coefficient of GALVIN (1968) presented in Table I.

The tidal range at Royan predicted by the SHOM (Service Hydrographique et Océanographique de la Marine) was 3.4 m for the 15th of May 2000 and 3.8 m for the 17th of May 2000. The data analysed from RUNTI were in good agreement with these predictions and indicated a tidal excursion of 3.3 m on the 15th of May and of 3.8 m on the 17th of May 2000. The flood tide commenced at 7:59 UTC on the 15th of May and at 9:21 UTC on the 17th of May. The average current speed measured on the beach was about 0.5 ms^{-1} on the 17th of May, ranging from 0.3 to 0.8 ms^{-1} (Table I, Figure 3). As shown in Figure 3, it appears that the strongest currents were measured at mid-tide, rather than at the beginning and at the end of each tidal cycle, indicating the importance of tide-controlled processes over wave influence. However, a greater effect of the waves may be observed on the upper part of the beach (Rig 3). It also appeared that the current speed were higher on the upper beach (0.3 to 0.8 $m.s^{-1}$) than on the lower beach (0.2 to 0.5 $m.s^{-1}$). Finally, the currents maintained an almost constant direction, 150°N to 270°N, during the whole tidal cycle.

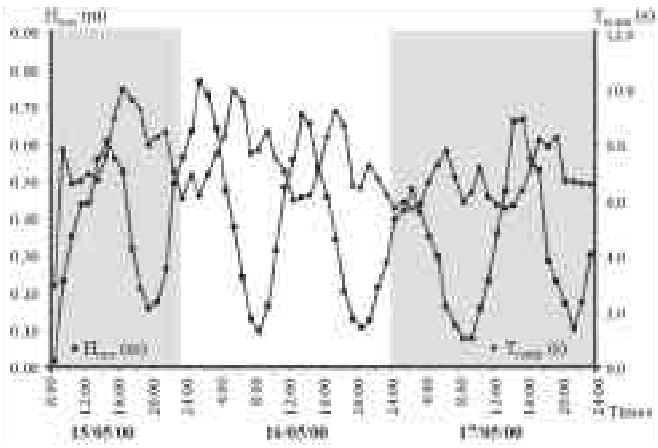

Figure 2. Offshore wave conditions during the field experiments measured at the position marked as RUNTI in Figure 1a.

Table 1. Hydrodynamic characteristics of the field experiments. The different parameters were calculated for the duration of each trap deployment. Bb = Breaker coefficient, Tmean = mean wave period (s), Hrms = root mean square wave height (m), Tmb = mean wave period at the breaker point (s), U = mean current velocity (m/s) and P= plunging waves.

Date Time	Depth (m)	H_{rms} (m)	T_m (s)	Hrms Breakers (m)	Tmb (s)	Surf zone width (m)	B_b	Breaker Type	U (m/s)	Average Direction (Degrees N)
15/05/00										
09:45	9.9	0.46	6.9	0.45	6.9	95	0.022	P		
12:00	11.6	0.63	6.9	0.59	6.9	125	0.029	P		
14:00	12.7	0.86	7.6	0.79	7.6	170	0.032	P		
16:12	12.1	0.69	9.9	0.71	9.9	126	0.017	P		
17/05/00										
11:00	9.8	0.33	6.1	0.33	6.1	69	0.020	P	0.41	107
13:30	12.0	0.80	5.8	0.65	5.6	149	0.045	P	0.60	70
15:20	12.9	0.94	6.4	0.78	6.4	177	0.044	P	0.36	90
17:20	12.6	0.75	8.2	0.72	8.2	153	0.024	P	0.51	133
19:20	10.6	0.30	7.7	0.34	7.8	69	0.013	P	0.35	130

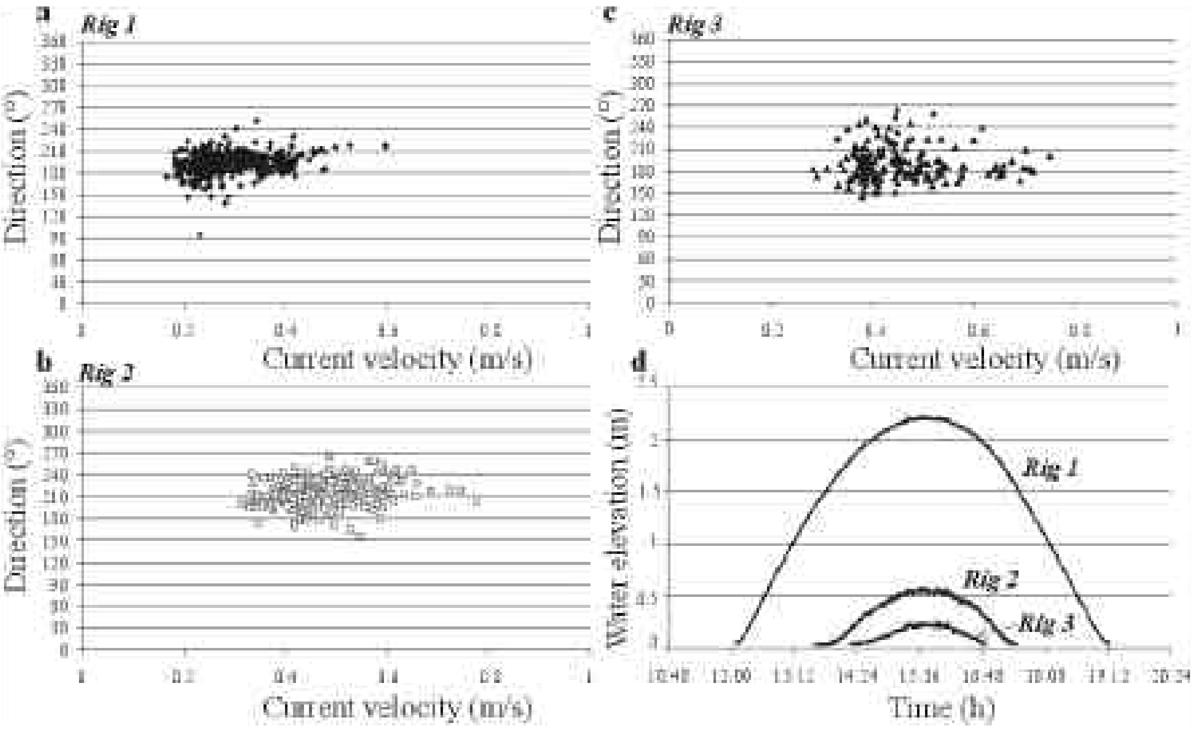

Figure 3. Hydrodynamic conditions measured by the different rigs on the beach (see Figure 1b for the position). a) Currents on the lower part of the beach, b) Currents on the middle part of the beach, c) Currents on the upper part of the beach, d) Changes in water depth at the three rigs.

Grain-Size Distribution Profile in the Water Column

In the present study the grain-size distributions of trapped sediments (Figure 4) indicate that the median size decreased slightly away from the bed, and ranges from 0.207 mm to 0.332 mm. The finest sediment was found in the highest slieve in the trap, with the exception of the samples collected on the 15th of May 2000 at 9:45. It also appears that the sediments collected on the 15th of May at 9:45 and on the 17th of May at 11:00 were finer than the others. Changes in the vertical distribution were small, with less than 0.056 mm variation throughout the water column and it must be noted that the biggest changes occurred around high tide.

Similar results were observed by KENNEDY *et al*. (1981), NIELSEN (1983), OSBORNE and GREENWOOD (1993), WANG *et al*. (1998), CIAVOLA *et al*. (1999) and WILLIAMS *et al*. (2000). KENNEDY *et al*. (1981) reported that the bottom sediment was coarser than the suspended below breaking waves at Bull Island, South Carolina. From 99 bottom and 552 suspended sediments samples, WANG *et al*. (1998) observed a vertical distribution in mean grain size characterised by less than –1Ø (0.5 mm) variation, for most of the 29 locations investigated on the southeastern coast of the United States

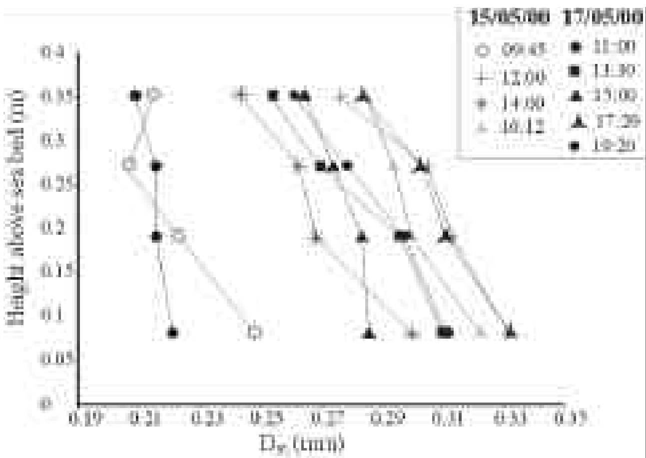

Figure 4. Median grain size distribution of the trapped sediment throughout the water column

and the Gulf coast of Florida, representing a wide range of sediment sizes and textures. This vertical grain size distribution was also observed for different morphological features: swash zone, breaker line, mid-surf zone, trough and bar. CIAVOLA *et al*. (1999) observed, on a low-energy steep beach in southern Portugal, an upward decrease of the sediment mean grain size throughout the water column of the surf zone. WILLIAMS *et al*. (2000) found a reduction of 0.07 mm in the diameter of grains in suspension over the depth range 5.3 cm to 40 cm. According to these authors and to the presented results, the vertical sediment distribution is independent from grain size. The distribution of grain size observed during the present study may be caused by the vertical mixing mechanisms in the surf zone, due to turbulence and existence of large-scale convective eddies.

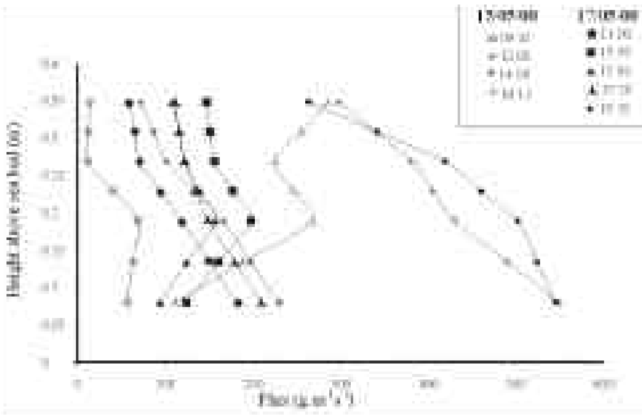

Figure 5. Sediment fluxes throughout the water column

Sediment Fluxes throughout the Water Column

Figure 5 represents fluxes calculated using sediment captured in the streamer traps at the specified mouth elevation. In many data sets the weight of the trapped sediment increases exponentially or linearly towards the bottom; however, some curves have a S-shaped profile, with the maximum quantity of trapped sediment found at 0.19 m or at 0.35 m above the bed (e.g. at 15:20 and 17:20 on the 17th of May, and at 16:12 on the 15th of May). The depth-integrated transport rates ranged from 17.3 to 191.1 g m^{-1} s^{-1}.

The general theory of a decrease in sediment transport rates away from the bed has been confirmed in other studies (e.g. KRAUS, 1987; OSBORNE and GREENWOOD, 1993; BEACH and STERNBERG, 1996; OSBORNE and VINCENT, 1996; CIAVOLA *et al*., 1999; WILLIAMS *et al*., 2000). KRAUS (1987) for instance, using sediment traps in the surf zone, observed a decreasing trend in the transport rate away from the bed. GREENWOOD *et al.* (1990) found that concentration gradients over the lowest 0.20 m of the water column varied with wave cycles. Large decay rates to near-uniformity, as well as occasionally inversions with height, were observed. GREENWOOD *et al*. (1990) related these changes with the varying intensity of turbulence from one half of the wave cycle to the next, as a wave group passes, and to the vertical propagation of separation vortices shed from rippled beds. Osborne and Greenwood (1993) related the different fluctuations in sediment concentrations at higher elevations to the importance of vertical convection and settling processes. BEACH and STERNBERG (1996) found that, under plunging waves (swell of Hs = 0.5 m and T = 10-12 s), the concentration of suspended sediment decreased linearly and exponentially away from the bed, with some curves presenting a S-shaped profile such as those of Figure 5. Their results indicate also that plunging waves were responsible for 53-60% of the suspended load and could suspend very high concentrations of sediment up to 0.54 m above the bed. Because no bedforms were observed during our experiment, the variability of transport fluxes in the water column may be attributed to differential sediment settling and to plunging wave action.

Numerical simulations of sand resuspension under plunging breakers were undertaken by PEDERSEN *et al*. (1995) pointed out that instantaneous profiles, in a region dominated by convective transport due to coherent vortex structures, show plumes of high concentration. This process led to strongly irregular patterns, where profiles with increasing concentration levels towards the surface were common. The existence of greatest transport rates 0.19 m above the seabed is most likely due to large-scale vortices induced by the breaking process.

Tidal Influence on the Transport Fluxes

Transport rates observed during the second tidal cycle on 17th of May presented a pattern similar to the recorded current variations. To notice that the deployment of the trap at the beginning and at the end of the tidal inundation occurred more or less at the same position, on the lowest part of the intertidal zone. Sediment transport rates at the end of the falling tide were about 5 times greater than those measured at the beginning of the rising tide. It was also noticed that the median grain size was in general finer at the beginning of each tidal cycle, probably associated to lower energy levels.

DAVIDSON *et al.* (1993) observed a similar marked tidal asymmetry in sediment resuspension; suspension values were up to one order of magnitude higher on the ebb than on the flood. They attributed this asymmetry to the destruction of a ripple field located outside the surf zone. MASSELINK and PATTIARATCHI (2000) found a similar result, attributing the asymmetry to the combined effects of larger bed roughness and stronger mean nearshore flows during the ebbing tide. In the present study, changes in sea bed morphology are probably not responsible for the differences observed as no bedforms were seen in the field. The increase in sediment resuspension during the ebb tide might be related to beach dewatering, as initially suggested by GRANT (1948). TURNER (1990, 1993) explained further the effects of the water table, differentiating an upper unsaturated zone, that promotes upslope sediment accretion on the rising tide, and a lower saturated zone that promotes down slope sediment transport during the ebbing tide. When the beach is saturated during the ebb tide, erosion of the upper beach is enhanced and sediments are transported offshore as bedload. These sediments may be resuspended by wave action in the surf zone, thus generating greater sediment fluxes.

CONCLUSIONS

Tidal action was predominant in generating currents on the studied beach, but a weak increase of the wave influence was noted on the upper part of the beach.

Sediment sampling with streamer traps pointed out that the median grain size of the transported sediment ranged from 0.207 mm to 0.332 mm, decreasing slightly with distance above the bed. The vertical mixing mechanisms in the surf zone is most probably responsible for this vertical grain size distribution, suggesting the role of turbulence and the existence of convective eddies.

Finally, a possible role of the beach groundwater may explain the tidal asymmetry in sediment suspension, characterised by a sediment flux weaker at the beginning of the tide than at the end. However this aspect needs further investigation by field measurements of water table fluctuations.

ACKNOWLEDGMENTS

The field experiments in the Gironde were part of the TMR Project SWAMIEE (contract ERBFMRX-CT97-0111), partially financed by the European Union. Ó. Ferreira was also partially supported by the project CROP (contract PDCTM/P/MAR/15265/1999). Many thanks to M. Castro, S. Falati, U. Neumeier for helping in the field. The sensors used on the beach were on loan from the Southampton Oceanography Centre. We also acknowledge the City Council of Royan for authorising the field work.

LITERATURE CITED

ALLEN, J.R., 1985. Field measurement of longshore transport: Sandy Hook, New Jersey, USA. *Journal of Coastal Research*, 1(3), 231-240.

BEACH, R.A. and STERNBERG, R.W., 1996. Suspended-sediment transport in the surf zone: response to breaking waves. *Continental Shelf Research* 16(15), 1989-2003.

CASTAING, P., 1981. Le transfert à l'océan des particules estuariennes, cas de la Gironde. Thèse d'Etat, n° 701, Université de Bordeaux I, 530 pp.

CAVIGLIA, F.J., 1994. Computation of longshore currents and sediment transport. *Computers and Geosciences* 20(6), 905-917.

C.E.R.C. 1987. "The streamer sediment trap." *Report CETN-II-1*, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Mississippi, 6 p.

CIAVOLA, P., TABORDA, R., FERREIRA, Ó. and DIAS, J.M.A., 1999. Sand transport measurements on beaches: an intercomparison between fast response sensors (OBS) and fluorescent tracer dispersal, *Proceedings of Coastal Sediments'99*, New York, American Society of Civil Engineers, pp. 955-969.

CIAVOLA, P., FALATI, S., CALDERONI, G. and TESSARI, U., 2000. RUNTI: a lightweight benthic lander for the assessment of sediment transport in lagoon environments. Proceedings of *Oceanology* International 2000, 1-7 March 2000, Brighton, UK, pp. 451-460 (CD-Rom).

DAVIDSON, M.A., RUSSEL, P.E., HUNTLEY, D.A. and HARDISTY, J., 1993. Tidal asymmetry in suspended sand transport on a macrotidal intermediate beach. *Marine Geology*, 110, 333-353.

GALVIN, C.J., 1968. Breaker type classification on three laboratory beaches. *Journal of Geophysical Research*, 73(12), 3651-3659.

GRANT, U.S., 1948. Influence of watertable on beach aggradation and degradation. *Journal of Marine Research*, 7, 655-660.

GREENWOOD, B., OSBORNE, P.D. BOWEN, A.J., HAZEN, D.G. and HAY, A.E., 1990. Nearshore sediment flux and bottom boundary dynamics the Canadian coastal sediment transport programme (C-COAST). *Proceedings of 22nd Coastal Engineering Conference*, New York, American Society of Civil Engineers, pp. 2227-2240.

HOWA, H., 1993. Hydrodynamique et flux sédimentaires dans un domaine d'embouchure. Proceedings of 4ème *Congrés Français de Sédimentologie*, Paris, Publication ASF, pp. 181-182.

KANA, T.W., 1976. A new apparatus for collecting simultaneous water samples in the surf zone. *Journal of Sedimentary Petrology*, 46(4), 1031-1034.

KANA, T.W., 1977. Suspended sediment transport at Price Inlet, S.C.. *Proceedings of Coastal Sediments'77*, New York, American Society of Civil Engineers, pp. 366-382.

KENNEDY, S.K., EHRLICH, R. and KANA, T.W., 1981. The non-normal distribution of intermittent suspension sediments below breaking waves. *Journal of Sedimentary Petrology*, 51(4), 1103-1108.

KRAUS, N.C., 1987. Application of portable traps for obtaining point measurements of sediment transport rates in the surf zone. *Journal of Coastal Research*, 3(2), 139-152.

LARSON, M. and KRAUS, N.C., 1995. Prediction of cross-shore transport at different spatial and temporal scales. *Marine Geology*, 126, 111-127.

LEGIGAN, P. and CASTAING, P., 1981. La pénétration des sables marins dans les estuaires, cas de la Gironde. *Comptes Rendus de l'Académie des Sciences*, 292, 207-212.

LEVOY, F., MONFORT, O., ROUSSET, O. and LARSONNEUR, C., 1994. Quantification of longshore transport in the surf zone on macrotidal beaches. *Proceedings of 24th International Conference of Coastal Engineering*, New York, American Society of Civil Engineers, 2282-2296.

MALLET, C., HOWA, H.L., GARLAN, T., SOTTOLICHIO, A. and LE HIR, P., 2000a. Residual transport model in correlation with sedimentary dynamics over an elongate tidal sandbar in the Gironde Estuary (Southwestern France). *Journal of Sedimentary Research*, 70(5), 1005-1016.

MALLET, C., PAIREAU, O., HUNTLEY, D and COLLINS, M. 2000b.In situ measurements of Saint-Georges Bank sedimentary dynamics (Gironde Estuary). *Proceedings of the VIIe Colloque international d'Océanographie du Golfe de Gascogne*, 4-6 Avril 2000, Biarritz, pp. 223-229.

MASSELINK, G. and PATTIARATCHI, C., 2000. Tidal asymmetry in sediment resuspension on a macrotidal beach in northwestern Australia. *Marine Geology*, 163, 257-274.

NIELSEN, P., 1983. Entrainment and distribution of different sand sizes under water waves. *Journal of Sedimentary Petrology*, 53(2), 423-428.

NIELSEN, P., 1984. Field measurements of time-averaged suspended sediment concentration under waves. *Proceedings of 19th International Conference of Coastal Engineering*, New York, American Society of Civil Engineers, 51-72.

OSBORNE, P.D. and GREENWOOD, B., 1993. Sediment suspension under waves and currents, time scales and vertical structures. *Sedimentology*, 40, 599-622.

OSBORNE, P.D. and VINCENT, C.E., 1996. Vertical and horizontal structure in suspended sand concentrations and wave-induced fluxes over bedforms. *Marine Geology*, 131, 195-208.

PEDERSEN, C., DEIGAARD, R., FREDSØE, J. and HANSEN A., 1995. Simulations of sand in plunging breakers. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 121(2), 77-87.

PORT AUTONOME DE BORDEAUX, 1980. Etude sédimentologique des plages de Saintonge et du banc Saint-Georges. *Internal Report*, 30p.

ROSA, F., BLOESCH, J. and RATHKE, D.E., 1991. Sampling the settling and suspended particulate matter. *In*: MUDROCH, A. and MACKNIGHT, S.D. (ed.), *Handbook of techniques for aquatic sediments sampling*, CRC Press, Boca Raton (USA), 97-130.

TURNER, R.J., 1990. The effects of a mid-foreshore groundwater effluent zone on tidal-cycle sediment distribution in Puget Sound. *Journal of Coastal Research*, 6(3), 597-610.

TURNER, R.J., 1993. Water table outcropping on macrotidal beaches: a simulation model. *Marine Geology*, 115, 227-238.

WANG, P., DAVIS JR., R.A. and KRAUS, N.C., 1998. Cross-shore transport of sediment texture under breaking waves along low-wave-energy coasts. *Journal of Sedimentary Research* 6(3), 497-506.

WILLIAMS, J.J., BELL, P.S. THORNE, P.D., TROUW, K., HARDCASTLE, P.J. and HUMPHERY, J.D., 2000. Observed and predicted vertical suspended sediment concentration profiles and bedforms in oscillatory-only flow. *Journal of Coastal Research* 16(3), 698-708.