Modulation of Wave Energy by a Linear Sand Bank in the Gironde Estuary (France): Implications for Coastal Zone Management

CONFERENCE PAPER · SEPTEMBER 2002

5 AUTHORS, INCLUDING:

Paolo Ciavola
University of Ferrara
116 PUBLICATIONS **742** CITATIONS

Corinne Corbau
University of Ferrara
3 PUBLICATIONS **3** CITATIONS

Littoral 2002, The Changing Coast. EUROCOAST / EUCC, Porto – Portugal
Ed. EUROCOAST – Portugal, ISBN 972-8558-09-0

Modulation of Wave Energy by a Linear Sand Bank in the Gironde Estuary (France): Implications for Coastal Zone Management

P. Ciavola[1], S. Falati[1], C. Corbau[1], O. Paireau[2] & M. Collins[2]

[1]*Dipartimento di Scienze della Terra, Università di Ferrara, C. so Ercole I d'Este, 32, 44100 Ferrara, Italy, cvp@unife.it*

[2]*SOC, University of Southampton, European Way, Southampton SO14 3ZH, Hampshire, United Kingdom*

Abstract

Two benthic landers were deployed behind the St. Georges Bank, a linear sand bank located in proximity of the northern bank of the mouth of the Gironde Estuary, for several tidal cycles, to measure near bed processes. One of the main outcomes of the deployments is the role of the bank in modulating wave energy. The wave height measured behind the bank oscillates in response of the tidal variations (i.e. higher waves coincide with high water). Therefore, the bank acts as a natural offshore breakwater, protecting the beaches behind it. Man-made activities such as dredging could have an impact on the shoreline, therefore should be avoided unless a proper impact assessment is undertaken.

1. INTRODUCTION

Linear sand banks can be found at many locations which experience meso and macro-tidal ranges in different environmental contests, from open-shelf banks like in the North Sea (Davis & Balson, 1992) to gravel and sand banks within estuaries, often associated to complex bedforms patterns (Mallet *et al.* 2000a; 2000b; Tresensaux *et al.* 1994).

Dyer & Huntley (1999) recently provided an exhaustive review of forms and processes associated to these features, describing six broad categories of morphologies. The same authors have highlighted than sand on these features can be transported both as bedload and in suspension, with sedimentary inputs generated by coastal erosion and/or sediment transport gradients. The interplay between variability in sand supply, waves and tidal currents makes difficult to define equilibrium conditions for these banks.

The same authors cited above state the economic importance of sand banks. In countries where aggregate extraction from the sea bed is common practice, e.g. the UK, they represent potential reservoirs. However, wave transformation around and across the banks often allows the existence of beaches along the coast protected by the banks. Therefore, the sustainability of dredging activities must be carefully considered before issuing production licenses.

This paper presents and experimental investigation of wave dissipation across a linear sand bank in the Gironde Estuary in France. The investigation is of relevance to coastal management in the area, as some of the beaches behind the bank are being artificially replenished. The key issue was to analyse the role of this bank in reducing wave energy.

2. SITE DESCRIPTION

The field experiments were conducted on the Saint-Georges Bank in the Gironde Estuary (Figure 1) on two separate occasions, from the 25 to the 26 of September 1999 and from the 15 to the 18 of May 2000. The Gironde is a macrotidal estuary, with a spring tidal range exceeding 5 m. The tide is semi-diurnal and almost symmetric at the estuary mouth, in the area of the Saint-Georges Bank. The main central channel is ebb-dominated, whereas the Saint-Georges Channel is flood dominated, with maximum surface currents of about 2 ms^{-1}.

The mean annual fresh water discharge into the estuary is around 900 m^3s^{-1}, but the mean monthly discharge varies strongly from winter (4500 m^3s^{-1} in January) to summer (235 m^3s^{-1} in August), with exceptional floods reaching 7500 m^3s^{-1} (Castaing 1981).

Swell waves mainly originate from the West and the Northwest (Castaing 1981; Mallet *et al.* 2000a). The average swell within the estuary is characterised by amplitudes of less than 1 m, with mean wave period of 5 - 6 s (Howa 1993). Wave refraction generates a longshore up-estuary drift along the right margin, where the study area is located.

The line of sediment flux convergence corresponds to the crest of the Saint-Georges Bank. Downstream of the Suzac and La Vallière headlands, longshore countercurrents have been observed, penetrating into the pocket beaches and circulating trough the Saint-Georges Channel (Port Autonome de Bordeaux 1980; Mallet *et al.* 2000). Consequently, anticlockwise current gyres are observed during flood and clockwise current gyres occur during the ebb tide (Port Autonome de Bordeaux 1980).

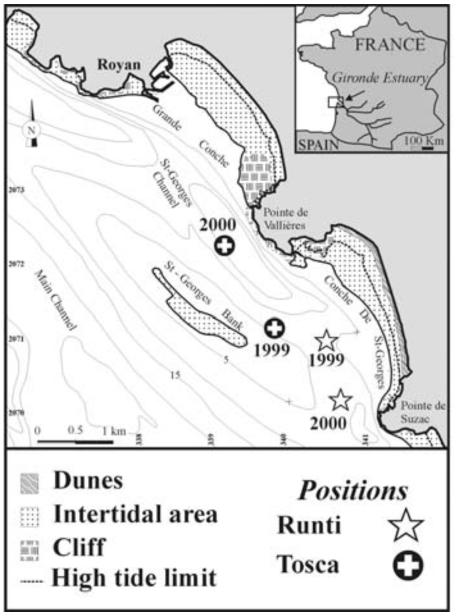

Figure 1: Bathymetry of the Bank of St. George and position of instrument deployments. Each position is identified by a different symbol and the year of deployment. The kilometric grid uses the Lambert II Projection, while water depths are expressed in meters below Mean Low Water Springs.

The bank, located between Saint Georges Beach and the main estuarine channel, is a linear sand bank nearly attached to the Suzac Headland (Figure 1) and was previously classified as a down-estuary feature by Mallet *et al.* 2000a.

Historical records show that the bank appeared in 1824, growing steadily over the last century with a total volume of 26 10^6 m^3.

At present it is an elongated feature, 5 km long, 1.2 km wide and rises up to 1 m above the level of mean low water springs. The sandbar is asymmetric in its cross-section, with a gentle slope facing Northeast and a steep slope facing Southeast. The asymmetry is the result of the up-estuary migration of the sand bar during the last 14 years (Mallet *et al*. 2000a).

The dominant process responsible for the maintenance of the sandbar seems to be the depth-averaged main tidal flow, rather than the secondary circulation due to the headlands, or the interaction between the tidal flow and the seabed (Mallet *et al*. 2000a).

The bar consists of fairly well sorted medium sized sand being related to the longshore drift along the right margin of the outlet, driven by tidal currents and wave processes (Legigan & Castaing 1981).

3. EXPERIMENTAL SET-UP

It was decided to arrange a set of current meters, pressure transducers and Optical Back-Scatter sensors around two benthic platforms. These were deployed by a research vessel (Cote d'Aquitaine) using an H-Frame and data was recorded on-board of the landers by internal micro-processors sampling at 4 Hz. In this paper only wave data are discussed. During the 1999 cruise the University of Ferrara's benthic lander RUNTI (Ciavola et al. 2000) and the SOC's TOSCA (Voulgaris et al. 1995) were both deployed in the inner swale of the bank, in front of St. George's Beach (Figure 1). During the 2000 cruise the TOSCA lander was deployed at the north-eastern edge of the bank, while RUNTI was at the southern boundary.

TOSCA (Figure 2) is a large tripod (2.8 m high) which on this occasion was measuring salinity, temperature, current velocity, waves and turbidity at three elevations. RUNTI (Figure 3) is rather smaller (1.2 high) and was measuring currents, waves and turbidity at one level.

Figure 2. The Tosca Lander of the Southampton Oceanography Centre being lifted ready for deployment. Notice the scale compared to the crew members.

Processing of the time series was carried out using a suite of Matlab routines to calculate the characteristics of surface waves using standard spectral analysis techniques. Pressure readings were converted into water depths correcting for the air pressure measured simultaneously by the *Observatoire du Littoral* (F. Pinet *pers. comm.*).

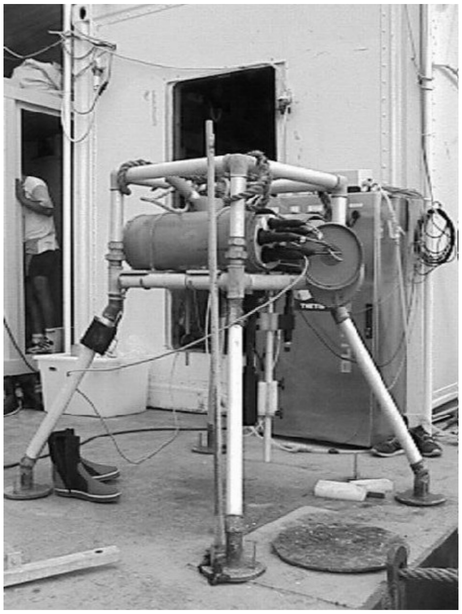

Figure 3: The Runti Lander of the University of Ferrara. Notice the scale compared to the pair of boots.

4. RESULTS AND DISCUSSION

During the first deployment both landers were at the same mean water depth (9.2 m) during the experiment, despite being at different locations. That is because behind the bank there is a platform that is on average 10 m deep, as it is evident even in the coarse map of Figure 1.

During the first deployment a total of 22 hours of wave data were collected simultaneously by both platforms. Halfway throughout the experiment the RUNTI lander became partially buried by a migrating bedform, so that the current meter stopped acquisition. Therefore the wave directions are referred to the TOSCA lander. The dominant wave direction during the experiment was 335°N, corresponding to N-NW.

The wave climate is summarised in Table 1 as the main measured parameters. It is evident that there is a good agreement between the periods, but at the TOSCA site waves were over 60% higher than at the RUNTI site. To notice that waves were locally generated, but at the TOSCA site they experienced a longer fetch, while where RUNTI was located, the site was partially sheltered by the Point de Vallèries (Figure 1).

If the time series of wave height are plotted together with the tidal curve (Figure 4), their distribution clearly mimics the tidal curve, suggesting a possible influence of water depth changes on wave energy dissipation.

Table 1: Wave characteristics measured during the 1999 experiments. Values are the average of all hourly measurements.

PARAMETER	RUNTI	TOSCA
Mean Period (s)	7.2	6.8
Mean Zero-up Crossing Period (s)	6.6	6.4
Mean Significant Wave Height (m)	0.64	0.95

To notice also that this difference starts to become increasingly evident from 2 hours before High Tide, reaching the maximum magnitude at around high tide. Thereafter, as the tide starts to ebb, the difference becomes smaller, becoming virtually null towards low tide. If the ratio between wave heights at the TOSCA site and that at the RUNTI one is considered (Figure 6), this tidal influence on local wave height becomes even clearer.

The second deployment lasted for a longer time interval, with 91 hours of wave activity being monitored at the same time by both landers. The wave climate presented in Table 2 indicates again a considerable difference in wave exposure of the two sites. TOSCA measured waves 55% higher than RUNTI. To notice that on this occasion the wave climate was much more energetic, with the wave height at TOSCA reaching a significative value of over 3 metres (Figure 5). Wave direction was comparable with that of 1999, with an average of 351°N. To notice that on this occasion TOSCA was at the northern end of the bank, located in the proximity of the St. George Channel, thus more exposed to open sea-swell, which was probably undergoing considerable refraction in this area, as suggested by Mallet *et al.* (2000b).

Table 2: Wave characteristics measured during the 2000 experiments. Values are the average of all hourly measurements.

PARAMETER	RUNTI	TOSCA
Mean Period (s)	6.9	5.4
Mean Zero-up Crossing Period (s)	6.5	5.1
Mean Significant Wave Height (m)	0.56	1.09

In any case, the picture of changes in wave height related to the tidal signal remains consistent across the 7 ½ tidal cycles monitored here. One thing that remains to be assessed is the presence of wave refraction due to countercurrents.

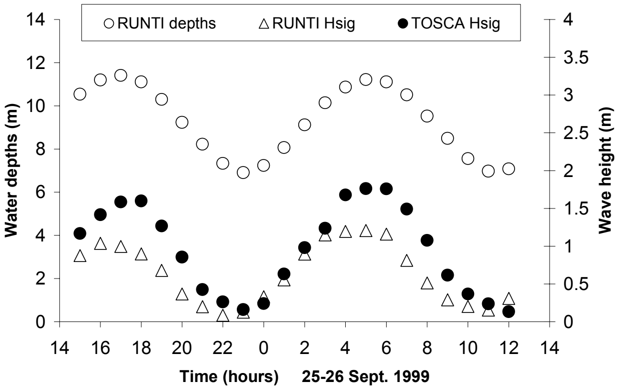

Figure 4: 1999 wave data

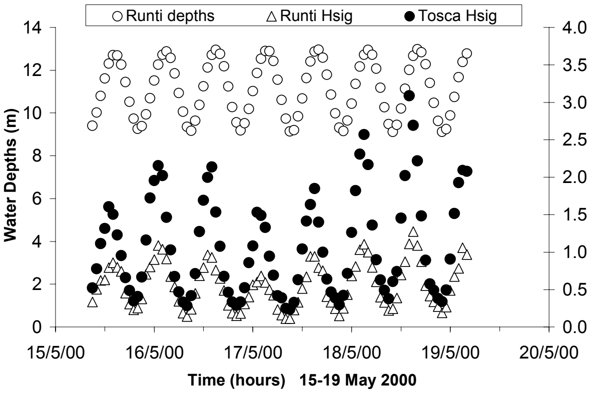

Figure 5: 2000 wave data

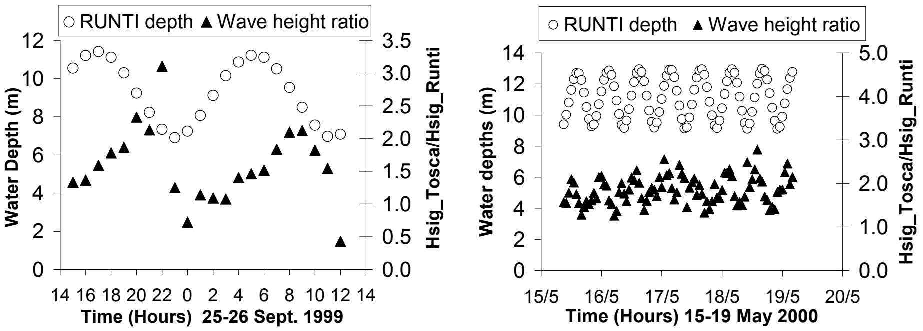

Figure 6: Wave energy setting behind the bank

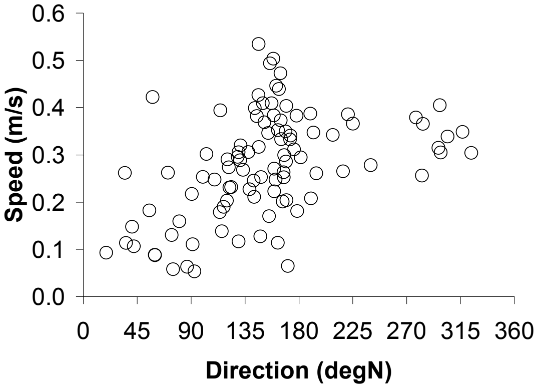

Figure 7: Measured tidal currents at RUNTI, 50 cm above the bed during the 2000 campaign.

A plot of the tidal current dispersion shows how this side of the bank is clearly dominated by flows aligned with the main axis of the bank. To notice that numerical modelling indicated that this part of the bank is flood dominated (Mallet *et al.* 2000a). However, the diagram of Figure 7 seems to indicate a concentration of flow incoming directions along the SSE-NNW, especially for what concerns the maximum currents observed. Under these conditions, the current during the flood was running almost in the same direction as the waves. On the other hand, during the ebb it was running against them, therefore it may in part responsible for the lowering of the wave heights observed during both campaigns.

5. CONCLUSIONS

The field observation which were carried out outlined the role of the Bank of St. George in controlling tidal circulation and wave energy on the nearshore area behind it. If in the future dredging of the bank is going to take place, coastal managers must assess the effect of changes in bank shape and asymmetry. If no proper evaluation will be undertaken, cascade effects leading to coastal erosion may take place.

ACKNOWLEDGEMENTS

The field experiments in the Gironde were part of the TMR Project SWAMIEE (contract ERBFMRX-CT97-0111), partially financed by the European Union. The survey vessel (the Cote d'Aquitaine) was kindly provided by the French CNRS through the University of Bordeaux. We are grateful to R. Gonzales for assistance in the field and for providing the index map. This paper is dedicated to the crew of the *Simba* fishing vessel that sunk during the storm of the night of 28/09/1999.

REFERENCES

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.

Davis Jr, R.A., Balson, P.A. 1992. Stratigraphy of a North Sea tidal sand ridge. *Journal of Sedimentary Petrology*, 62, 116-121.

Dyer, K.R., Huntley, D.A. 1999. The origin, classification and modelling of sand banks and ridges. *Continental Shelf Research*, 19, 1285-1330.

Evans, C.D.R., Ciavola, P. 1995. *Sediment Transport Paths around Nash Bank and Its Surrounds: an Interpretation from Bedform Evidence*. BGS Technical Report WB/95/19C, British Geological Survey, Keyworth, Nottingham, United Kingdom.

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

Legigan, P., 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.

Mallet, C., Howa, H.L., Garlan, T., Sottolichio, A., 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., Collins, M. 2000b. *In situ* measurements of the Saint-Georges Bank sedimentary dynamics (Gironde Estuary. *Oceanographie du golfe de Gascogne*, Acte de Colloquie, 31, Ifremer

Port Autonome de Bordeaux 1980. Etude sédimentologique des plages de Saintonge et du banc Saint-Georges. *Port Autonome de Bordeaux Internal Report*, p 30.

Tresensaux, A., Stolk, A., Tessier, B., Chamley, H. 1994. Surficial sedimentology of the Middelkerke Bank (southern North Sea). *Marine Geology*, 121, 43-55.

Voulgaris, G., Wilkin, M.P., Collins, M.B., 1995. The *in situ* passive acoustic measurement of shingle movement under waves and currents: instrument (TOSCA) development and preliminary results. *Continental Shelf Research*, 15, 1195-1211.