Morphodynamics of intertidal bars on wave-tide-dominated beaches: the role of longshore currents

Université du Littoral Côte d'Opale

Coastal Geomorphology and Shoreline Management Unit - EA 3599
189 A, Avenue Maurice Schumann
59140 Dunkerque
Tél.: 03-28-23-76-21 Fax: 03-28-23-76-23

Géo-Dal, Equipe d'Accueil 3599

Edward J. ANTHONY and Mouncef SEDRATI
anthony@univ-littoral.fr ; sedrati@univ-littoral.fr

Beaches with multiple intertidal bar-trough systems have received increasing attention since the 1950s when the term "ridge and runnel" was first applied by King and Williams (1949) to describe their particular morphology. A number of recent studies have explored the roles of wave shoaling, surf and swash, and of vertical and horizontal tidal excursion rates on the mobility of intertidal bars (Masselink and Anthony 2001 ; Kroon and Masselink 2002 ; Anthony *et al.* 2004, 2005 ; Masselink 2004 ; Masselink *et al.*, 2006). It may be suspected, however, from the spatial variability of the intertidal morphology of these beaches, that some of the temporal cross-shore profile variability is induced by important longshore processes (Anthony *et al.* 2004, 2005 ; Sedrati and Anthony 2005) that have recieved little attention in the morphodynamic studies devoted to these beaches. The present study contributes to a better understanding of the interactivity between these processes by comparing the morphology and hydrodynamics of two macrotidal beaches in northern France characterised by spring tidal ranges exceeding 7 m and by equilibrium sediment budgets.

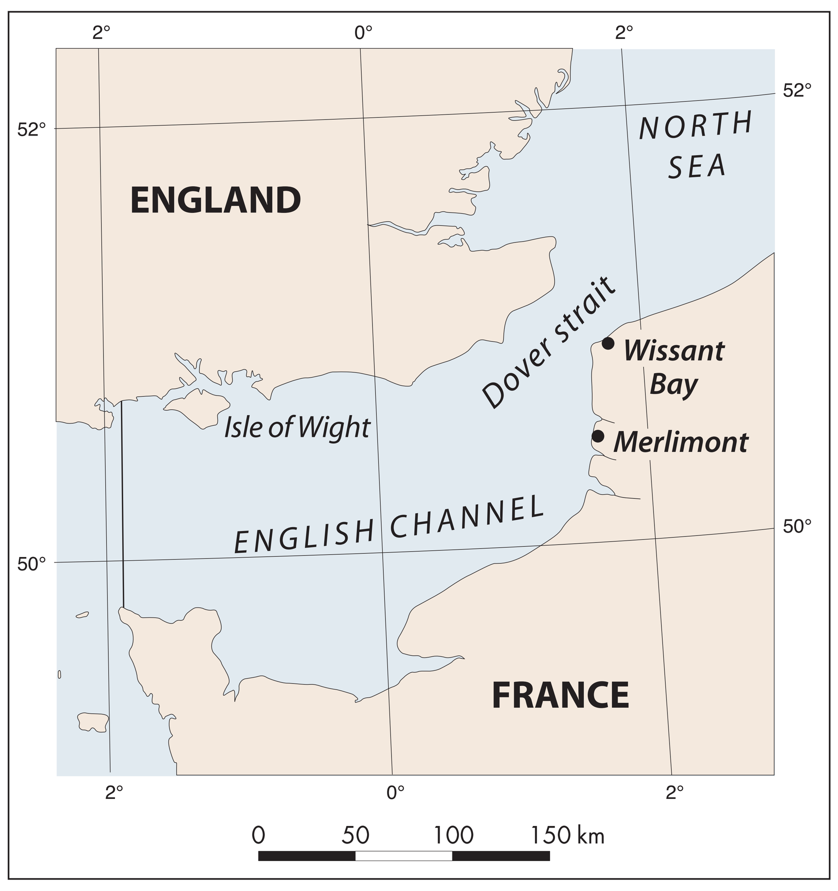

Fig.1: Location map of Merlimont and Dune d'Amont (Wissant Bay).

The results discussed in this paper concern two beaches, respectively the Dune d'Amont (Wissany Bay) facing the Dover Strait, and Merlimont facing the eastern English Channel (Fig. 1). These sites are typical of mixed wave-tide dominated environments (Anthony and Orford, 2002; Anthony *et al.* 2004). They are affected by semi-diurnal tides with spring tide ranges that decrease northwards from 8.2 m in Merlimont to 7.2 m in Wissant Bay. Both sites are subject to strong offshore tidal currents with mean velocities ranging from 0.5 to 2 m. During conditions of significant wind stress (sustained wind speeds > 8 m.s^{-1}), the peak spring tide velocities are two to five times larger than 'normal' spring tide current velocities. The waves in Merlimont are essentially from west to southwest, in response to the synoptic winds. In Wissant Bay they are from west to west-southwest, with fetch and coastal orientation conditions restricting the incidence of southwesterly waves. Recorded offshore waves heights for both sites range from 0.25 to 1.5 m during modal conditions, and may attain up to 3 m during storms. South to southwesterly winds are largely dominant on these beaches. Wind forcing significantly enhances the mean current velocities recorded on these beaches (Anthony *et al.* 2004, 2005 ; Sedrati and Anthony 2005). These sites thus display a relatively more energetic wave and tidal current regime than most other intertidal barred beaches described in the literature.

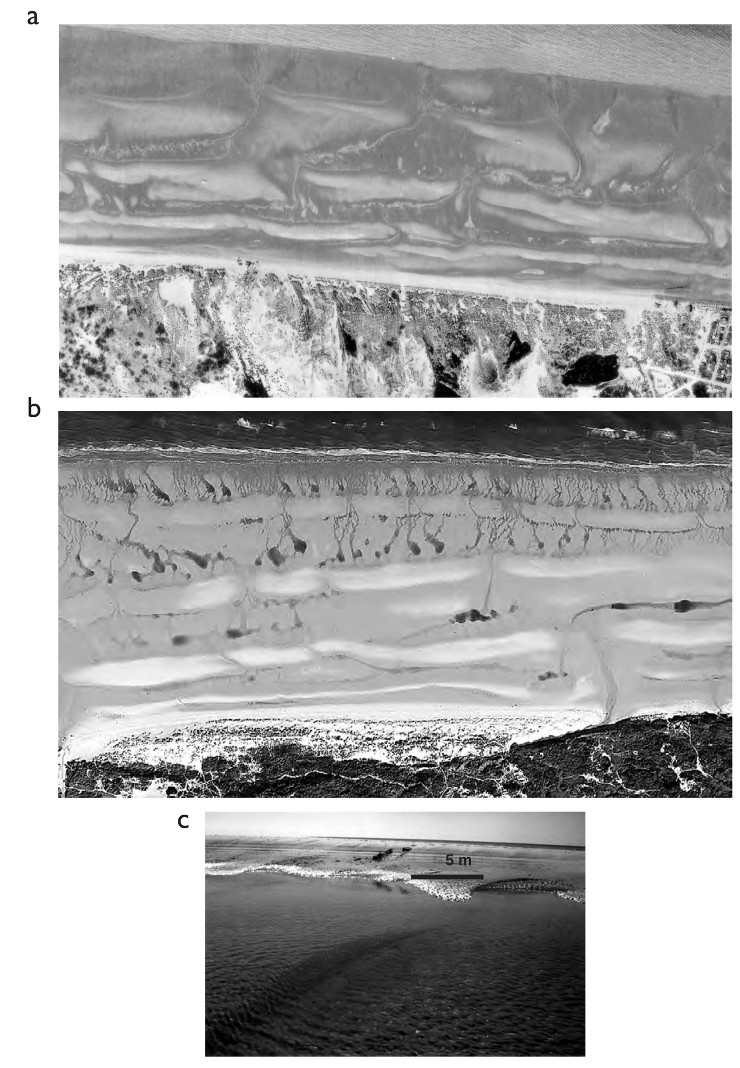

Fig. 2: Aerial photographs (a, b) showing respectively Merlimont and Dune d'Amont beaches, and ground photograph (c) depicting longshore migrating crescentic dunes attached to bar faces.

The present study contributes to a beter understanding of the interactivity between tide and wave processes by comparing the morphology and hydrodynamics of these two macrotidal beaches (Fig. 2). The data from on which this study is based comprise hydrodynamic and topographic measurements carried out during two field experiments conducted respectively from April 24 to May 2, 1997 (Merlimont) and from January 16 to 28, 2004 (Dune d'Amont). The full results are reported in Anthony *et al.* (2004, 2005) and Sedrati and Anthony 2005.

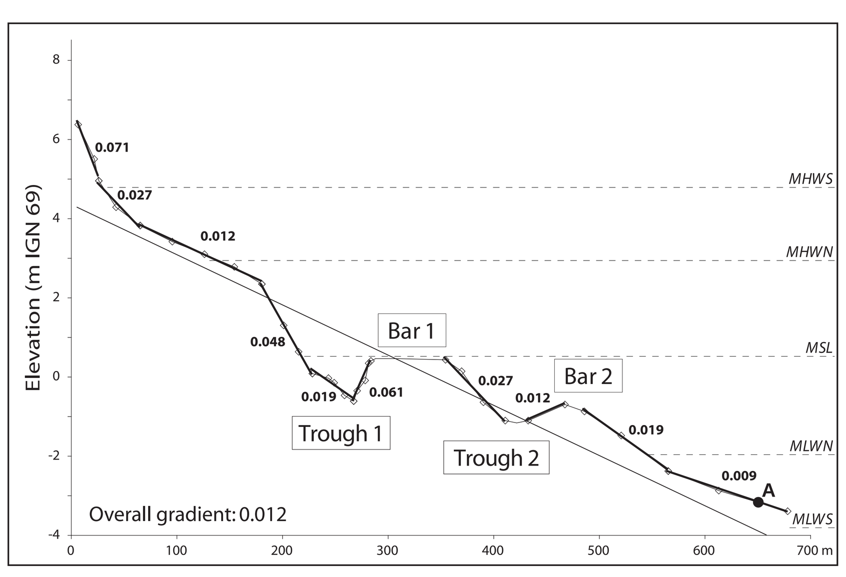

Fig. 3: The central beach profile on Merlimont beach, showing slope segments and loction of currentemeter (A).

The morphology of Merlimont beach during the experiment was characterised by an overall gradient of 0.012 but by marked variations associeted with two pronounced intertidal bar-trough systems around the mid-tide zone (Fig. 3). Dune d'Amont beach exhibited three pronounced bar-trough systems situted in the mid-tide zone too with an overall gradient of 0.024 (Fig. 4). Both beaches showed significant meso-scale topographic variations caused by channel systems entrenched in the troughs, and by pronounced meso-scale bedforms (Fig. 2, c) in these troughs. Northeastward (Dune d'Amont beach) and northward (Merlimont) longshore migrating 3D crescentic dunes having wavelengths of several metres were observed flanking or becoming attached to the landward and the seaward bar faces (Fig. 2, c)

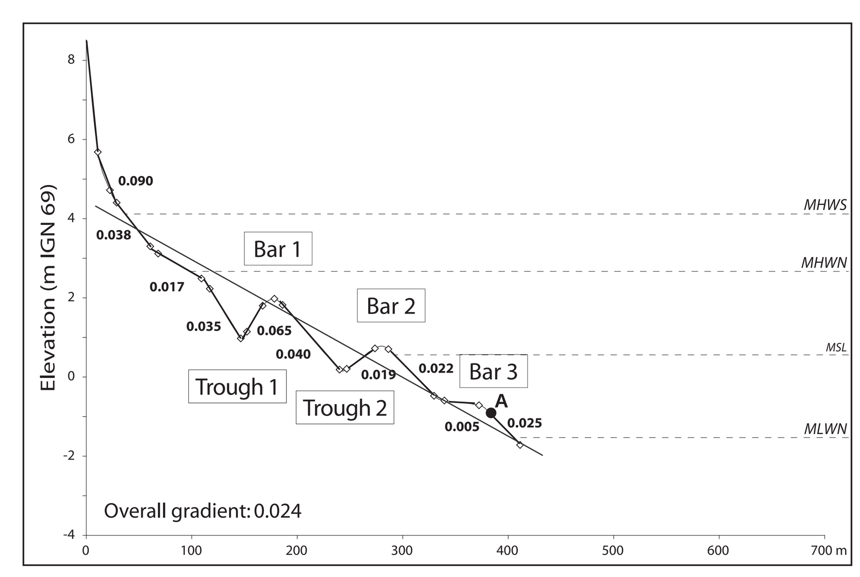

Fig. 4: The central profile on Dune d'Amont beach, showing slope segments and loction of currentemeter (A).

Figure 5 shows typical hydrodynamic records during calm and high wave energy conditions. During calm conditions, the peak cross-shore currents, which show strong coherence with wave signatures and are thus wave-generated, were two to five times weaker than the longshore current velocity peaks (see tides 1, 2 and 3 in Fig. 5, A and tide 8 in Fig. 5, B). However, throughout high wave energy conditions, which correspond with significant wind stress (sustained wind speeds > 8 m.s^{-1}), the peak longshore current velocities attained up to 1.5 m.s^{-1} on Dune d'Amont beach and 0.8 m.s^{-1} in Merlimont.

The wave-generated cross-shore currents measured on the two beaches during calm and high wave-energy conditions were thus rather weak, and were subordinate to strong longshore currents generated by tides and by wind forcing. These strong longshore flows mitigated the intensity of the cross-shore flows and induced the longshore migration of medium-sized bedforms that largely explained short-term profile change (Fig. 6). The prominent bar-trough systems in the mid-tide zone of both beaches remained stable in position although they underwent significant morphological change (Fig. 6).

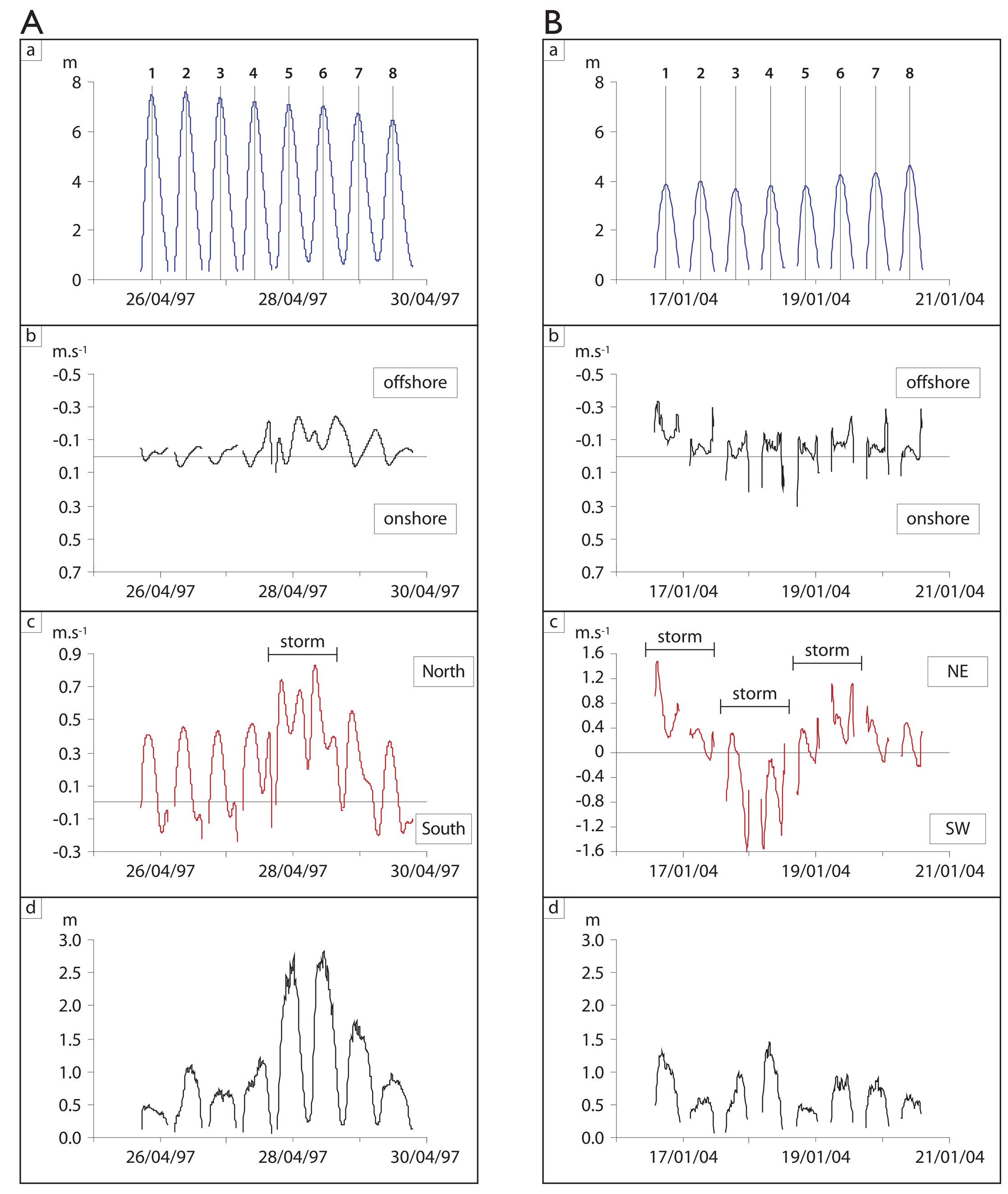

Fig. 5: Typical records of water levels, mean currents and significant wave heights measured on Merlimont (A) and Dune d'Amont beaches (B); (a) water levels, (b) long-shore currents, (c) cross-shore currents, and (d) the significant wave heights.

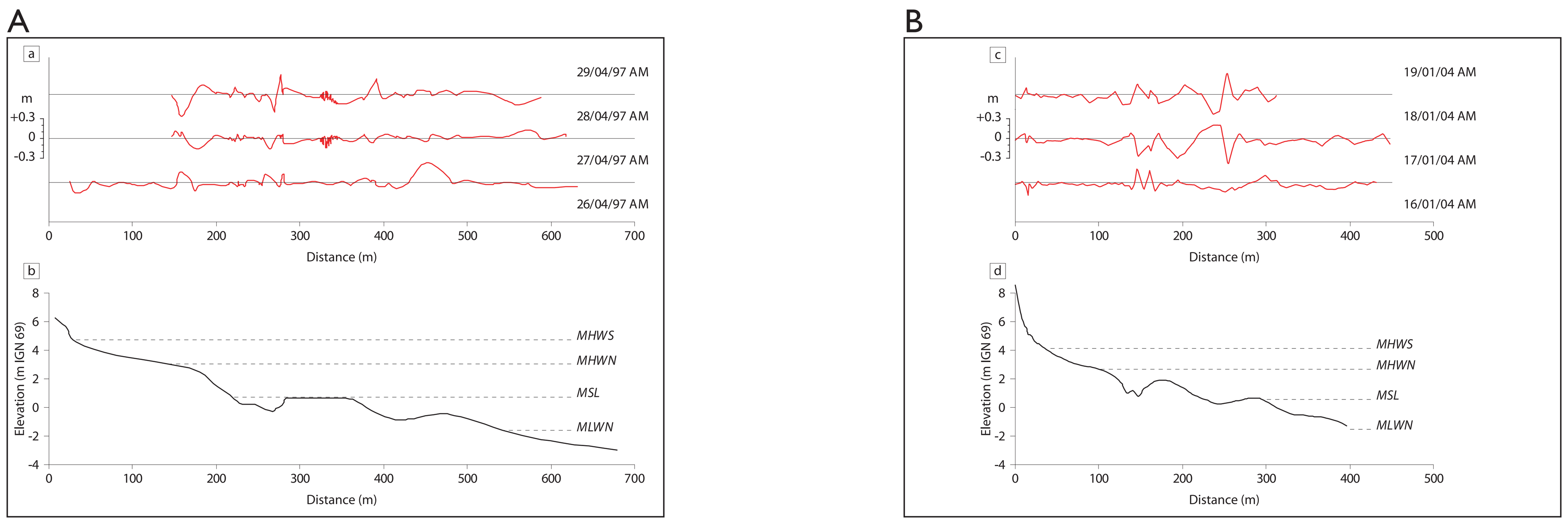

Fig. 6: (a) Daily net profile change of Merlimont (A) and Dune d'Amont beaches (B) corresponding to the hydrodynamic records shown in Fig. 5 ; (b) reference profile for both sites

Limited cross-shore bar migration on these beaches probably reflects a morphodynamic adjustment involving pronounced bars resistant to change, and thus liable to promote morphological lag, and well-entrenched troughs maintained by channelled high-energy intertidal flows that evacuate groundwater, swash overflow and ebb tidal discharge. The study highlights the importance of longshore flows and their morphological effects. This significant longshore component needs to be fully considered in order to gain a better understanding of the morphodynamics of beaches with multiple intertidal bars.

REFERENCES

Anthony, E.J., Levoy, F., and Monfort, O. (2004) "Morphodynamics of intertidal bars on a megatidal beach, Merlimont, Northern France," Mar. Geol 208, 73-100.
Anthony, E.J., Levoy, F., Monfort, O., and Degryse-Kulkarni, C. (2005) "Short-term intertidal bar mobility on a ridge-and-runnel beach, Merlimont, Northern France," Earth Surf. Process. Landforms 30, 81-93.
King, C.A.M., Williams, W.W., 1949. Formation and movement of sand bars by wave action. Geogr. J. 113, 70- 85.
Kroon, A., Masselink, G., (2002) "Morphodynamics of intertidal bar morphology on a macrotidal beach under low-energy wave conditions, North Lincolnshire, England," Mar. Geol. 190, 591- 608.
Masselink, G. (2004) "Formation and evolution of multiple intertidal bars on macrotidal beaches: application of a morphodynamic model," Coast. Eng 51 (8-9), 713-730.
Masselink, G., and Anthony, E.J., (2001) "Location and height of intertidal bars on macrotidal ridge and runnel beaches," Earth Surf. Process. Landf. 26, 759-774.
Masselink, G., Kroon, A., & Davidson-Arnott, R.G.D. (2006) "Morphodynamics of intertidal bars in wave-dominated coastal setting - A rewiew," Geomorphology. 73, Issuses 1-2, 33-49.
Sedrati, M., (2002) "Analyse des courants sur un estran macrotidal : Baie de Wissant, nord de la France," Mémoire de DEA. Université du Littoral Côte d'Opale, Dunkerque. 55 pp.
Sedrati, M., Cohen, O., and Anthony, E.J., (2003) "Interaction entre le régime des courants tidaux et la variation de la distribution longitudinal des sables sur un estran macrotidal ," J. Rech. Océanogr.
Sedrati, M., and Anthony, E.J., (2005) The role of longshore currents in intertidal bar mobility on a macrotidal beach under high-energy wave conditions, Dune d'Amont, Wissant Bay, Northern France. Proceedings Coastal Dynamics, 2005, ASCE, paper on CD-ROM.

FEDER
BEACHES AT RISK
This is part of INTERREG III - Project BAR (Beaches at risk).
We also thank the Nord Pas-de-Calais Regional Council for research support in various ways.
RÉGION NORD PAS DE CALAIS