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Vertical distribution of longshore sediment transport on barred macrotidal beaches, northern France

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ABSTRACT

The vertical distribution of longshore sediment transport was measured on sandy macrotidal barred beaches of Northern France under low to moderate wave energy conditions, using streamer traps collecting sand at different elevations above the bed. Longshore sediment flux measurements and wave and current data were collected at several locations along cross-shore transects in order to analyse the relation between the vertical patterns of suspended sand transport and the forcing hydrodynamics across the bar-trough topography. Suspended sediment fluxes generally showed a typical upward decrease in longshore transport, revealing that near-bed transport represents the major transport mode on these macrotidal beaches, notably over the bars where the highest rates of sediment transport were measured. Conversely to previous studies in which the shape of the vertical distribution was either independent of the location in the surf zone or which showed an increase in suspended transport over intertidal bars, our results revealed a strong upward decrease in longshore sediment transport over bars, especially under higher wave energy conditions, whereas more uniform vertical distributions were observed in troughs. These differences in the vertical distribution of longshore sediment flux can be explained by spatially variable wave breaking and surf zone processes over the bar-trough topography and by the distribution of small-scale bedforms across the intertidal zone, which influence sand resuspension processes and control the shape of the vertical profiles of sediment transport. Larger longshore sediment fluxes over bars can be explained by the action of breaking waves that are responsible for increased sediment remobilization, but the dominance of spilling breakers on the studied beaches likely results in significant turbulence dissipation, leading to limited sand resuspension in the water column. Comparatively, landward propagating surf bores over bars favour an increase in sediment concentration at higher elevations above the bottom in the adjacent trough.

1. Introduction

The vertical distribution of sediment transport, and particularly suspended sediment transport, has been increasingly studied in coastal/marine environments during the last decades, as fast-response optical or acoustic sensors for recording wave orbital velocities and sediment concentration became more widely available (Osborne and Greenwood, 1993; Aagaard and Greenwood, 1995; Vincent and Osborne, 1995; Beach and Sternberg, 1996; Voulgaris and Collins, 2000). In macrotidal coastal environments, the use of such instrumentation enabled the study of small-scale processes ranging from acoustic turbulence of near-bed suspended sediment in highly turbid waters of macrotidal estuaries (Sottolichio et al., 2011) to wave-induced sand resuspension mechanisms responsible for variations in suspended sediment concentrations on barred beaches (Osborne and Vincent, 1996; Vincent and Osborne, 1995; Webb and Vincent, 1999), including the effects of bedforms or bed roughness on the vertical distribution of sediment transport (Davidson et al., 1993; Webb and Vincent, 1999; Masselink and Pattiaratchi, 2000). Although these studies considerably increased our understanding of small-scale sedimentary processes on macrotidal beaches, there is still a lack of knowledge about the vertical distribution of longshore sediment transport at a mesoscale on sandy beaches characterized by a bar-trough morphology.

Even if a number of studies were recently conducted on the morphodynamics of macrotidal barred beaches during recent years (Levoy et al., 2000; Masselink and Anthony, 2001; Kroon and Masselink, 2002; Anthony et al., 2004; Sedrati and Anthony, 2007; Maspataud et al., 2009), only a few studies have been specifically dedicated to the measurement of longshore sediment transport.

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Estimates of longshore transport on macrotidal beaches were obtained in a small number of studies using fluorescent tracers (Levoy et al., 1994a; Voulgaris et al., 1998; Stépanian et al., 2001; Sedrati and Anthony, 2007) or streamer traps deployed across the beach and/or surf zone (Levoy et al., 1994b; Corbau et al., 2002). More recently, Cartier and Héquette (2011a, 2011b, 2013) highlighted the high variability of longshore sediment transport across the intertidal zone of multi-barred macrotidal beaches and underlined the role of the bar-trough morphology on longshore sediment transport rate variations, using a series of sediment traps and hydrodynamic instruments. The latter studies notably showed that longshore sediment transport rate is generally strongly reduced in the troughs while significantly larger quantities of sand are transported over the intertidal bars, but the vertical distribution of sediment fluxes across the bar-trough systems was not analysed in detail.

The present paper specifically examines the influence of the bar-trough topography of macrotidal beaches on the vertical distribution of longshore sediment transport through the water column. Data were collected on three multi-barred sandy beaches of Northern France under low to moderate wave energy conditions. Measurement of sediment transport on the shore of Northern France is a difficult task because of high organic content (Vantrepotte et al., 2007) and presence of fine grained suspended sediments in coastal waters (Chapalain and Thais, 2000), which preclude the use of high resolution devices for measuring sand concentrations. In addition, in and near the breaker zone, breaking waves generate air bubbles that can induce erroneous sediment concentration estimates from optical or acoustic sensors, especially when bubbles are associated with organic matter (Battisto et al., 1999; Puleo et al., 2006). Due to these limiting conditions, streamer traps were preferred for measuring sand transport on the macrotidal beaches investigated in the present study.

2. Study area

This study has been conducted on three sandy macrotidal barred beaches of northern France (Fig. 1). The first field experiment site (Zuydcoote) is located near the Belgian border, facing the North Sea; the second site (Wissant Bay) is on the shore of the Dover Strait, while the third study site (Hardelot) is located on the coast of the eastern English Channel. Tidal range increases from the Belgian border to the English Channel, spring tide amplitude

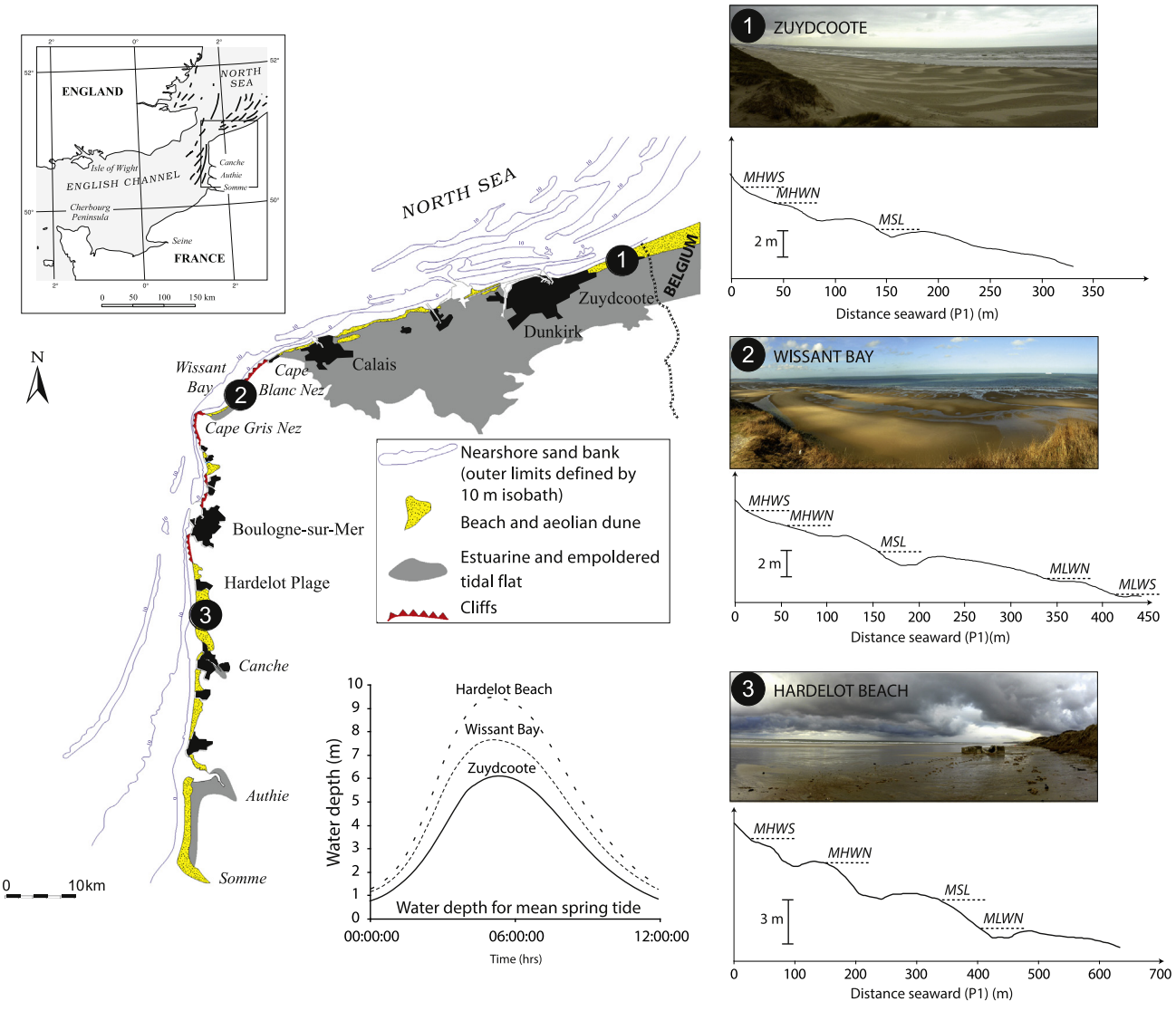

Fig. 1. Location of the study sites along the coast of Northern France: 1) Zuydcoote; 2) Wissant Bay; 3) Hardelot Beach. A shore perpendicular beach profile and a panoramic photograph are shown for each study site. Height of mean high water at spring (MHWS) and neap (MHWN) tides and of mean low water at spring (MLWS) and neap (MLWN) tides are shown on the beach profiles.