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Wave control on the rhythmic development of a wide estuary mouth sandbank: A process-based modelling study

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ABSTRACT

This study presents the numerical hindcast of the morphological and stratigraphic evolution of a wide estuary mouth sandbank located along the French Atlantic coast (Marennes-Oléron Bay), and primarily investigates the respective contribution of tide and waves to its pluri-decadal evolution. Firstly, the morphodynamic hindcast appears strongly improved when tide and waves are considered in the forcing rather than only tide. Secondly, the modelling results suggest that the strong seasonal variation of the wave climate in this area explains the rhythmic lateral accretion of the bank (i.e. normal to the main currents direction) observed in seismic reflection profiles. The grain size variation in the area of sediment accretion is also characterized by a seasonal cycle. Finally, repetitive bathymetric surveys and seismic profiles revealed that the lateral accretion of the bank is associated with about one seismic reflector per year, which is in agreement with our modelling results when assuming that these seismic reflectors are due to the seasonal variation of the grain size. These new results may be considered when studying the morphological evolution and the stratigraphy of other tidal sandbanks potentially affected by waves.

1. Introduction

Sandbanks appear widely in coastal and shelf seas, where sand is abundant enough and hydrodynamic conditions are sufficient to move the sediment material. Understanding the evolution of these bedforms is important for coastal activities such as navigation and dredging, but also to quantify sediment exchange with adjacent shorelines. Due to the different classifications of sandbanks and ridges in the literature (e.g. Pattiaratchi and Collins, 1987; Swift et al., 1991; Dyer and Huntley, 1999; hereinafter DH99), some confusion has been observed in their terminology. In order to unify the approaches of marine geologists and physical oceanographers, DH99 proposed a classification of sandbanks and ridges which will be used in the present study.

Though the formation and maintenance of tide-dominated sandbanks like open shelf or headland associated sandbanks (types 1 and 3 in DH99, respectively) are well explained theoretically (e.g. Huthnance, 1982; Signell and Harris, 2000), estuary mouth sandbanks (type 2 in DH99), which include sandbanks emplaced in wide estuaries and in tidal inlets (i.e. ebb and flood deltas), have for a long time received less attention (DH99). More precisely, while the emergence of morphodynamic modelling provided a substantial improvement in the understanding of the processes responsible for the development and morphological changes of tidal inlets (e.g. Cayocca, 2001; Dastgheib et al., 2008; Dissanayake et al., 2009; Nahon et al., 2012), wide estuary mouth sandbanks have received very little attention, potentially because they are less frequent than ebb and flood deltas. Yet, these sandbanks are very interesting because their development in shallow waters and their exposure to waves could suggest that they may not be only tidally controlled.

Numerous studies have provided qualitative information on this type of sandbanks (e.g. Ludwick, 1974; Harris, 1988; Gómez and Perillo, 1992; Chaumillon et al., 2002; Kapsimalis et al., 2004) but, to our knowledge, no study has managed to quantify the respective contribution of tide and waves to the long-term morphodynamic of these sandbanks. In order to do so, process-based morphodynamic modelling systems appear nowadays as attractive tools since they allow to perform coastal morphodynamic simulations by coupling currents, waves, sediment transport, and bottom change. Moreover, the recent development of multi-class and multi-layer (MCML) methods in sediment transport models allows accounting for the granulometric heterogeneity of the sediment, and even computing numerical stratigraphy. One can cite the work of Geleynse et al. (2010, 2011) and Viparelli et al. (2014) who have successfully simulated the formation of river deltas and their stratigraphy. Nevertheless, such promising coupled approaches still have to be applied to other coastal environments, such as wide estuary mouth sandbanks.

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In this study, a horizontally two-dimensional (2DH), unstructured grid, morphodynamic-stratigraphic modelling system was used to investigate the respective contribution of tide and waves to the 40-year retrospective evolution (period 1960 to 2000) of a wide estuary mouth sandbank located along the French Atlantic coast in the Marennes-Oléron Bay. To this aim, two morphodynamic simulations starting with the bathymetry of 1960 were considered, the first including tidal forcing only and the second including tidal and waves forcing. The sandbank bathymetry measured in 2000 together with seismic data were then used to assess the morphological and stratigraphic numerical results.

In the next section, the study area is presented along with a summary of previous knowledge available for this sandbank. The morphodynamic modelling system is described in the third section, with emphasis on the MCML method which has been implemented into the sediment transport module. Finally, the confrontation between numerical results and field data are presented and discussed in the fourth and fifth sections respectively.

2. Study area

2.1. Geomorphic setting

The Longe de Boyard sandbank is a wide estuary mouth sandbank located along the French Atlantic coast, in the northern entrance of the Marennes-Oléron Bay (Fig. 1). It is about 8 km long and 2 km wide with a tide-dominated morphology (flood lobe), and its bed elevation ranges from about −17 m from mean sea level (MSL) near the flanks up to −3 m MSL at the southern end of the sandbank. The internal architecture of this sandbank was revealed by seismic profiling (Chaumillon et al., 2002, 2008) and three main seismic units were identified: an upper one characterized by fine and medium sand, lying on an

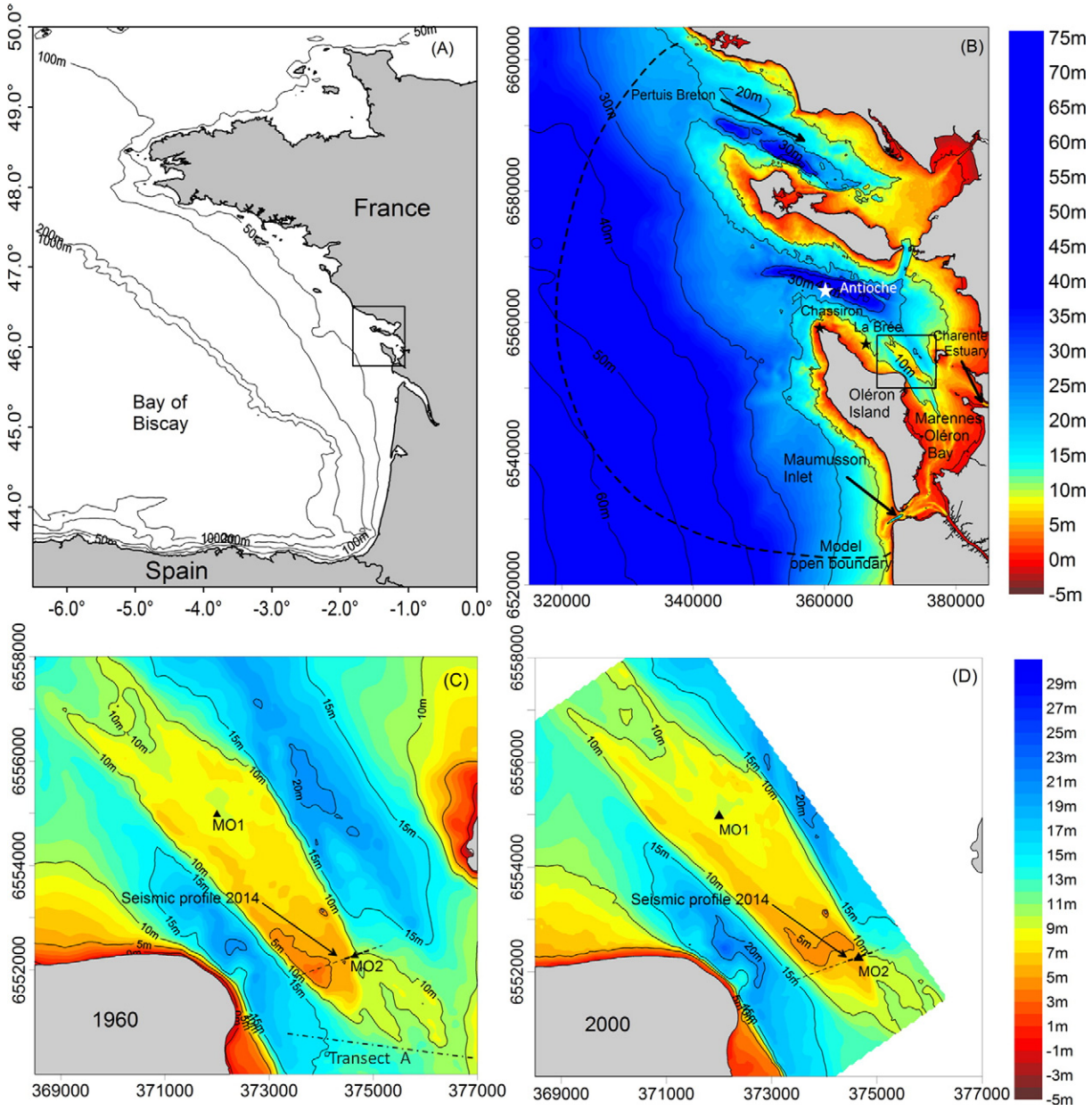

Fig. 1. (A) Location of the study area in the Bay of Biscay. (B) Bathymetric map of the study area with respect to mean sea level, with location of the Longe de Boyard sandbank (black square) in the Marennes-Oléron Bay, near the Charente Estuary. (C) and (D) Bathymetry of the sandbank measured in 1960 and 2000 respectively, with location of the seismic profile realized in 2014, the transect A corresponding to current velocity measurements, the wave station MO1, and the numerical core station MO2. Coordinates of (B), (C) and (D) are in meters (Lambert-93).