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Definition of storm thresholds for significant morphological change of the sandy beaches along the Belgian coastline

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ABSTRACT

In this paper a storm threshold for significant morphological change along the Belgian coastline is presented. Using a dataset covering topography, bathymetry and hydrodynamic conditions for the period 1983–2007, the main erosive years on the one hand, and the most severe storm events on the other hand have been selected. The topographic data were processed into erosion and accretion trends (corrected for nourished volumes) for both the supratidal beach and the dune. In total 42 storms were recognised and for each of these storms, the maximum water level, the storm duration, the wave energy and the main wind direction have been determined. To link the eroded volumes to the storm events, the total erosion of all the affected areas per year (i.e. winter season) has been compared with the total wave energy of all the storm events that occurred during the same period. Based on the five most erosive winter seasons (1984, 1987, 1990, 1994 and 1995), it is concluded that in order to cause a significant morphological impact along major parts of the Belgian coastline, as a first indication an individual storm should be characterised by the following criteria: maximum significant offshore wave height higher than 4 m, maximum water level above + 5 m TAW, storm duration longer than 12 h, an induced wave energy above 6.5 E + 05 J/m² and wind direction between W and NW. Although the applied methodology has its limitations due to the wide time-spacing of the topographic measurements and the lack of details on beach morphological changes, the severest storm periods from the last 25 years clearly left significant marks in the time series of recorded volume evolution. Therefore the proposed thresholds provide a valuable first estimate of the threshold for significant morphological change along the entire Belgian coastline. If in the future pre- and post storm related beach morphology measurements would be available, the above defined thresholds could be refined or even thresholds for different sectors along the Belgian coastline could be established taken into account the beach morphology.

1. Introduction

The type of morphologic change that beaches can generally undergo in response to changing coastal processes is well documented in the literature e.g. Komar (1998) and Masselink and Pattiaratchi (2001). However the impact of storms on coastal morphology is still incompletely described in the scientific literature and has been only recently tackled (Morton, 2002). Implications of variability in storminess on coastal morphologies are still scarce (Ferreira, 2005). The definition of storm thresholds above which important morphological changes or damages to urban structures can be expected, is not consistently described in the scientific literature and such thresholds have not yet been defined for several European countries, including Belgium. Often, local coastal managers and planners are interested more in the site specific understanding of the morphodynamic behaviour of the beaches along a particular coastline.

One of the methods to define such a storm threshold is to assess the coastal vulnerability during storms by linking events of major morphological change and damage, with the respective hydrodynamic forcing in order to define critical thresholds for the hydrodynamic parameters. To do this one has to (i) find out the forcing mechanisms to which coastlines react (e.g. waves, water levels or both) and (ii) to establish a threshold based on observations of significant morphological change or damage to the coastal zone.

The goal of this paper is to present a storm threshold for significant morphological change along the Belgian coastline. The threshold is based on the analysis of the impact of extreme storm events registered between 1983 and 2007 and relations between the hydrodynamic forcing and the observed coastal erosion.

2. Regional setting — study area

The study area comprises the entire Belgian coastline illustrated in Fig. 1. The Belgian coastline is about 65 km long and is part of the

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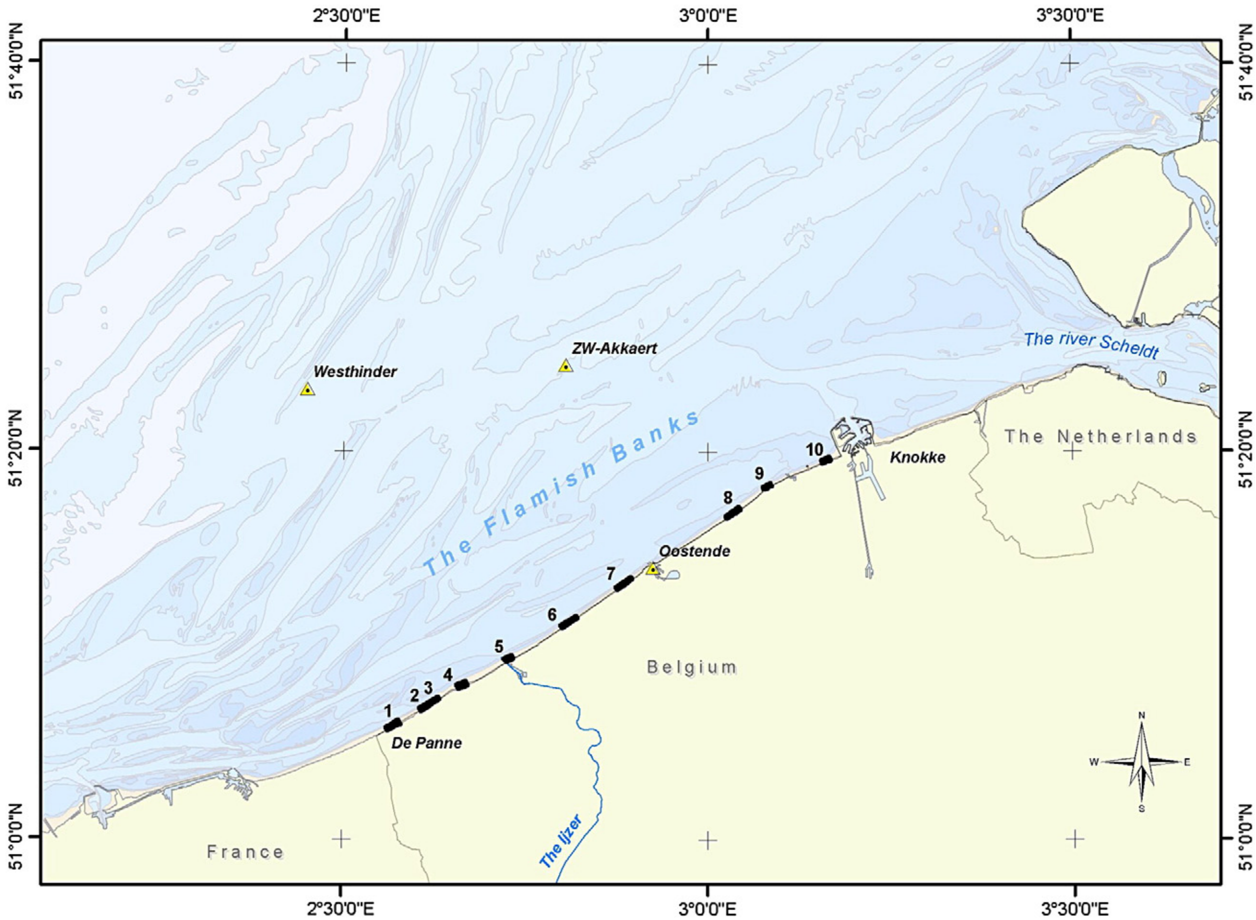

Fig. 1. Location of the Belgian coast, the 10 study sites (numbered), and the measurement locations of the Flemish banks monitoring network which have been used (triangles).

southern sandy North Sea coastline system. The coastline is oriented SW–NE and stretches from the estuary of the river Scheldt (the Netherlands) in the east to Dunkerque (France) in the west. The coastline consists of broad gently sloping sandy beaches backed by dunes, while on the shallow continental shelf numerous sandbanks occur, the Flemish Banks. The coastal dunes range in height between +5 m TAW and +30 m TAW, with the majority between +7 and +15 m TAW (TAW is a local height datum situated close to LAT — Lowest Astronomical Tide). Their width changes from about 2 km west of the *Ijzer* estuary to only a few hundred metres wide eastwards of the Ijzer (Lebbe et al., 2008). Behind the dunes a flat and vast coastal lowland is present. The beaches are in general wide and very gently sloping, characterised by spilling breakers and classified as dissipative. The slope of Belgian beaches increases from west (1.3%) to east (2.4%), resulting in narrowing of the intertidal beach width from the west (about 500–600 m in De Panne) to the east (about 200–300 m in *Knokke*) (Deronde et al., 2006). The natural beach sediments are characterised by fine to medium sand, mostly quartz grains, with a median diameter varying between 180 and 250 μm, and a natural peak of around 300 μm in the east (Depuydt, 1972). These observations are confirmed by recent work done by Deronde (2007) who remarked that in general along the Belgian coastline a gradient exists from fine-grained sand at the low water level to coarser sand on the dry beach. In areas where beach nourishment took place, the grain size tends to be coarser up to 400 μm (Deronde, 2007).

The tide along the coastline is semi-diurnal with a small asymmetry. All beaches are situated in a macro-tidal regime and the tidal range is typically between 3.5 m at neap tide and 5 m at spring tide. This important tidal range is linked to quite significant tidal currents, of which the peaks generally slightly exceed 1 m/s in the nearshore areas. Offshore waves are mainly driven by westerly winds and during storms surges southwest, west or northwest directions prevail. Because of the shallow water depth and the relatively short fetch, waves are typically short crested. The dominant wave sectors are SW to N and the main significant wave height at the shore is between 0.5 and 1.0 m, characterised by a wave period of 3.5 to 4.5 s (Van Lancker, 1999). The net longshore sediment transport by wind and waves has a predominant SW to NE direction. During N and NW storms important storm surges can occur. At present, more than 50% of the coast length suffers from erosion (Deronde et al., 2004; IMDC — International Marine and Dredging Consultants, 2010).

For several centuries anthropogenic activities along the Belgian coastline have attempted to reshape the coast, to maintain the coastline position or even to claim land from the sea and the natural interaction between the beach and the coastal dunes has been disrupted. The protection of the Belgian coastline actually is a combination of natural and artificial defence. Nowadays 60% of the coast has a hard coastal protection with seawalls, revetments and groynes (Lebbe et al., 2008). For two decades, emphasis has shifted to soft protection schemes, such as beach (and shoreface) nourishment and beach scraping to construct supratidal sand berms. Without these numerous protection actions the natural evolution along the Belgian coastline would be long term erosion and landward retreat (De Moor, 1992; DeWolf et al., 1993). Coastal erosion and accretion along the Belgian coastline is described in the coastline charts and the long term coastline trends (Vito and Afdeling Kust, 2009; IMDC — International Marine and Dredging Consultants, 2010) and sand loss rates up to 20 m^3/m/year were reported. Some major accretion areas at the coastline can be related to the presence of defence structures. This makes it difficult to single out the natural evolution of the beaches along the Belgian coastline.