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Numerical modelling of storm and surge events on offshore sandbanks

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ABSTRACT

This contribution uses a 3 dimensional coastal area numerical model, DHI's MIKE3, to simulate the impact of storm and surge events on offshore sandbanks. Three offshore sandbanks in the Bristol Channel are considered due to the region's sensitivity to anthropogenic pressures and the gradients in wave and tidal forcing in the area. Two extreme storm and surge events are simulated: one co-incident with spring tide and the other with neap tide. Reference simulations of astronomical tidal forcing only are also presented. It is shown that for the two sandbanks with greater wave exposure, storm conditions can provide a mechanism for the maintenance of crest position. For these cases, bed level changes over the crest are in the opposite direction compared to astronomically forced change. For the least wave exposed bank, both wave and tide only cases exhibit similar patterns of bed level change. Volumetric changes under astronomical forcing are shown to vary with changing maximum tidal current. Accretion occurs over a neap tidal cycle for all three sandbanks and as maximum tidal current increases the amount of accretion increases; however, over a spring tidal cycle accretion is observed for the less tidally dominated site but increasing maximum tidal current leads to reduced accretion and then erosion for the most tidally dominated bank. Volumetric changes under storm conditions are related to sandbank morphology and setting rather than relative wave exposure. The two single banks closely tied to headlands show similar magnitude of percentage volumetric change despite being at the two extremes of wave exposure and greater erosion occurs over the neap tide event. The sandbank that has associated secondary banks shows lesser percentage change and greater erosion over the spring tide event.

1. Introduction

Offshore sandbanks have societal importance as a form of natural coastal protection (Dolphin et al., 2007), a source of aggregates (Idier et al., 2010; Phillips, 2008; Van Lancker et al., 2010), sites for offshore wind installations and an important marine habitat (Atalah et al., 2013). Sandbanks can be important fish nursery areas (Neill, 2008) and the ecosystem function of offshore sandbanks mean that they are candidate SACs under the EU habitats directive (Atalah et al., 2013). Work conducted on sandbanks around the Welsh Coast has shown that the biological assemblages of sandbanks are distinct from other nearshore areas (Kaiser et al., 2004). The coastal protection function of offshore sandbanks is primarily related to wave dissipation over sandbanks leading to reduced wave energy on the lee side. Wave conditions have been linked to water depth over a sandbank (Park and Vincent, 2007). Model studies have shown that inshore wave height can vary by 0.5 m depending on tidal level (Coughlan et al., 2007). Sediment transport links between beaches and sandbanks have also been suggested (Dolphin et al., 2007; Phillips, 2008).

A significant body of work has investigated the dynamics of offshore sandbanks both via numerical modelling and experimental studies. Work has focussed on the role of tidal currents in bank formation and maintenance (Berthot and Pattiaratchi, 2005, 2006; Collins et al., 1995; Neill, 2008; Pattiaratchi and Collins, 1987), short term tidally induced sediment dynamics (Bastos et al., 2004), long term morphological (Horrillo-Caraballo and Reeve, 2008; Reeve et al., 2001) and volumetric changes (Lewis et al., 2014), sediment transport pathways around sandbank systems (Schmitt and Mitchell, 2014), between the nearshore and sandbanks (Dolphin et al., 2007) and on the behaviour and morphology of associated bedforms (Bastos et al., 2002; Scmitt et al., 2007). More recently, work has been conducted on the role of wave driven transport, however, there is not a large body of work focussing on wave or storm driven processes (Giardino et al., 2010). Measurement campaigns have shown that not only can storms reduce crest elevations but that grain size distributions can be affected with winnowing of material on the crest and deposition of finer particles in more sheltered areas (Houthuys et al., 1994). It has been demonstrated that waves can both magnify the quantity and alter the direction of sediment transport around sandbanks (Pattiaratchi and Collins, 1988). This means that there is the potential for storm events to have a role in the long term maintenance of sandbanks. However, there is some disagreement on the importance of storm impacts on sandbank morphology given their episodic nature. Measured data on sediment concentration on the Middelkerke Bank showed that over a 40 day period the majority of transport occurred during a few hours where large waves and strong

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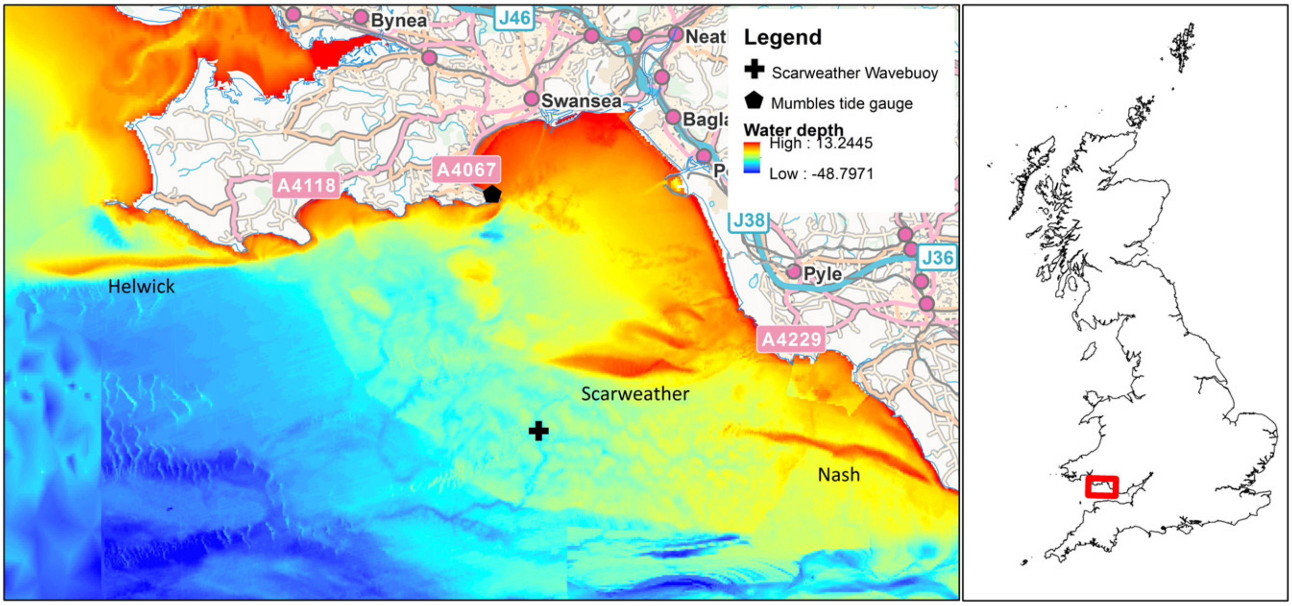

Fig. 1. A map showing the bathymetry of Swansea Bay with the Mumbles tide gauge, Scarweather Sands wave buoy and studied sandbanks marked (main panel) and a map of the United Kingdom showing the location of Swansea Bay (right panel).

current combined (Vincent et al., 1998). Conversely, other researchers hold that the infrequent nature of storms mean they are not important compared to the background stirring effect of low energy waves (van de Meene and van Rijn, 2000).

There is increasing pressure on the Bristol Channel environment both from industrial developments and climate change. Significant renewable energy infrastructure projects have been proposed in the Bristol Channel region such as tidal stream turbines (Ahmadian et al., 2012; Ahmadian and Falconer, 2012), the Severn Barrage (Xia et al., 2010), the Atlantic Array windfarm and various tidal energy lagoons (TLSB, 2014). These have the potential to impact wave (Fairley et al., 2014) and hydrodynamic (Xia et al., 2010) conditions in the area. Aggregate dredging in the region has been reported to remove 0.5×10^6 m^3 from the Nash sandbank every year (Lewis et al., 2014). Equally, climate change is predicted to lead to sea level rise in the Irish Sea of 0.47 m in the 21st Century (Olbert et al., 2012). Various studies have predicted that storm surges are likely to increase in both frequency and severity (Lowe and Gregory, 2005; Lowe et al., 2001; Wang et al., 2008) and wave climate may also become stormier via anthropogenic climate change.

These factors are not specific to the Bristol Channel; growing world population and increased utilisation of the coastal zone mean appropriate management strategies are essential worldwide (Dafforn et al., 2015) and evidently climate change is a global phenomenon. The increased capacity for coastal change and increased recognition that preservation of the current value and function of habitats is important means that it is crucial to develop understanding to facilitate better management. Developing understanding of storm event dynamics is particularly important due to the magnitude of change that can occur under such conditions and the predictions that extreme storms may increase in frequency (Lionello et al., 2008).

This paper specifically addresses the impact of storm and surge events on the morphology of offshore sandbanks in the Bristol Channel using the numerical model MIKE3FM from the Danish hydraulic institute. Three sandbanks are modelled: the Helwick Bank, Scarweather Sands and the Nash Bank (Fig. 1). Two storm events with similar parameters (H_s, T_p, *surge*), one co-incident with spring tide and one co-incident with neap tide are investigated to elucidate the difference between the impacts of storms impacting at different stages of the spring–neap cycle. Simulations consisting only of astronomical forcing are also presented. This provides new understanding of the differences in morphodynamics between storm wave and tidal forcing.

2. Study site

This study focusses on three sandbanks in the northern Bristol Channel, from west to east these are: Helwick, Scarweather and Nash (Fig. 1). All three sandbanks are around 10 km long with heights of about 20 m above the surrounding seabed. The Helwick and Nash Banks are single sandbanks, while the Scarweather Bank has two smaller associated

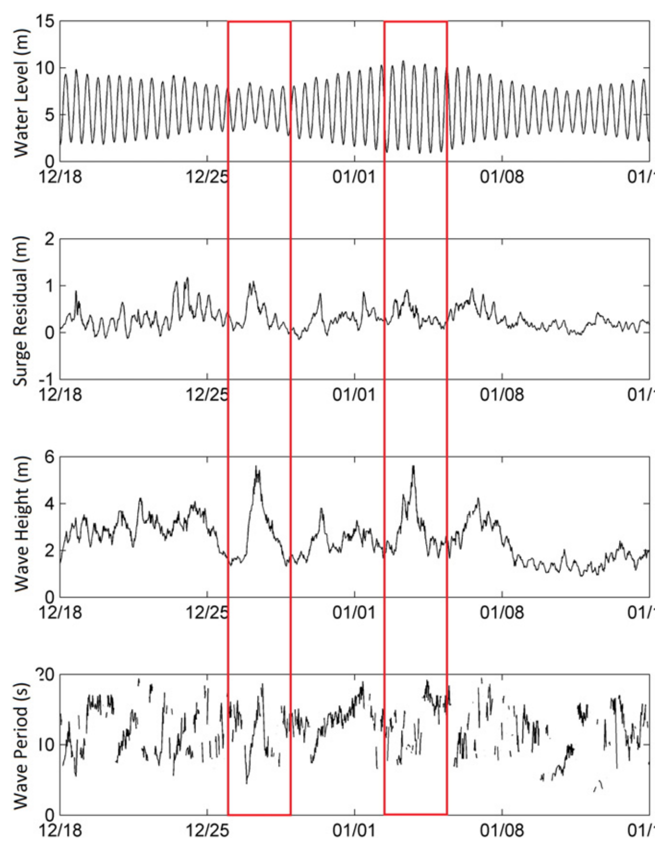

Fig. 2. Plots of wave and hydrodynamic parameters for the time period of interest with the two storms ringed in red.