OBSERVATION AND MODELLING OF SHOREWARD PROPAGATING ACCRETIONARY WAVES (SPAWs) ON MICROTIDAL BEACHES

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INTRODUCTION

At straight sandy coasts, wave-induced processes often lead to intriguing alongshore-variable morphology on spatial scales from 10s – 1000s of meters. The alongshore alternation in depth of crescentic nearshore bars, with landward-protruding shallower areas known as horns, is often reflected in the shoreline and beach morphology (e.g. Castelle et al., 2015). Observations have shown that the horns of crescentic bars may separate from the bar during storms and subsequently migrate onshore towards the beach during calmer periods as a spatially coherent structure, termed Shoreward Propagating Accretionary Wave, or SPAW (Wijnberg and Holman, 2007). Consequently, it is thought that such SPAWs play a role in the cross-shore exchange of sand, and the development of alongshore-variable morphology (Price et al., 2017). Here, we aim to (1) quantify the morphological evolution of a SPAW and (2) unravel the physical processes underlying its onshore migration and spatial coherence. To do so, we studied onshore migration of a SPAW using a process-based morphodynamic model.

FIELD SITES

We based our numerical modelling on observations from two field sites: Lido of Sète, (southeast France) and Egmond aan Zee (the Netherlands).

The Lido of Sète is a semi-diurnal, SE-facing, microtidal beach characterized by a double bar system located along a narrow and relatively straight sandy barrier in the northern part of the Mediterranean Sea. The modal wave climate is moderately energetic, with episodic severe storms. A large beach management program was developed at the Lido to fight against chronic erosion, involving the installation of a submerged breakwater (SBW) on the subdued outer bar (Figure 1b).

Egmond aan Zee is characterized by a tidal range of 1.2-2.1 m, waves are dominantly obliquely incident with typical wave heights of 1 – 1.5 m and wave periods of 4 -5 s. The cross-shore profile is characterized by 2-3 bars, depending on the phase of the net offshore bar migration cycle.

METHODOLOGY

In Lido of Sète, the SPAW event observations consist of a 3-month (October – December 2018) data set of daily rectified time-exposure images and 17 min pixel time series data (Holman et al., 2013) with the corresponding offshore wave and tide measurements. From the images we detected sandbar and shoreline positions (Bouvier et al., 2017) and applied the cBathy depth inversion algorithm (Holman et al., 2013 ; Bouvier et al., 2020) to quantify the subtidal morphology, including that of the SPAW, during the study period. Subsequently, these bathymetries and the offshore hydrodynamic data were used to initialize a process-based morphodynamic model.

In Egmond aan Zee, we used a bathymetric measurement (echo sounding) from November 2019, just before a SPAW started to migrate onshore, to create synthetic bathymetries as input for our model: an initially alongshore-uniform, double-barred bathymetry with a rectangular SPAW (Figure 2a). In this case, the model is driven with 1.5 m, 8 s waves approaching at a 15 degree angle with respect to the coast.

The numerical model used for this study is the nonlinear morphodynamic model 2DBeach, including both cross-shore and alongshore sediment-transport processes (Dubarbier et al., 2017). This allows for the simultaneous onshore movement of a bar while developing alongshore variabilities, making it particularly suitable for studying a SPAW event. The model consists of four combined modules: a spectral wave model, a shortwave-averaged and depth-integrated flow model, an energetic-type sediment transport model and a bed evolution model. See also Bouvier et al. (2019) for details.

RESULTS

Over the 3-month period of observations from Lido of Sète, we observed the emergence of a SPAW from a crescentic bar during a storm with peak significant wave heights reaching 2.8 m on 10 October (Figure 1a).

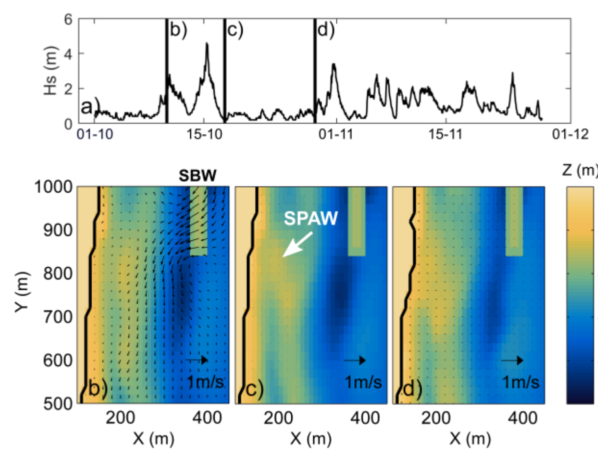

Figure 1 – a) Time series of offshore significant wave heights (Hs) during the study period, (b-d) bathymetries estimated with video images from Lido of Sète at different dates showing the SPAW evolution with the associated wave-driven circulation computed by the model.

The SPAW pursued to develop during the next storm event on 15 October, detaching from the inner bar, migrating onshore and welding with the beach in the following days during calm conditions (Figures 1b-d). The resulting beach accretion locally led to a significant (>10 m) seaward extension of the shoreline. The depth inversion results further quantify these observations, showing the emergence and onshore migration of a spatially coherent morphological feature. Preliminary modelling results show the capability of the model to reproduce above morphological evolution, indicating that wave-driven cell-circulation over the SPAW drives the onshore migration while maintaining the spatial coherence of the SPAW.

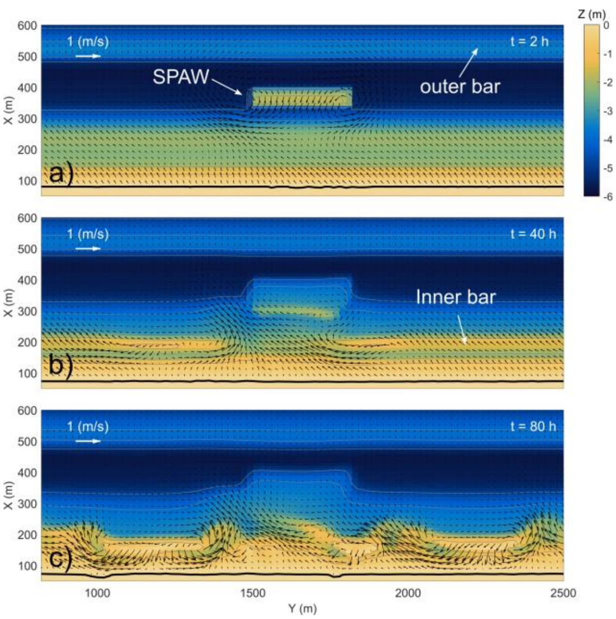

Figure 2 – Morphodynamic evolution of a SPAW and the nearshore zone, including an inner and outer bar, based on observations from Emond aan Zee. After a simulation time of (a) 2 hours, (b) 40 hours and (c) 80 hours. Arrows indicate the associated wave-driven circulation computed by the model.

Figure 2a shows the bathymetry, based on the measurement from Egmond aan Zee, used to initialize the synthetic model runs. The SPAW can be seen to migrate onshore while maintaining its spatial coherence (Figure 2b) before it merges with the inner bar (Figure 2c). During this onshore migration, the SPAW changes shape and leaves a 'trail' of sand in the trough. This implies that a SPAW loses sand during its migration. An onshore flow over the center of the SPAW, predominantly due to wave-non-linearity, drives the onshore migration, whereas cell circulation at the tips of the SPAW remain in place until the SPAW merges with the inner bar. As the SPAW approaches the inner bar a rip current starts to develop on the left side of the SPAW (Figure 2b), due to the oblique wave incidence from the right.

During the conference, we will present a systematic analysis of the processes underlying the observed SPAW morphodynamics.

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