Marine Geology 368 (2015) 25–41

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

Sandbar straightening under wind-sea and swell forcing

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ARTICLE INFO

Article history:
Received 9 January 2015
Received in revised form 18 June 2015
Accepted 24 June 2015
Available online 2 July 2015

Keywords:
Beach morphology
Nearshore sandbar
Oblique waves
Rip channels
Video imagery

ABSTRACT

Sandbar straightening on natural beaches is known to occur following storm events. However, on a typical south-west Western Australia beach, sandbar straightening is observed under low amplitude wind-sea forcing in summer and remains alongshore-variable following high wave events associated with winter storms. During summer, diurnal variations in wave height and direction are associated with a strong sea breeze cycle. At the peak of the sea breeze the local wind-sea approaches the beach obliquely, driving strong alongshore currents. The occurrence of the seasonal, obliquely-incident wind-sea provides the opportunity for testing the role of the wave angle on sandbar straightening. The location of the bar crest is observed using time exposure video images and the alongshore variability is quantified using the standard deviation of the sandbar position. The role of wave incidence angle on alongshore-variability is highlighted, as the sandbar straightens in the presence of oblique wave forcing associated with summer sea breezes, and remains alongshore-variable with normally incident wave forcing. The transition from alongshore-variable to alongshore-uniform also depends on the antecedent bathymetry, in particular the distance between the shore and the bar crest. When the sandbar is further offshore, alongshore variability persists in the presence of strong sea breezes.

1. Introduction

Beach morphology continually changes in response to changing wave conditions, and several beach classification schemes have been proposed in the literature (Wright and Short, 1984; Lippmann and Holman, 1990). Three major morphological beach states were identified by Wright and Short (1984): reflective, intermediate and dissipative. Intermediate beaches were divided into four additional states in ascending order, from low-dissipative state to highly-dissipative state: Low Tide Terrace (LTT), Transverse Bar Rip (TBR), Rhythmic Bar Beach (RBB) and Longshore Bar Trough (LBT).

Ranasinghe et al. (2004) investigated the transition between states on Palm Beach, Sydney, Australia, where the up-state transition from any of the lower states to Longshore Bar Trough (LBT) morphology occurred during high wave events over relatively short time scales. In contrast the down-state transition typically occurred sequentially from LBT to RBB to TBR and LTT and evolved more slowly under lower wave energy conditions. Ranasinghe et al. (2004) find that the mean residence time is 5.4 days for LBT and 9.3 days for LTT at Palm Beach. Lippmann and Holman (1990) find that it is 2.5 days for LBT and 18 days for LTT at Duck (North Carolina). For the outer bar of Surfers Paradise (Gold Coast, Australia), a double sandbar system, Price and Ruessink (2011) find median residence times of 49 days for the dissipative state, nine days for LBT, three days for eTBR (erosive TBR), 13 days for RBB and 24 days for TBR. Van Enckevort et al. (2004) find longer timescales at Noordwijk (Netherland), with patterns in the bar lasting over 10 months (the length of the data set). They suggest that the timescales are related to the volume of sand in the bars, as well as water depth over the bar and in the trough.

Considerable attention has been paid to the processes governing morphological evolution in the nearshore, particularly the transition to lower beach states, RBB and TBR, which are often manifested in the form of alternating shoals and rip channels with striking alongshore rhythmicity (Holman and Bowen, 1982; Lippmann and Holman, 1990). Early studies considered the morphology to be a response to infragravity motion (frequency < 0.05 Hz) (Bowen and Inman, 1971; Huntley and Bowen, 1973; Guza and Inman, 1975). Bowen (1969) showed that the superposition of normally incident waves and sub-harmonic edge waves produced regularly spaced rip currents, though the alongshore spacing was much less than that typically observed on natural beaches (Holman et al., 2006; Turner et al., 2007). In the nineties, attention shifted to self-organized behavior associated with morphodynamic instabilities in the nearshore (Falques et al., 1996, 2000; Deigaard et al., 1999). These models produce regularly-spaced rip channels and shoals in the absence of any forced alongshore periodicity in the incident wave forcing. While both forced and self-organized behavior might contribute to the development of RBB and TBR morphologies (Stive and Reniers, 2003), a numerical study of combined forced and self-organized behavior reported by Reniers et al. (2004) conclude that self-organization was the dominant mechanism.

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http://dx.doi.org/10.1016/j.margeo.2015.06.010
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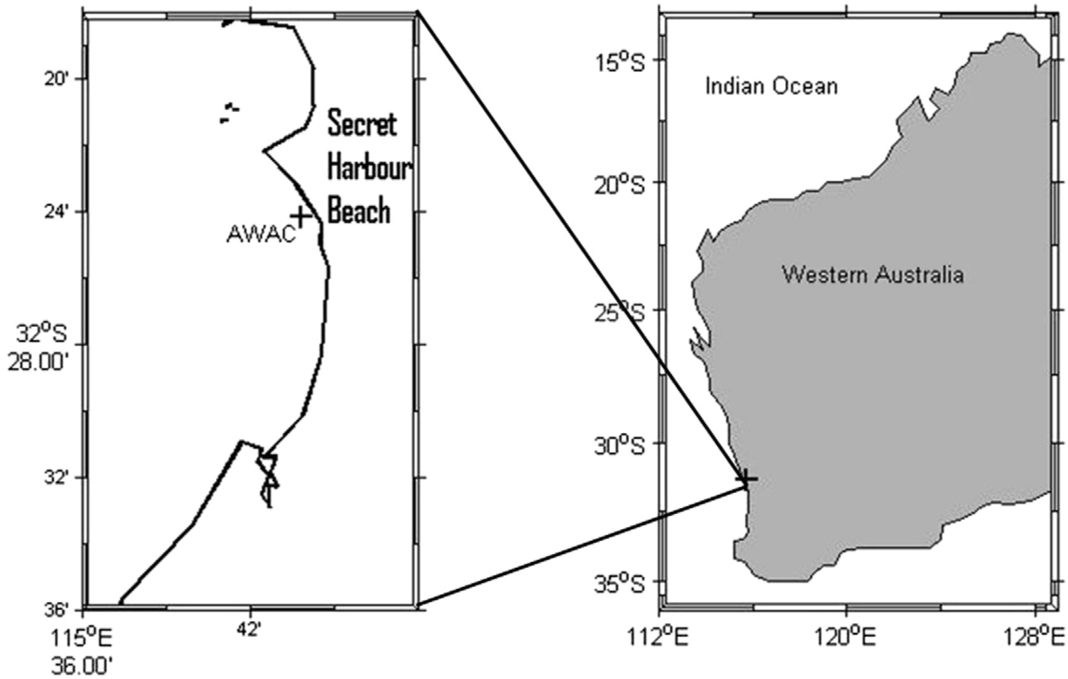

Fig. 1. Location of the field site.

Empirical approaches, for example Wright and Short (1984), conclude that a reasonable predictor of beach state is provided by the non-dimensional sediment fall velocity:

$$\Omega = H_b/(w_s T_p) \tag{1}$$

where w_s is the median sediment fall velocity, T_p the peak wave period and H_b is the wave height at breaking, given by (Ruessink et al., 2003):

$$H_b = \left(\frac{\gamma}{g}\right)^{1/5}\left[H_{m0}^2 c_{g0}\cos\theta_0\right]^{2/5} \tag{2}$$

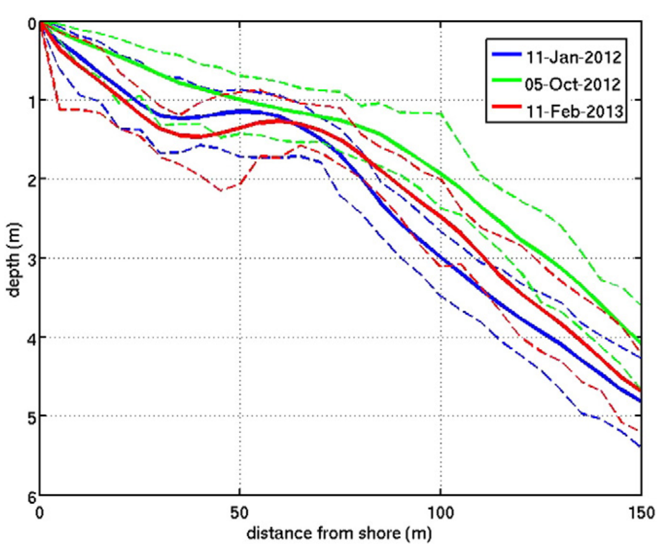

Fig. 2. Bathymetry cross-shore profile, solid line: alongshore-average, dashed lines: alongshore minimum and maximum, from bathymetry surveys.

Table 1
Argus camera details.

Lens details					
Camera 1	Camera 2	Camera 3	Camera 4	Camera 5	Camera 6
Fujinon 12.5 mm	Fujinon 12.5 mm	Pentax 8 mm	Pentax 8 mm	Fujinon 12.5 mm	Fujinon 12.5 mm

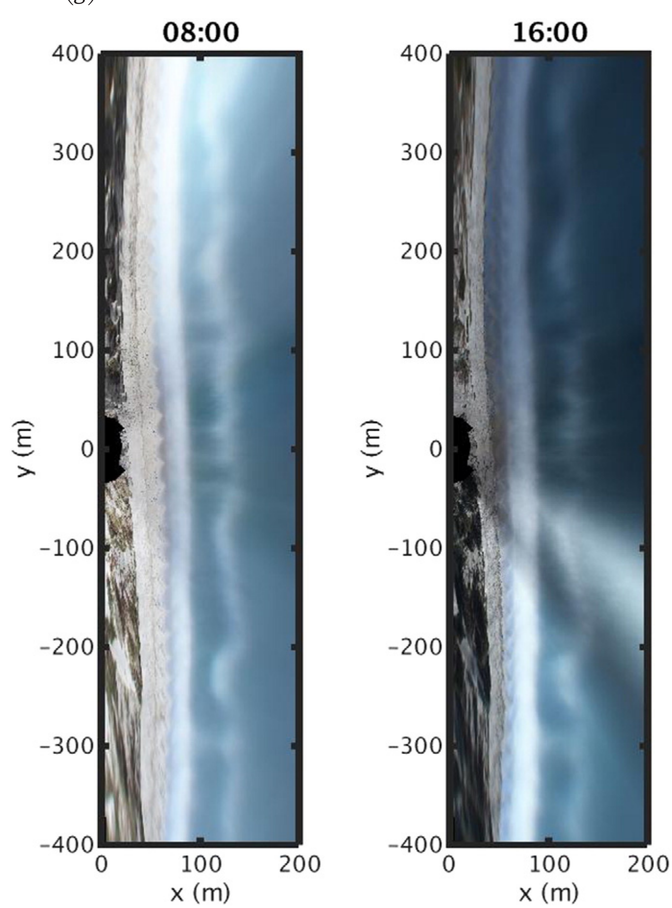

Fig. 3. Timex images, 4 February 2013 at a) 8 pm and b) 4 pm. Radial patterns in intensity are associated with different cameras and sun glint.