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Interannual cross-shore sandbar migration

Abstract

We analyze a 7.5-year data set of daily time-exposure images collected at the double-barred Surfers Paradise, Gold Coast, Australia. We demonstrate that the sandbar variability is predominantly steered by the annual signal in the wave height. However, extreme events that result in a wave height several times the annual average cause the sandbar system to shift into another state: (i) the outer sandbar migrates offshore further than usual and subsequently decays by onshore migration; (ii) during the next period of high waves the inner sandbar migrates offshore to take its place as the new outer bar, and a new bar is created onshore. Then, the dominance of the annual variability resumes until the next extreme event.

1. Introduction

Nearshore sandbars are ubiquitous features along micro- to mesotidal, wave-dominated sandy coasts. Along some coasts, the dominant type of long-term (> years) sandbar variability is interannual net offshore migration (NOM), whereby a sandbar is generated close to the shoreline, then migrates net offshore for several years, and finally decays in the outer nearshore (e.g., Ruessink and Kroon, 1994; Plant et al., 1999). At other sites, cross-shore sandbar variability is dominated by storm response rather than by an interannual trend (Wright and Short, 1984). The reasons for this intersite variability are not well understood.

Our aim is to document the temporal variability in sandbar position at storm, seasonal and interannual time scales for a double-barred, swell-dominated system at the northern Gold Coast, Australia, previously perceived to be dominated by storm response. We show that extreme events, with wave heights several times the annual average, can trigger net offshore migration similar to that observed elsewhere.

2. Data

Our data comprise 7.5 years of daily time-exposure video images from Surfers Paradise, the Gold Coast, Australia (Figure 1). Waves breaking on the sandbars cause high-intensity (white) bands in the images (Figure 2). An alongshore tracking algorithm finds the cross-shore position of maximum intensity for each sandbar. Time series of alongshore-averaged cross-shore sandbar position and the offshore root-mean-square wave height H_{rms} are provided in Figure 3.

Figure 1 Location of the study site

3. Results

a) The inner and outer bar have multi-annual lifetimes. In July 2000, February 2002, and July 2006 the inner bar migrated offshore to the position of the (former) outer bar. At the same time, a new inner bar was generated near the shore. While at other sites the shift of the inner bar to the outer-bar position takes at least a year, it took less than about 2 weeks at the Gold Coast.

b) The shift of the inner bar to the position of the outer bar is the ending of a series of bar-behavioral events that commenced during a period of high waves with H_{rms} > 3 m, about 3 to 4 times the annual average. Figure 4 provides plan view images for the event in early 2006:

A. During the major storm in February 2006, the outer bar migrated some 75 to 100 m further offshore than usual (Figures 4c and k, Figure 3a);

B. During the subsequent period of lower waves, the outer-bar breaker pattern, while shifting onshore, changed in appearance from an alongshore distinct breaker line into a vague and blobby breaker pattern (Figures 4d-f). We interpret this as the decay of the outer bar by onshore migration.

C. Ultimately, the spatially incoherent outer-bar breaker zone attached to the inner bar (Figures 4f-h and k);

D. During the next period of higher waves, the inner migrated offshore at rates of 5-30 m/day to the position of the (former) outer bar (Figures 4i-k).

We term this series of events episodic NOM to distinguish it from the interannual NOM observed elsewhere (e.g., Figure 5).

c) As long as H_{rms} < 3 m, the inner and outer bar respond primarily to the seasonal variability in wave height. Both bars are located further during the higher-energy, first half of the calendar year and further onshore during the lower-energy, second half of the year. The seasonal variance in position accounts for about 55% of the total variance at both bars. The events with H_{rms} > 3 m thus shift the outer and, ultimately, the inner bar in a different state.

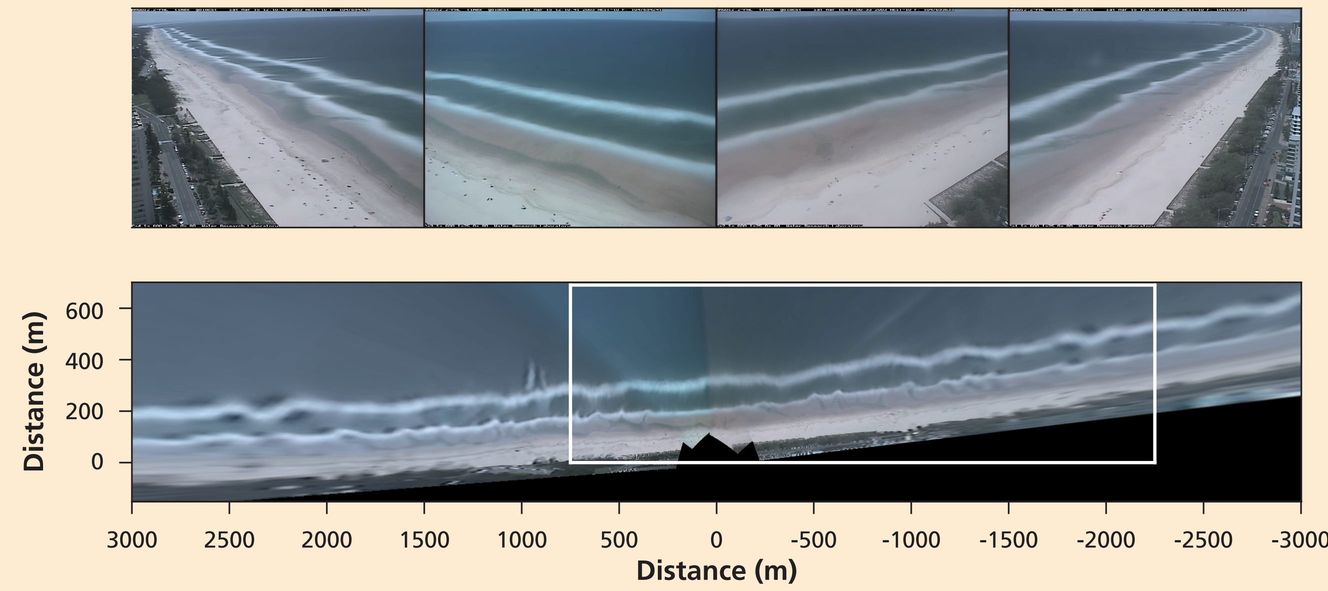

Figure 2 The four oblique, 10-min time-exposure images (top row) are merged and rectified to yield a plan view image. The two alongshore white lines represent wave breaking on the sandbars. The white rectangle outlines our study area.

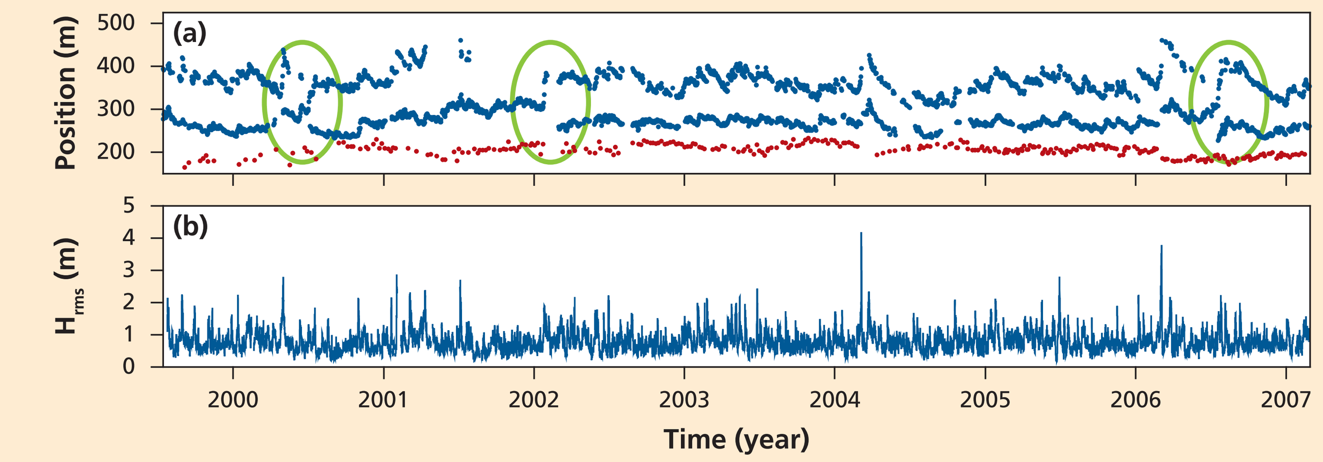

Figure 3 Time series of (a) the alongshore-averaged position of the inner and outer sandbar, and of the mid-tide shoreline (red dots) and (b) offshore root-mean-square wave height at Surfers Paradise. The green circles in (a) outline the 3 moments when the inner bar migrates offshore to become the new outer bar. Time-exposure images of the third event are provided in Figure 4.

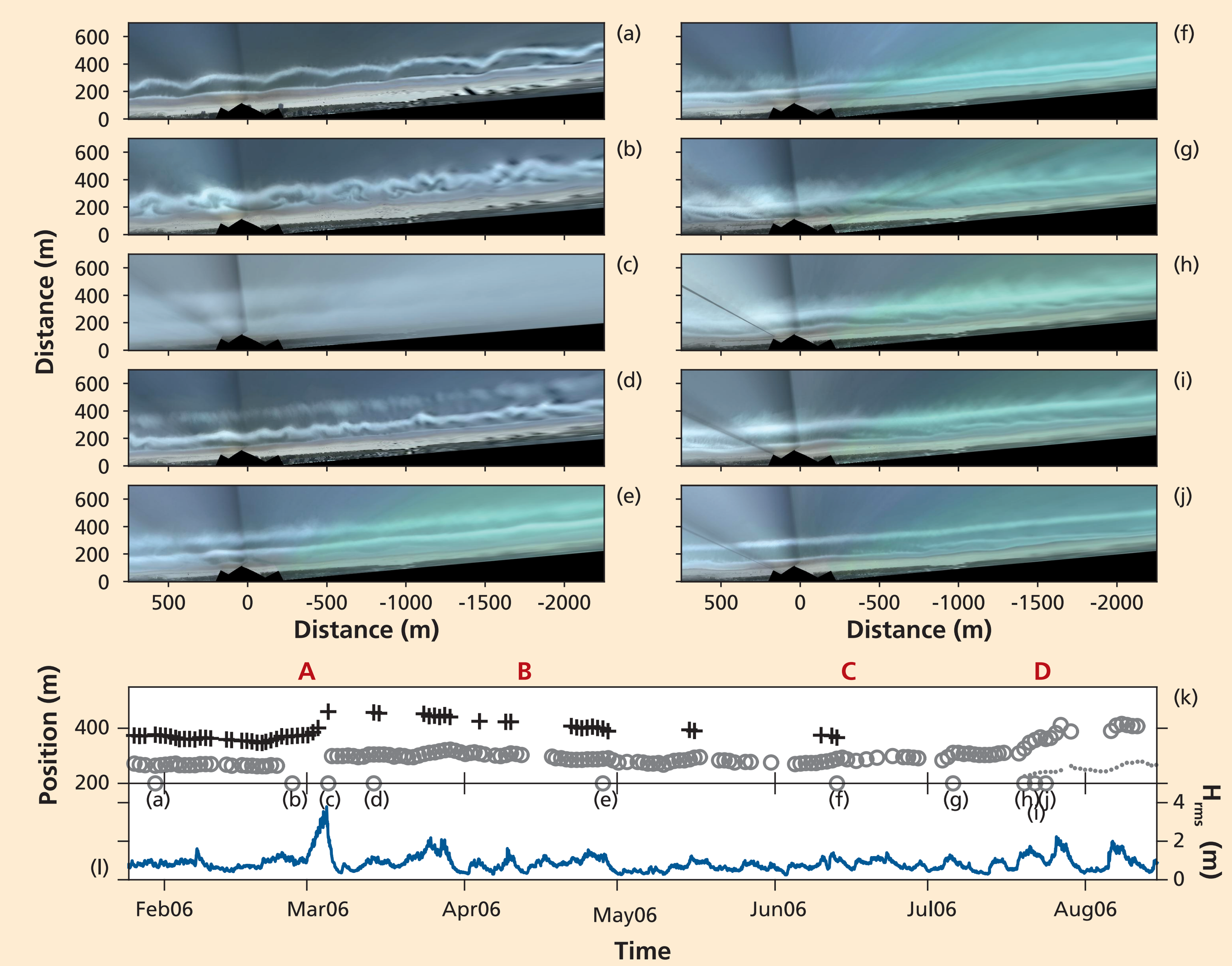

Figure 4 (a-j) Time exposure images, (k) alongshore-averaged sandbar position and (l) offshore root-mean-square wave height versus time. The timing of the images is indicated on the time axis of (k). The symbols in (k) represent the different sandbars.

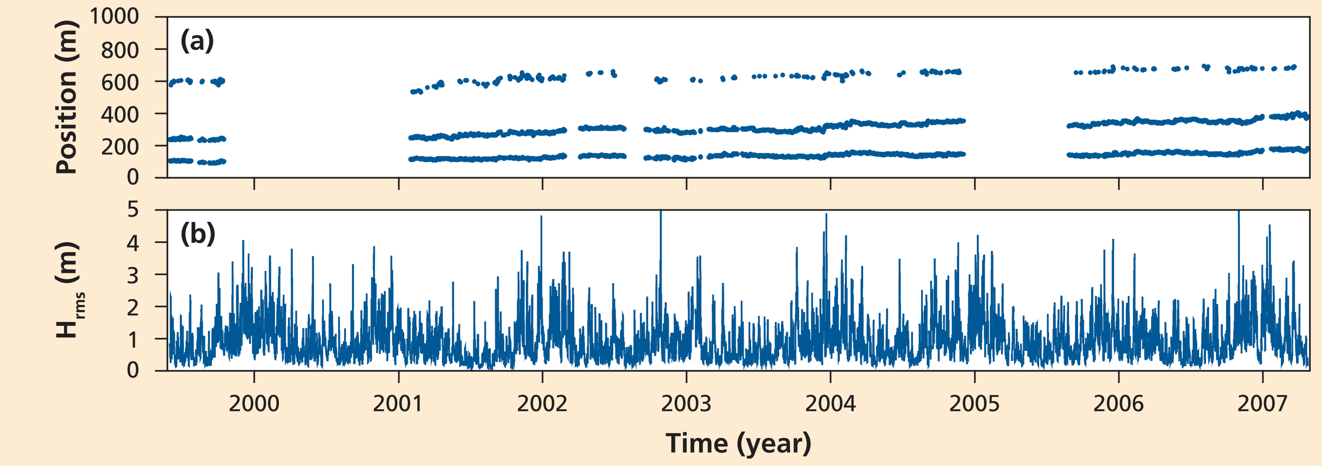

Figure 5 Time series of (a) the alongshore-averaged position of the inner, middle, and outer sandbar and (b) offshore root-mean-square wave height at Egmond aan Zee, the Netherlands. Annual surveys since 1964 have shown that the Egmond sandbars behave in an offshore directed cycle with a periodicity of about 15 years. The 8 years shown here are thus part of a single cycle.

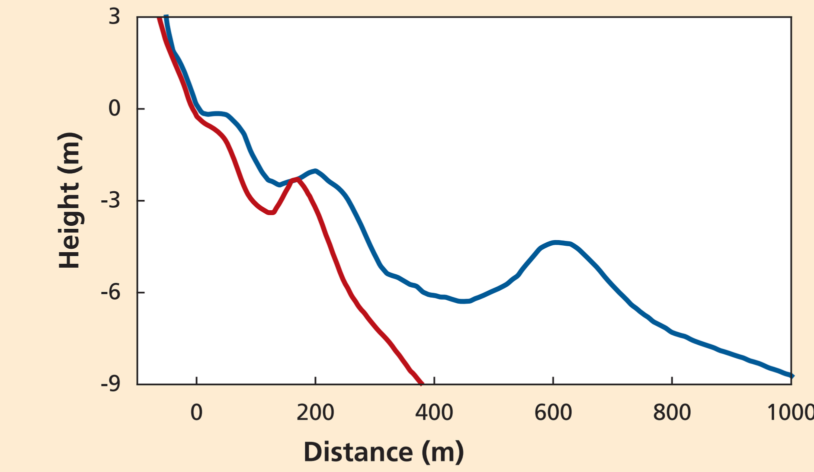

Figure 6 Typical cross-shore depth profiles at Surfers Paradise (red line) and Egmond (blue line). Note the difference in size of the outer bar at Surfers Paradise (distance ≈ 150 m) and at Egmond (distance ≈ 600 m).

4. Discussion

The sandbar variability at Surfers Paradise differs remarkably from that other sites, compare Figure 3 to Figure 5. At Egmond, the net offshore bar migration lasts for several years and is not coupled to individual storms, or even groups of storms. Note, for instance, that wave heights that at the Surfers Paradise would trigger a NOM episode result in only a minor change in sandbar position at Egmond. The major difference between Egmond and Surfers Paradise is the size of the sandbars (Figure 6). Because the sediment volume involved in sandbar migration strongly controls the relaxation time and the morphological inertia within the sandbar system, we suggest that small sandbars (maximum height < 0.5-1 m), such as along the Gold Coast, exhibit episodic NOM, while large and hence more inert sandbars (maximum height of 1 m or more), such as found along the Dutch coast, develop interannual NOM.

Acknowledgments

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References

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