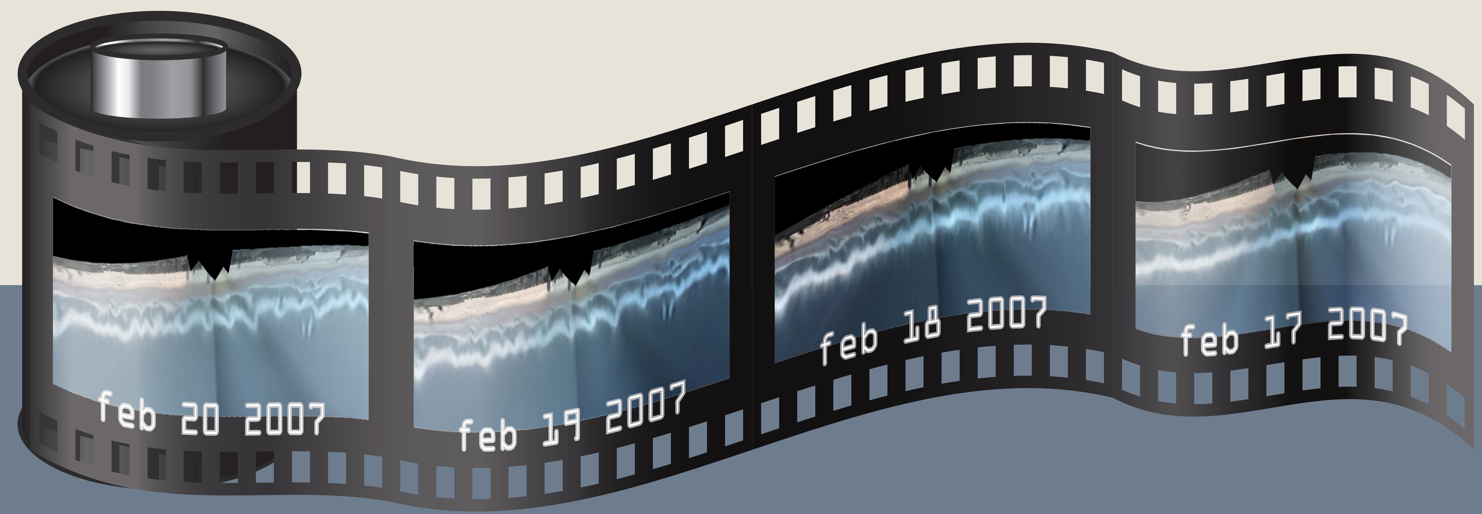
Dynamical Attractors for Sandbar Behavior



Abstract

Alongshore sandbars are often present in the nearshore zones of storm-dominated micro-to mesotidal coasts. The processes generated by waves and wave-breaking cause changes in sandbar shape and location. Sandbar behavior can be modeled with a feedback model that describes how the sandbar shape and position change with respect to some equilibrium state. We study the properties of this dynamical attractor as a function of the wave height.

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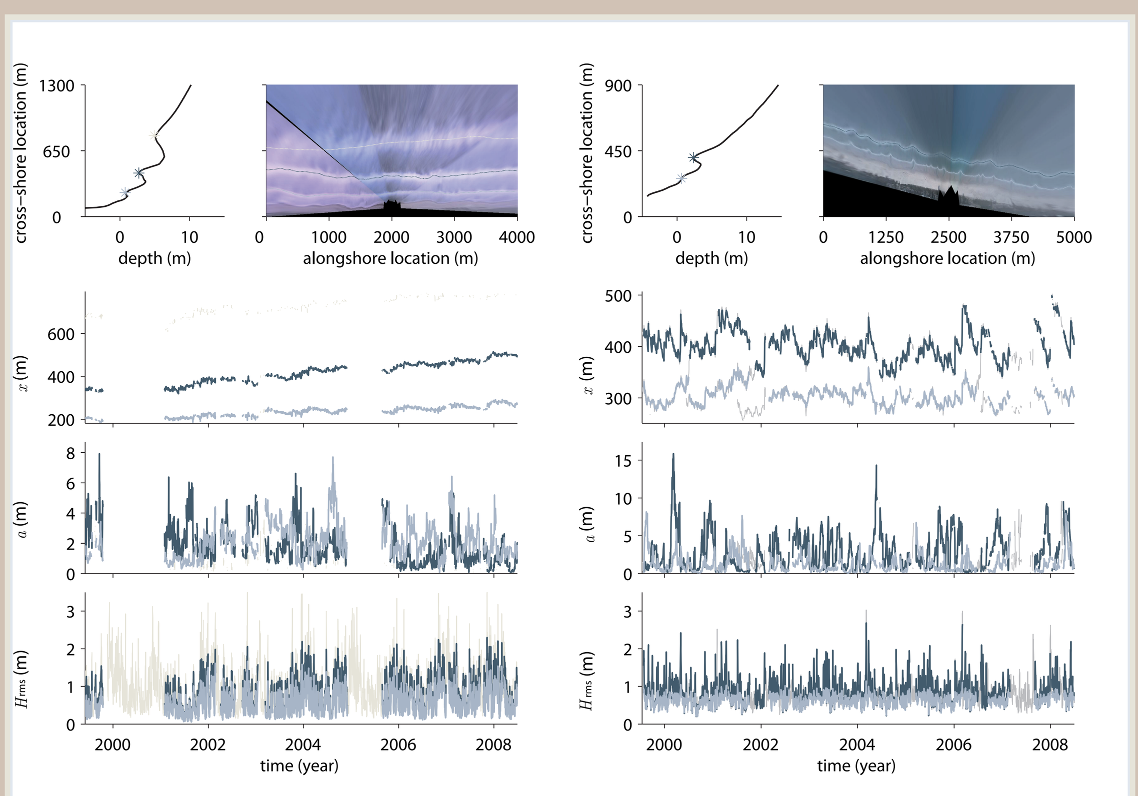
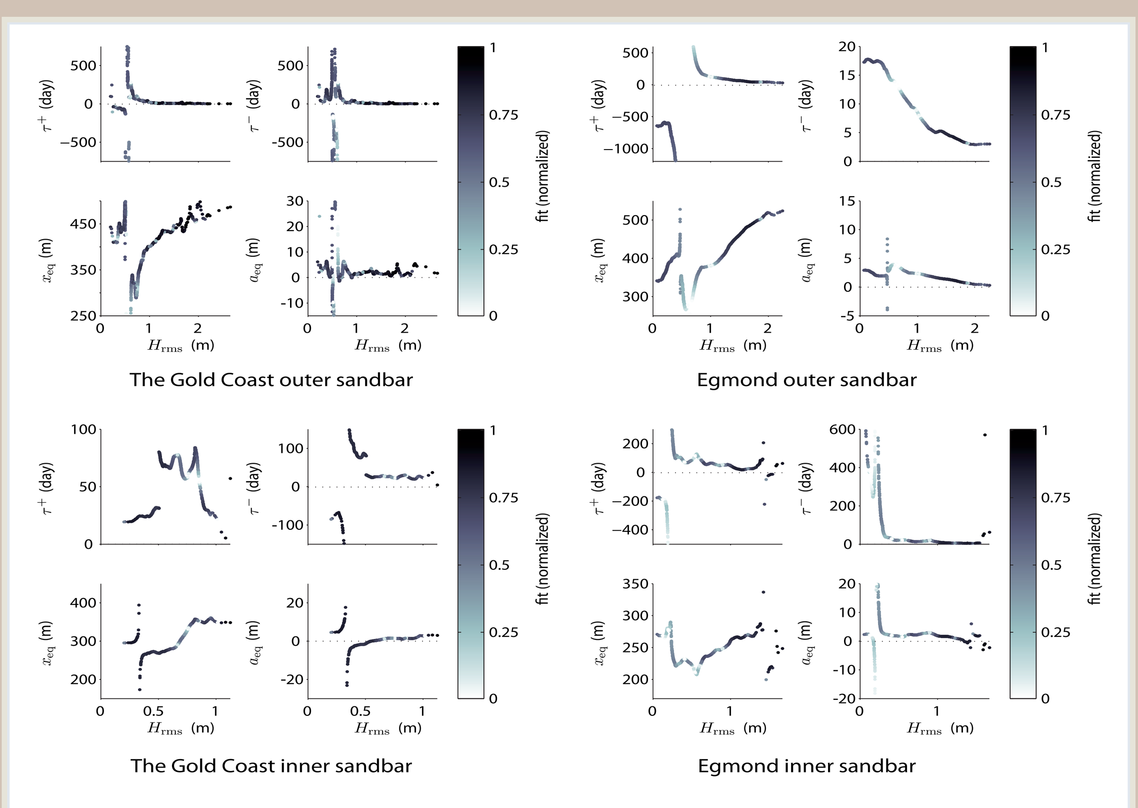
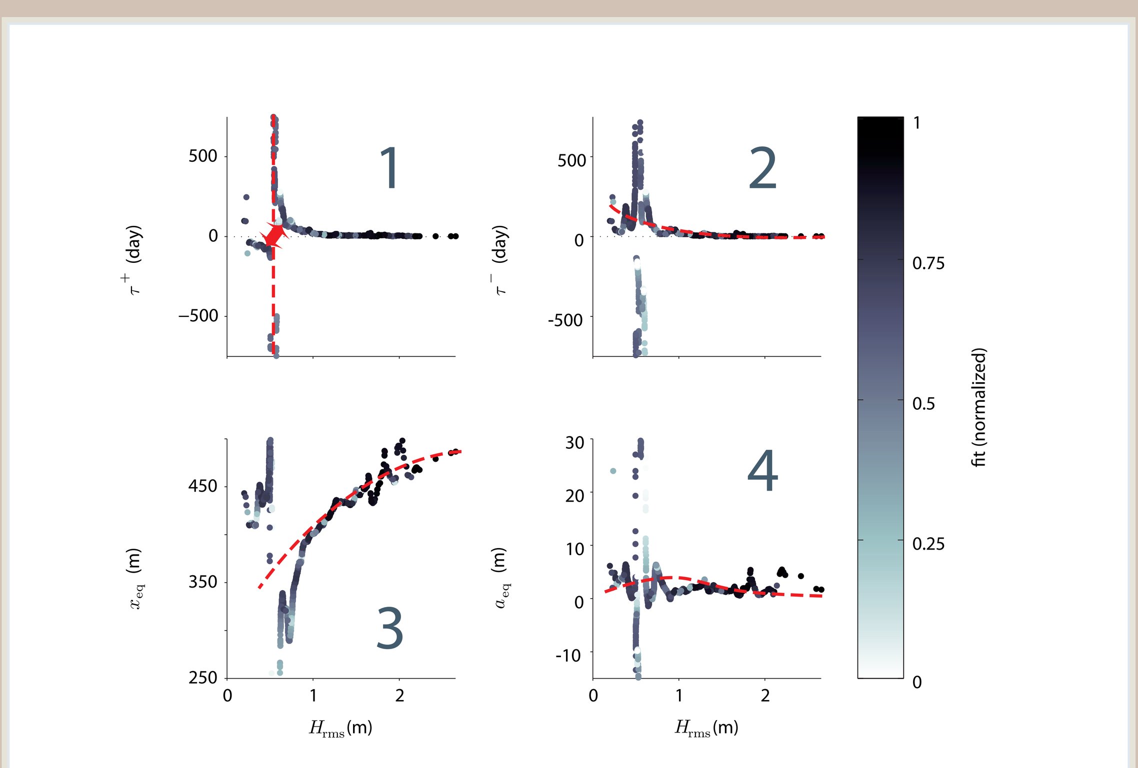


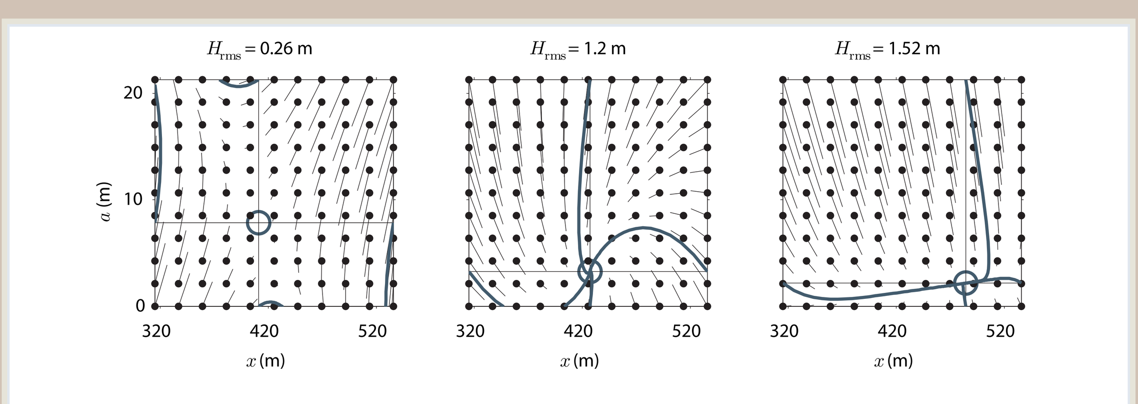
The Gold Coast data — Egmond data



Equilibrium states and response times for all datasets



Equilibrium states and response times for The Gold Coast outer sandbar



Phase portraits for The Gold Coast outer sandbar

Data

Sandbar and wave data are available in the Argus program. Each hour an image of the nearshore zone is taken. Waves breaking on the sandbar crest cause high intensity (white) bands in the images. An alongshore tracking algorithm finds the cross-shore position of maximum intenstiy for each sandbar. Average cross-shore sandbar positions x and amplitudes of crescentic shapes a are computed from the tracked sandbar positions each day. Data of the main forcing factor, the incoming waves, are measured at offshore located buoys and averaged over one day. Local wavheights $H_{\rm rms}$ seaward of each sandbar are computed using a wave-transformation model and several measured profiles. Two datasets with different sandbar behavior are used; (1) The Gold Coast, Australia and (2) Egmond, The Netherlands.

Analysis

A sandbar is driven toward the cross-shore location of maximum wave breaking. This equilibrium location $x_{\rm eq}$ moves seaward with increasing waveheight. The alongshore variability of a sandbar is captured in the crescentic shape amplitude. During periods with intermediate and small waveheights, crescentic shapes start to develop and increase in amplitude. The crescentic amplitude might not grow towards an equilibrium state $a_{\rm eq}$, but it is bounded at both the seaward and landward side.
The time it takes for a sandbar to reach the equilibrium location and crescentic amplitude for a certain waveheight, is the response time τ. The response time is generally larger than the timescale of the change in wave properties, which means that sandbar behavior can be characterized by evolution toward an ever-changing equilibrium state.

We use a linear empirical feedback model based on observations to study how the response times and equilibrium states of the sandbars depend on the wave height:

$$\frac{d}{dt}X(t)=AX(t)+BF(t)$$

with

$$X(t)=\begin{bmatrix} x(t) \\ a(t) \end{bmatrix}$$

and

$$F(t)=\begin{bmatrix} 1 \\ H_{\rm rms}(t) \end{bmatrix}$$

and A and B are 2x2 matrices. The cross-terms in A allow for the inclusion of feedback terms between cross-shore sandbar position and crescentic shape amplitude.

The eigenvalues of A and $A^{-1}\ B\ F$ give the response times, coupling and equilibrium states for a given wave height. Using a linearization procedure we infer the values of matrices A and B for each wave height in the data. From this we derive how the equilibrium states and response times change as a function of the wave height.

Results

We plot the equilibrium states and response times as functions of the wave height and find:

- the cross-shore sandbar position and crescentic amplitude are coupled for lower waves, but uncoupled for higher waves
- response of crescentic amplitude is much faster than response of the sandbar position

1. system switches to different mode of behavior at wave heights of 0.3 (inner) or 0.5 (outer) meter; probable causes: ~~noise~~, ~~presence of inner sandbar or shoreline~~, onset of wave breaking?
2. response time decreases with increasing wave height
3. equilibrium sandbar position does ***not*** scale quadratically with the wave height, but with the square root of the wave height
4. equilibrium crescentic amplitude reaches maximum for intermediate waveheights

Conclusion

Sandbar systems evolve toward a dynamical equilibrium that is a function of the wave height. For non-breaking waves the system moves away from equilibrium (unstable). During periods with low wave heights the coupling between crescentic structures and sandbar position is important. For higher waves the response time of the crescentic amplitude is smaller than that of the cross-shore position, and the crescentic shapes do not affect the cross-shore sandbar position.