Morphological Response to Low Frequency Motions in the Surf Zone

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Low frequency gravity wave motions such as edge waves and leaky waves (Ursell, 1952) as well as low frequency vorticity motions such as shear waves (Bowen and Holman, 1989) have been the subject of intense research in the last two decades. One of the reasons these motions are of interest to the coastal researcher is that their temporal and spatial scales generally correlate well with the scales associated with longshore periodic morphological features (e.g. Holman and Bowen, 1982). The aim of this study is to utilize numerical experiments to explore the link between low frequency surf zone motions and the movement of the bottom.

Approach

The coupled evolution of the short wave field, the induced low frequency climate and the morphological response is an extremely complicated problem. Interactions and feedback mechanisms between all three elements exist. We concentrate on isolating the interaction between the low frequency gravity or vorticity climate and the bottom bathymetry. Since this is still a considerably difficult task, we approach the problem by keeping our modeling equations as simple as possible while still retaining leading order effects. The model equations used for the water and bottom motions are described below.

The nonlinear shallow water equations dictate the time dependent behavior of the short-wave averaged water surface elevation and velocities. The equations include the effects of unsteady forcing due to the radiation stress created by modulated short waves. Also included are the effects of dissipation due to bottom friction and lateral momentum mixing induced by turbulence and the depth variations of the current velocities. The evolution of the short wave climate is modeled using the time dependent energy equation for the short waves. The irrotationality of the wavenumber is used to account for refraction effects of the short waves. The model has been extensively tested and used to simulate generation and propagation of gravity motions such as subharmonic edge waves (Özkan-Haller and Kirby, 1997) as well as vorticity motions such as shear instabilities of the longshore current (Özkan-Haller and Kirby, 1998).

In the scope of this study we also consider the time dependent evolution of the ocean bottom. In order to compute the coupled evolution of the bottom in relation to edge waves or shear waves, we adopt a conservation equation for the bottom that states that the still water depth will change due to differences in the inflow and outflow of sediment flux. Such a principle can be expressed as

$$\frac{\partial h}{\partial t} + \nabla \cdot \vec{q} = 0 \tag{1}$$

where h is the water depth measured from the still water level and $\vec{q}$ is the volumetric sediment flux rate due to bedload and suspended sediment transport. The specification of the sediment flux is of course a complicated matter. Preliminary results have been obtained by retaining a very simple expression due to Schielen *et al.* (1993) for the sediment transport rate with the objective of identifying possible physical mechanisms. Such an approach has so far led Falqués *et al.* (1996) to a better understanding of bed-flow instabilities in the presence of a longshore current. However, the modeling scheme is such that the effect of more sophisticated expressions for the sediment transport rate can also be investigated.

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Results

Computations have been carried out to observe the coupled variation of the bottom bathymetry in relation to shear instabilities of the longshore current. Shown here is a case where the bottom bathymetry is initially planar and the incident short waves approach the beach obliquely creating a longshore current that subsequently develops longshore progressive instabilities. Snapshots of the the resulting vorticity field are shown in Figure 1 and are typical of shear wave evolution. The initial longshore uniform current develops vortex pairs that are released offshore. Figure 2 shows the corresponding bottom evolution. Depicted is the departure of the bottom from a plane beach. We note that the vortex pairs cause the erosion of the nearshore region. The sediment is then carried further offshore by the vortex pairs. These preliminary results suggest that energetic vorticity motions have the potential to strongly influence large scale nearshore sediment dynamics.

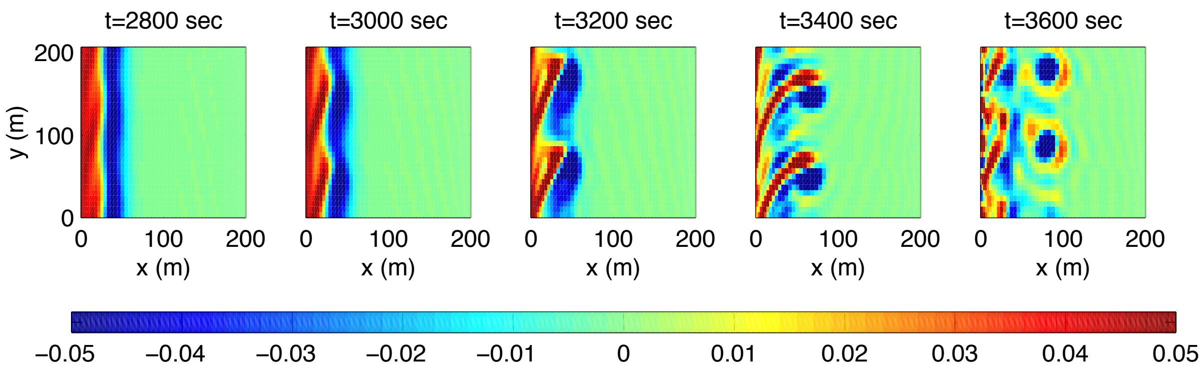

Figure 1: Snapshots of vorticity (1/s)

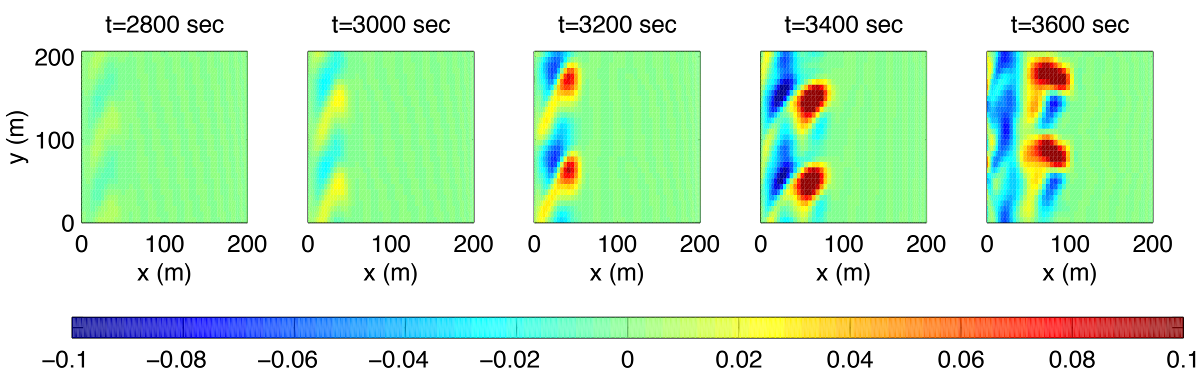

Figure 2: Snapshots of the bathymetry (departure from a plane beach) (m).

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