Instabilities and Nonlinear Evolution of Wave-Induced Longshore Currents in the Surfzone

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Obliquely incident waves on open coastal beaches generate a strong, longshore-directed jet confined between the mean shoreline position and the outer edge of the surfzone. The resulting longshore current is strongly sheared in the cross-shore direction, with shears on the order of 0.01 - 0.05 s^{-1}. The profiles have an inflection point on the seaward side of the profile and should be unstable to small wavy perturbations in the longshore direction. Linear stability analysis confirms this and predicts growing waves with maximum growth rates at frequencies on the order of 0.001 Hz. These waves are known in the coastal oceanography literature as "shear waves".

In this study, we employ a pseudospectral solution of the nonlinear shallow water equations (Özkan-Haller and Kirby, 1997) in order to study the long-time evolution of instabilities. The results depend strongly on the nature of the beach profile studied and on the relative importance of frictional effects, with instabilities evolving to both regular and chaotic wave trains through pathways dominated by vortex pairing events. Figure 1 illustrates a characteristic vorticity field evolving over a barred beach profile, with the beach located along the left of each panel and the surfzone confined to a region within 100 m of the left boundary. The longshore current is flowing from bottom to top in each panel. The predicted flow fields are controlled primarily by two standard parameters, a bottom friction coefficient and a coefficient representing the effect of vertical current variations on cross-shore mixing of time-averaged momentum flux (denoted as dispersive mixing). The friction coefficient largely determines the magnitude and cross-shore distribution of the mean longshore current, which is nearly insensitive to the balance between dispersive mixing and the effects of Reynolds stresses induced by the large scale shear waves. The dispersive mixing coefficient controls the balance between dispersive and large scale mixing effects, effectively controlling the energy level in the shear wave climate. Resulting longshore currents and spectra of shear wave fluctuations are compared to field data, and reasonable agreement is found. Additional documentation may be found in Özkan-Haller and Kirby (1998), who examine a range of conditions during the 1986 SuperDuck field experiment.

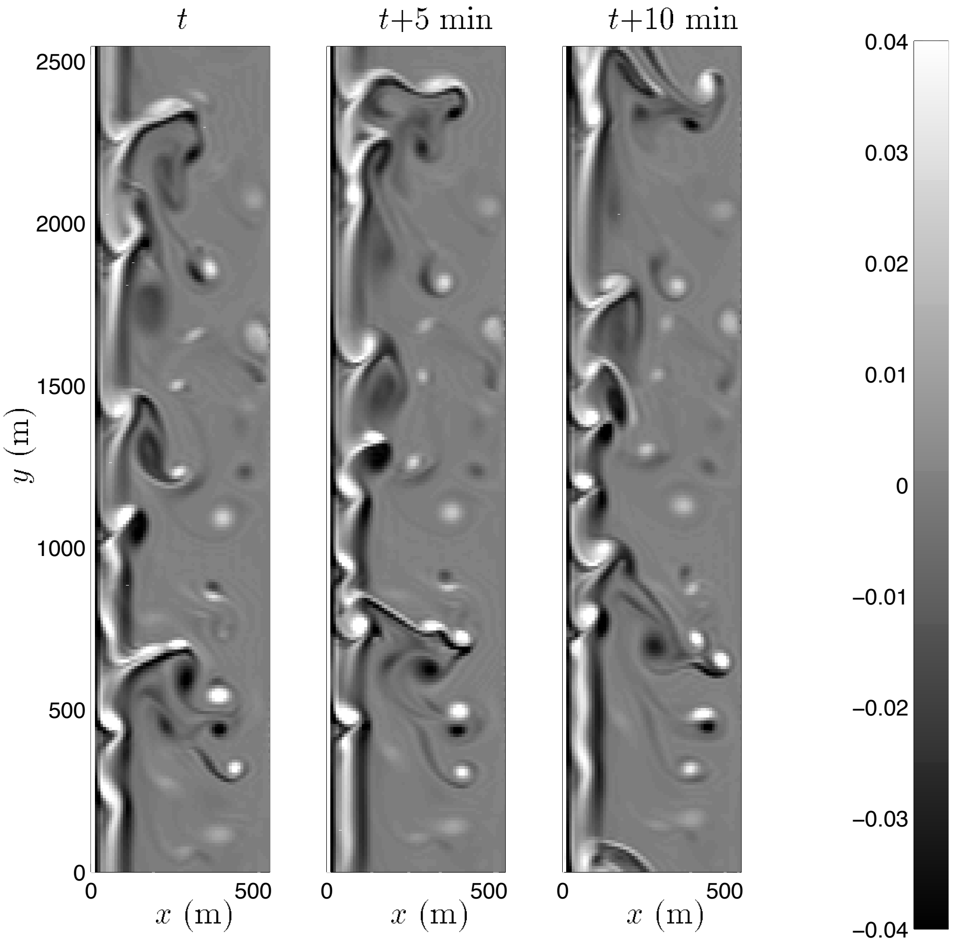

Figure 1: Three snapshots of the flow field associated with an unstable longshore current over a barred beach profile. Beach is to the left in each panel.

References

Özkan-Haller, H. T. and Kirby, J. T., 1997, "A Fourier-Chebyshev collocation method for the shallow water equations including shoreline runup", *Applied Ocean Res.*, **19**, 21-34.

Özkan-Haller, H. T. and Kirby, J. T., 1998, "Nonlinear evolution of shear instabilities of the longshore current: A comparison of observations and computations", submitted to *J. Geophys. Res.*