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Morphogenesis and morphodynamics of sandy beaches

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In this experimental project, we study the development of a granular cross-shore beach profile under water wave forcing. We generate waves in a narrow flume 3 m long and 8 cm wide, which contains light plastic particles. Waves propagate through a deep water region ($h_0 \approx 10$ cm) before attaining an erodible beach. The shear stress exerted by the waves on the granular bottom produces transport and modifies the beach profile until an equilibrium is reached. Using a homogeneous lighting from the side, we measure by contrast the incident wave amplitude and reflection coefficient in the deep region, as well as the wave asymmetry and wave height in the breaking zone. Thus far two parameters are controlled: incident wavenumber k_0 and wave amplitude a_0. By keeping constant the deep water depth, we change the initial beach slope, showing that this initial condition does not influence the final profile in the zone after breaking (swash zone).

By using wave energy conservation and wave breaking criteria, we predict and measure experimentally the breaking depth h_b and the length of the swash zone, where the breaking point is indicated by the maximum wave height H_b and the minimum mean water level. Our experiments follow the relation $h_b = (\tanh k_0 h_0 / (\gamma k_0))^{1/5} H_0^{4/5}$ [1], where k_0, h_0 and H_0 correspond to the incident wavenumber, depth and wave height, respectively; and $\gamma = H_b/h_b$ is the breaking ratio ($\gamma \approx 0.8$, given by the literature in ocean waves, agrees very well with our experiments).

The beach length, slope and curvature are determined by the several contributions, among which stand out the grain density and size, the shear stress and the wave dissipation [2]. By measuring the surface displacement in the swash zone and using mass conservation, we estimate the fluid velocity near the bottom and consequently the critical shear stress. In addition, we measured experimentally the viscous fall velocity of the grains u_∞. These variables, together with the reflection coefficient which sets the net mass transport, permit us to model and verify experimentally the beach cross-shore profile. Particular attention is given to the beach step [3,4] generated by a backwash vortex [5] under certain physical conditions.

In the following, our goal is to obtain quantitative results describing the dynamic of the phenomenon and contributing to the physical understanding of the beach morphology.

References

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