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Development and stability of bed forms: a numerical analysis of dune pattern coarsening and giant dunes

Xin GAO, Clement NARTEAU, and Olivier ROZIER

Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Univ Paris Diderot, UMR 7154 CNRS, 1 rue Jussieu, 75238 Paris Cedex 05, France (narteau@ipgp.fr).

We investigate the development and stability of transverse dunes for ranges of flow depths and velocities using a cellular automaton dune model. Subsequent to the initial bed instability, dune pattern coarsening is driven by bed form interactions. Collisions lead to two types of coalescence associated with upstream or downstream dominant dunes. In addition, a single collision-ejection mechanism enhances the exchange of mass between two consecutive bed forms (through-passing dunes). The power-law increases in wavelength and amplitude exhibit the same exponents, which are independent of flow properties. Contrary to the wavelength, dune height is not only limited by flow depth but also by the strength of the flow. Superimposed bedforms may propagate and continuously destabilize the largest dunes. Then, we identify three classes of steady-state transverse dune fields according to the periodicity in crest-to-crest spacing and the mechanism of size limitation. In all cases, the steady state is reached when the bed shear stress in the dune trough regions is close to its critical value for motion inception. Such a critical shear stress value is reached and maintained through the dynamic equilibrium between flow strength and dune aspect ratio. Comparisons with natural dune fields show that many of them may have reached such a steady state. Finally, we infer that the sedimentary patterns in the model may be used to bring new constraints on the stability of modern and ancient dune fields.