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In desert, complex patterns of dunes form. Under unidirectional wind, transverse rectilinear dunes or crescent shaped dunes called barchan dunes can appear, depending on the amount of sediment available. Most rectilinear transverse sand dunes are observed to fragment, for example at White Sands (New Mexico, United States of America) or Walvis Bay (Namibia).
We develop a reduced complexity model to investigate the morphodynamics of sand dunes migrating over a non-erodible bed under unidirectional wind. The model is simply based on two physical ingredients, namely, the sand capture process at the slip face and the cross-wind sand transport. The efficiency of the sand capture process is taken to be dependent of the dune height and lateral diffusion is considered on both the windward and lee sides of the dune. In addition, the dune cross section is assumed to be scale invariant and is approximated by a triangular shape. In this framework, the dune dynamics is reduced to the motion of a string representing the dune crest line and is expressed as a set of two coupled nonlinear differential equations.
This simple model reveals its ability to reproduce basic features of barchan and transverse dunes. Analytical predictions are drawn concerning dune equilibrium shape, stability and long-term dynamics. We derive, in particular, analytical solutions for barchan dunes, yielding explicit relationships between their shape and the lateral sand diffusion; and analytical predictions for the migration speed and equilibrium sand flux. A stability analysis of a rectilinear transverse dune allows us to predict analytically the wavelength emerging from fluctuations of the dune crest. We also determine the characteristic time needed for the rectilinear dune to fragment into a multitude of barchan dunes. These outcomes show that extremely simple ingredients can generate complex patterns for migrating dunes.
From several dune field data, we are able to determine values of the model parameters and in particular the intensity of the lateral sand diffusion on upwind and downwind sides of the dune, bringing a new light on sediment transport processes.