Geophysical Research Abstracts
Vol. 14, EGU2012-3546, 2012
EGU General Assembly 2012

Morphodynamics of star dunes

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Star dunes are among the biggest and the most impressive dunes in Earth sand seas. Nonetheless, they remain poorly studied, probably because of their apparent complexity. They are massive pyramidal dunes with interlaced arms whose slip faces are oriented in various directions. Being large, they can integrate wind properties over a wide range of time scales. Thus, they are observed for wind regimes with multiple directions, and may result from the amalgamation of dunes or from the development of arms on a well-established dune pattern. In both cases, the roles of wind directional variability and secondary flow have been emphasized but not precisely quantified. Here, we report simulations where the star dune shape results from a a combination of longitudinal dunes, which form the star dune arms. These arms may radiate and so interact with the other dunes in the field. This mass exchange, controlled by the morphodynamics of star dunes arms, must play an important role in the large-scale arrangement of star dunes networks. We first demonstrate that star dune arms orientation maximizes the flux in the direction of crests. This is opposed to the usually admit dunes orientation, which maximizes the sediment transport perpendicular to the crest. Indeed, depending on sand availability, dunes development results from the growth of a wave on a sand bed or from a net transport of sediment, which grows and extends an isolated longitudinal dune over a non-erodible soil. These two different mechanisms lead to two different modes of crests orientation. Then, we show that the propagating arms reach a stationary state characterized by constant width, height and growth rate. These are controlled by the frequency at which the wind changes direction. Arm width and height increase, whereas the propagation speed decreases with a decreasing frequency. These morphodynamics properties are helpful to assess from pattern observation the variability of wind directionality over several time scales.