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Direct validation of dune instability theory

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Modern dune fields are valuable sources of information for the large-scale analysis of terrestrial and planetary environments and atmospheres, but their study relies on understanding the small-scale dynamics that constantly generate new dunes and reshape older ones. Here, we designed a landscape-scale experiment at the edge of the Gobi desert, China, to quantify the development of incipient dunes under the natural action of winds. High-resolution topographic data documenting 42 months of bedform dynamics are examined to provide a spectral analysis of dune pattern formation. We identified two successive phases in the process of dune growth, from the initial flat sand bed to a meterhigh periodic pattern. We focus on the initial phase, when the linear regime of dune instability applies, and measure the growth rate of dunes of different wavelengths. We identify the existence of a maximum growth rate, which readily explains the mechanism by which dunes select their size, leading to the prevalence of a 15-m wavelength pattern. We quantitatively compare our experimental results with the prediction of the dune instability theory using transport and flow parameters independently measured in the field. The remarkable agreement between theory and observations demonstrates that the linear regime of dune growth is permanently expressed on low-amplitude bed topography, before larger regular patterns and slip faces eventually emerge. Our experiment underpins existing theoretical models for the early development of eolian dunes, which can now be used to provide reliable insights into atmospheric and surface processes on Earth and other planetary bodies [1].

[1] L. Ping, C. Narteau, Z. Dong, P. Claudin, S. Rodriguez, Z. An, L. Fernandez-Cascales, C. Gadal, and S. Courrech du Pont, P.N.A.S. **118**, 17, (2021)

Fig. The mobile anemometer mast and incipient dunes.