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Dune linear stability analysis under multidirectional wind regimes

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Terrestrial sand seas show a variety of dune patterns reflecting the diversity of the wind regimes under which they formed. However, despite the growing interest in dune dynamics, there is still no description of the dune instability mechanism under multidirectional wind regimes. Here, we extend the two-dimensional linear stability analysis of a flat sand bed to three-dimensions to incorporate temporal changes in wind properties (strength and orientation) into the physical modelling of dune formation. Considering the simplest case of bidirectional flow regimes, we show that the transition from transverse to oblique or longitudinal patterns is controlled by the transport ratio N and the divergence angle θ between the two flow directions. These results agree with field observations and can be compared to the theoretical predictions of Courrech du Pont *et al*. (2014) to evaluate the feedback of dune shape on flow speed. In addition, our analysis shows that the most unstable wavelength does not depend only on the saturation length L_{sat}, with a hydrodynamic prefactor characterizing the flow over a wavy bottom, but also on the relative shear velocity. Under a multidirectional flow regime, we highlight the dependence of the wavelength on the distribution of sand flux orientation. We find that wider distributions produce larger wavelengths.