Explaining the origin of planetary bedforms across the discrete-continuum boundary in granular transport

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Wind-blown sand surfaces on Earth, Mars, and other planetary bodies are covered by multiscale bedforms. There are currently two ways to understand their physical origin: a hydrodynamic instability associated to spatial transients in a continuum description of sand transport, and a 'granular' instability arising from the discrete nature of grain motion within the transport layer. Field and experimental evidence on Earth, water and Mars suggests that there is no obvious scale separation between bedforms emerging from either mechanism, which lead to the question of which description (discrete or continuum) is the correct one to explain a given bedform. Here I will try to answer this question based on two dimensionless numbers, a Knudsen-like number defined as the ratio of the mean hop length and bedform wavelength, and a boundary layer number defined as the ratio of the transport layer height and the thickness of the inner boundary layer arising due to the bedform-induced flow modulation.