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The Origin of Aeolian Dunes – PIV measurements of flow structure over early stage protodunes in a refractive-index-matching flume

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Understanding the initiation of aeolian dunes poses significant challenges due to the strong couplings between turbulent fluid flow, sediment transport, and bedform morphology. While much is known concerning the dynamics of more mature bedforms, open questions remain as to how protodunes are formed, as well as the mechanisms by which they continue to evolve. The structure of the turbulent flow field drives the mobilization or deposition of sediment, thus controlling the initial formation of sand patches, yet is also strongly influenced itself by local conditions such as surface roughness and moisture. Furthermore, an additional feedback on the flow and transport is exerted by the sand patches themselves once they begin to form.

As protodunes begin to develop from this initial deposition, their morphologies possess unique characteristics involving a reverse asymmetry of the stoss and lee sides, wherein the crest begins upstream, close to the toe, and gradually shifts downstream toward the "regular" asymmetric profile exhibited by more mature dunes. However, these early stages of development also involve very gentle slopes and low profiles which make field measurements of the associated flow particularly challenging.

The current research effort involves a combination of field measurements, documenting the initiation and morphological development of sand patches and protodunes, in concert with detailed measurements of the flow-form interactions in a laboratory flume. The work presented herein focuses primarily on experiments conducted in a unique flow facility wherein high-resolution measurements of the turbulent flow field associated with the early stages of protodune development are obtained utilizing particle-image velocimetry (PIV) in a refractive-index-matched (RIM) environment. The RIM technique facilitates flow measurements extremely close to model surfaces as well as unimpeded optical access which are critical to understanding the flow-form coupling. A series idealized, fixed-bed models are fabricated to mimic the key morphological characteristics of early protodune development observed in the field, and the flow measurements

associated with them are analyzed to reveal the mechanisms controlling the bedform dynamics.