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Turbulent flow and sand dune dynamics: identifying controls on aeolian sediment transport.

C. Weaver and **G. Wiggs**

Arid Environmental Systems Research Group, Oxford University Centre for the Environment, Oxford, UK (giles.wiggs@ouce.ox.ac.uk)

Sediment transport models are founded on cubic power relationships between the transport rate and time averaged flow parameters. These models have achieved limited success and recent aeolian and fluvial research has focused on the modelling and measurement of sediment transport by temporally varying flow conditions. Studies have recognised turbulence as a driving force in sediment transport and have highlighted the importance of coherent flow structures in sediment transport systems. However, the exact mechanisms are still unclear. Furthermore, research in the fluvial environment has identified the significance of turbulent structures for bedform morphology and spacing. However, equivalent research in the aeolian domain is absent. This paper reports the findings of research carried out to characterise the importance of turbulent flow parameters in aeolian sediment transport and determine how turbulent energy and turbulent structures change in response to dune morphology.

The relative importance of mean and turbulent wind parameters on aeolian sediment flux was examined in the Skeleton Coast, Namibia. Measurements of wind velocity (using sonic anemometers) and sand transport (using grain impact sensors) at a sampling frequency of 10 Hz were made across a flat surface and along transects on a 9 m high barchan dune. Mean wind parameters and mass sand flux were measured using cup anemometers and wedge-shaped sand traps respectively. Vertical profile data from the sonic anemometers were used to compute turbulence and turbulent stress (Reynolds stress; instantaneous horizontal and vertical fluctuations; coherent flow structures) and their relationship with respect to sand transport and evolving dune morphology.

On the flat surface time-averaged parameters generally fail to characterise sand transport dynamics, particularly as the averaging interval is reduced. However, horizontal wind speed correlates well with sand transport even with short averaging times. Quadrant analysis revealed that turbulent events with a positive horizontal component, such as sweeps and outward interactions, were responsible for the majority of sand transport. On the dune surface results demonstrate the development and modification of turbulence and sediment flux in key regions: toe, crest and brink. Analysis suggests that these modifications are directly controlled by streamline curvature and flow acceleration. Conflicting models of dune development, morphology and stability arise when based upon either the dynamics of measured turbulent flow or mean flow.