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Sweeping up sand: coherent flow structures and sediment entrainment

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The concept of the existence of ordered structures within airflow has been explored by a handful of researchers over the last decade. Studies have identified the presence of structures associated with the turbulent bursting process using conditional sampling techniques on high frequency velocity measurements. Additionally, attempts have been made to relate these coherent structures to the aeolian sediment transport system. In this study quadrant analysis was used to identify near-surface coherent flow structures within wind velocity data measured over a flat, sandy surface in western Namibia. High frequency (10 Hz) data from a tower of sonic anemometers and saltation sensors were analysed to reveal the relationship between individual turbulent events and sand entrainment and subsequent transport.

Results reveal that the airflow is dominated by the presence of ejections and sweeps. In combination, they account for over 60% of all events. Ejections and sweeps have been recognised as the main constituents of the bursting process and result in the generation of turbulence, transferring energy from the mean flow. Although ejections were the most frequent event in the airflow (32-34%), they were not responsible for the majority of sediment transport (6-10%). Results indicate that the sediment transport system is essentially dominated by sweep events (48-57%). Interestingly, outward interactions were also responsible for a large proportion of sand transport (32-35%). These events contribute negatively to Reynolds shear stress and are relatively infrequent in the airflow. It is apparent that events characterised by a positive u' component are primarily responsible for aeolian sediment transport and this is discussed in relation to the importance (or otherwise) of kinematic stress to sediment transport.

The distribution of quadrant events with height highlights the relevance of the 'top-down' model for aeolian transport dynamics. Sweep events were more prevalent closer to the ground surface reiterating the notion of a translation of flow further from the surface to a positive horizontal quadrant event at the surface. Further analysis suggests that these sweep events, which represent a downdraft of turbulent flow towards the sediment bed, were the primary element of the airflow responsible for sediment entrainment (in contrast to sediment transport). This finding may have important ramifications for models of aeolian erosion.