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Vertical structure of aeolian turbulence in a boundary layer with sand transport

Zoe S. Lee and Andreas C.W. Baas
King's College London, Department of Geography, London, United Kingdom (zoe.lee@kcl.ac.uk)

Recently we have found that Reynolds shear stress shows a significant variability with measurement height (Lee and Baas, 2016), and so an alternative parameter for boundary layer turbulence may help to explain the relationship between wind forcing and sediment transport.

We present data that were collected during a field study of boundary layer turbulence conducted on a North Atlantic beach. High-frequency (50 Hz) 3D wind velocity measurements were collected using ultrasonic anemometry at thirteen different measurement heights in a tight vertical array between 0.11 and 1.62 metres above the surface. Thanks to the high density installation of sensors a detailed analysis of the boundary layer flow can be conducted using methods more typically used in studies where data is only available from one or just a few measurement heights.

We use quadrant analysis to explore the vertical structure of turbulence and track the changes in quadrant signatures with measurement elevation and over time. Results of quadrant analysis, at the 'raw' 50 Hz timescale, demonstrates the tendency for event clustering across all four quadrants, which implies that at-a-point quadrant events are part of larger-scale turbulent structures. Using an HSV colour model, applied to the quadrant analysis data and plotted in series, we create colour maps of turbulence, which can provide a clear visualisation of the clustering of event activity at each height and illustrate the shape of the larger coherent flow structures that are present within the boundary layer. By including a saturation component to the colour model, the most significant stress producing sections of the data are emphasised. This results in a 'banded' colour map, which relates to clustering of quadrant I (Outward Interaction) and quadrant IV (Sweep) activity, separate from clustering of quadrant II (Burst) and quadrant III (Inward Interaction).

Both 'sweep-type' and 'burst-type' sequences are shown to have a diagonal structure originating from the top of the boundary layer, indicating a downwards direction of eddy motion. While directionality of turbulence cannot be definitively determined, our results indicate that the top-down turbulence model is a suitable explanation, further supported by the presence of 'incomplete' eddies which originate at higher elevations but fail to extend to the surface. This provides the first evidence in support of a top down turbulence model as observed in aeolian geomorphology, and we present preliminary findings on its relationship to sand transport activity.

Lee, Z.S., Baas, A.C.W. (2016) Variable and conflicting shear stress estimates inside a boundary layer with sediment transport. Earth Surface Processes and Landforms; DOI: 10.1002/esp.3829