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3D boundary layer flow behaviour over a sandy beach surface: empirical and modelling analysis

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The aeolian movement of sand across and along back beach areas plays an essential role in the post-storm recovery of beach and dune systems, driving protodune formation and early stage embryonic dune forms that may go on to accumulate into foredune ridges. The response of the beach surface to wind forcing through lower boundary layer interactions with beach microtopography ultimately determines the degree of aeolian flux produced. Turbulent structures inside near-surface flow either inherited from outside the boundary layer or induced by the underlying sediment surface, are likely to play an important part in aeolian sediment transport patterns.

Using three vertical masts equipped with 16 x 3D sonic anemometers (50Hz sampling) in an array orientated parallel to the general incipient wind flow over the beach, several runs extending over 3 hours, captured a range of wind conditions operating at a beach site in Maghera Strand, Co. Donegal in NW Ireland. Detailed Terrestrial Laser Scans of the sand surface were also made before and after sampling campaigns to give detailed topographic measurements of the beach. These surface scans provided an underlying surface for 3D Large Eddy Simulation (LES) airflow modelling using computational fluid dynamics model OpenFOAM.

The combination of CFD modelling and multiple in situ anemometer measurements allowed detailed examination of a longitudinal transect of the boundary layer and its turbulence behaviour as the boundary layer developed over the beach surface. We interrogated the measured airflow for larger scale eddy migration through the boundary layer along with smaller turbulence features near the sediment surface. The instrumented array also provided field validation of the 3D LES modelling.

We found excellent agreement between modelled (CFD) airflow modelling and 3D sonic anemometer data which provides a further validation of CFD as a tool for accurately characterising boundary layer flow over aeolian surfaces. The work also highlights the complex nature of boundary layer behaviour with a range of spatial and temporal scales shown in turbulent structures driving aeolian sediment transport on natural sandy beach environments.