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Comparison of field measurements and CFD simulation of spatial offshore windflow patterns across a foredune system

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Aeolian sediment input into coastal dunes represents a key component of sediment budget analysis of beach-dune systems. Calculations of sediment input to the foredunes are traditionally based on onshore winds, often excluding the role played by offshore wind events. However, recent work has shown that offshore flows play an essential role in post-storm dune recovery and maintenance. As a perpendicular offshore flow meets the dune crestline the surface flow layer detaches from the ground and generates an area characterised by turbulent eddies in the dune lee slope. At some distance downstream the flow separates into an offshore "re-attached" component and a reversed component directed toward the dune toe, with the potential to transport sediment. The existence of flow separation or steering has previously been *qualitatively* linked with dune topography and angle of wind approach, but not yet quantitatively described.

This study was specifically developed to examine dune re-circulation airflow characteristics under a range of incident wind velocities and offshore directions. Field work was undertaken in April-May 2010 at Magilligan, Northern Ireland. Wind data was measured using a grid of ultrasonic anemometers deployed at the beach-dune surface covering an area of 90 m long-shore by 65 m cross-shore. The field investigation was supplemented by Computational Fluid Dynamic (CFD) simulations to help prepare the field test procedure and help site the rake of masts and it's mounting of ultrasonic anemometers. CFD simulations were also performed to explore the potential use and accuracy of CFD simulation in geomorphological investigations, and improve understanding of wind flow characteristics through 3D wind flow visualisation. Previous work by the authors has highlighted differences in the characteristics of leeward re-circulation and re-attachment patterns under scenarios of perpendicular and oblique offshore wind flows. In the present work, an attempt is made to identify the origin of unique spatial wind and flow separation and re-attachment characteristics discovered in the measured wind data. The ultrasonic anemometer measurements obtained on a grid 0.5 m above the terrain within the leeward recirculation zone indicated that the flow re-attachment points varies significantly along the fore-dune length.

The complimentary use of Computational Fluid Dynamics helps the investigation by allowing visualisation of basic wind flow characteristics. It also enables us to explore in detail whether the spatial wind flow features found in the leeward dune zone is primarily a function of subtle dune topography changes along the shoreline or whether terrain roughness at the windward and leeward zones is the dominant trigger in dictating leeside flow behaviour. Previous CFD simulation results were supported by our fieldwork measurements which suggested that the spatial wind distribution in the zone leeward of the fore-dune is in fact dependent on the changes in the topography along the dune crests with further correlations to wind direction and even wind speed. The work here attempts to quantify these influences.

In the present investigation a simplified geometry of the fore-dune surface terrain is created that closely mimics the 3-D topography but allows the isolation of terrain form, roughness and wind directional effects. We initially compare CFD results over the simplified 3-D fore-dune system with measured 3-D anemometry results then present simulations and comparisons for varying wind direction, terrain roughness and fore-dune form parameters. Results highlight that for offshore winds, relatively small undulations in foredune form may be the primary driver for the unique spatial distribution of the re-attachment point, more so than upstream roughness effects. It also confirms that dune orientation, relative to the offshore winds, is key in influencing alongshore steering or recirculating leeward flows and associated potential aeolian sand transport.