CFD AIRFLOW MODELLING OVER REVERSING TRANSVERSE RIDGES, MPEKWENI BEACH, SOUTH AFRICA.

Derek W.T. Jackson[1], Andrew Cooper[1], Andrew Green[2], Meiring Beyers[3], Errol Wiles[2], and Keegan Benallack[2]

[1]Centre for Coastal & Marine Research, School of Geography & Environmental Sciences, Ulster University, Northern Ireland, [2]Geological Sciences, University of KwaZulu-Natal, South Africa, [3]Klimaat Consulting & Innovation Inc. Guelph, Canada

Introduction: Reversing dunes [1,2] are relatively rare aeolian landforms that manifest apparently ‘stable’ dunefield dynamics with low net migration rates, and result in dunes effectively being ‘locked’ within a defined spatial area under strong bi-directional wind regimes. Unvegetated dunes are free to respond to the direct forcing of winds moving across their surfaces and can respond very quickly to changes in wind direction. How and why they move under bi-directional winds dictates the dynamics of the dunefield.

We still do not fully understand how surface airflow dynamics alters when flow quickly reverses over transverse dunes and when stoss slopes rapidly assume the tole of lee slopes and vice versa.

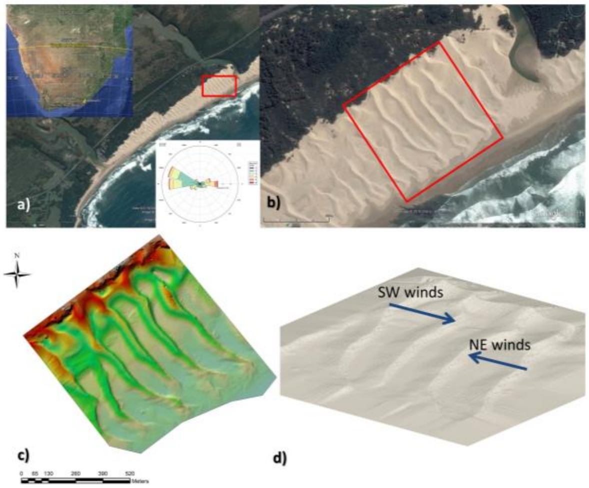

Fig. 1 (a) Mpekweni site and wind rose of Port Alfred (to west) (b) the northern section of the dune field surveyed (c) the TLS 3D area of computational domain over which the CFD model was run (d) bi-directional winds operating at reversing dunefield site.

Mpekweni is located on the Eastern Cape, South Africa and is subjected to strong bi-modal winds. The dune field is composed of sediment D_{50mean} of 0.28mm and is actively mobile between the fixed Pleistocene fossil dunes and the beach.

Methods: Using computational fluid dynamics modelling (OpenFOAM CFD code) with a RNG k-ε solver over a 3-D surface mesh [3], we present preliminary findings within a reversing transverse dune field at Mpekweni, Eastern Cape, South Africa. The main dunefield stretches 3km along the coast and is positioned between two estuaries, Mpekweni in the west and Mtati in the east (Fig. 1a,b) . Using a terrestrial laser scanner we surveyed an area of 750m x 750m to capture detailed topographic 3D dune surface to use in the CFD model.

CFD computational cell resolution was 1m x 1m, and two wind direction scenarios were considered; SW and NE winds (Fig.1 inset and d) which relate to local met rose at Port Alfred. Each simulation had a logarithmic inlet with an input of $10 ms^{-1}$ at 30m from the surface and a roughness parameter of 0.05m. Output was presented in the form of surface flow streamlines and superimposed over 3-D topo data. Cross-sectional slices of the boundary layer over the dunes was also presented to show detached and other flow characteristics.

Results:

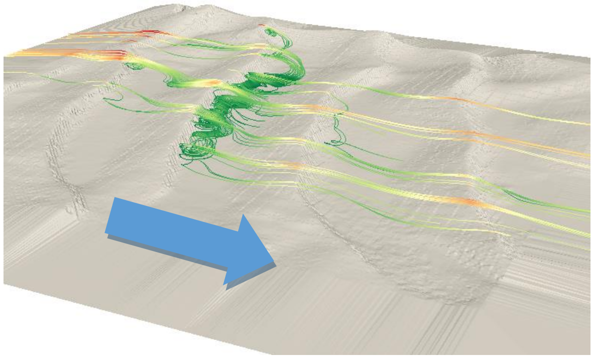

Fig. 2 Streamlines showing *detached* flow in lee and higher un-detached flow above crests under SW flows

SW flow results in:

- Dominance of lee slope flow separation
- Suppressed turbulence on stoss slope
- Stress more widely distribution on stoss slopes

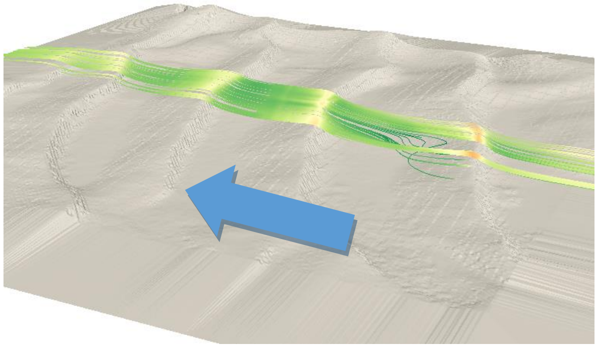

Fig. 3 Reversed wind direction (from NE) showing streamlines and largely *attached* flow in lee of dunes with now shaper inclined stoss slopes focussing flow to the crests

NE flow results in:

- Reduced flow separation
- Focussing of stress on crests
- Clustering of transport potential at crests?

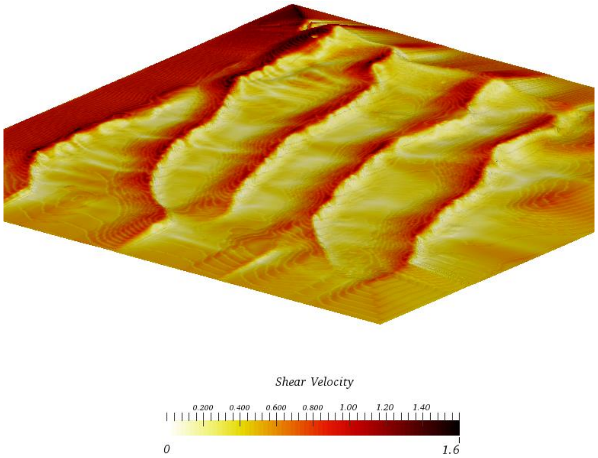

Fig. 4 Surface shear velocity plot showing a more even distribution of stress across the stoss slopes

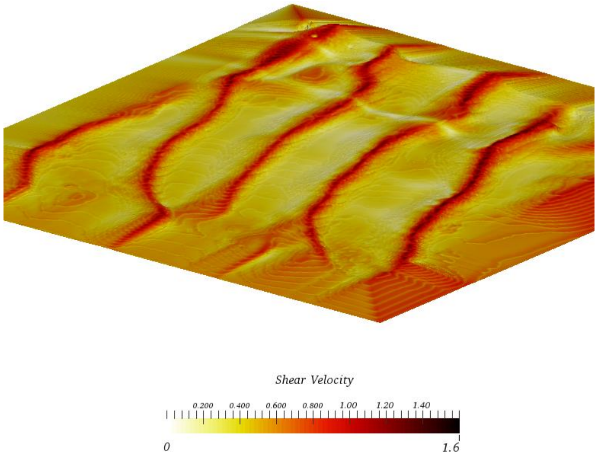

Fig. 5 Surface shear velocity plot showing a tightly focussed distribution of stress across the crest areas

Discussion & Conclusions: Results detail the behaviour of wind flow over transverse dunes under opposing (reversing) wind directions. During SW winds, flow behaves in a classic fashion where detachment and stoss side shear stress is evenly spread over gentle slopes with large undulating low shear zones in leeward wake of crests. However, when flow is flipped (NE winds), model results show more focussed stress along the crests and higher disturbance into the boundary layer over a less aerodynamic surface. These processes contribute to the reversing sequence these dunes undergo, with NE winds initially round the crests and then migrating dunes to the SW.

Main conclusions:

- Evidence of 3D flow, helical separation under SW winds i.e. significant flow steering and re-direction as the SW flow has more significant flow separation

- Simulated flow separation and steering for the reversed NE wind is heavily suppressed, likely due to the shallow change in the new ‘stoss’ slope.

- SW flow shows typical increased u* on the stoss slope (but distributed over larger area) and large undulating low shear zones in the leeward wakes.

- For NE winds, high shear is isolated to dune crests.

- Results highlight the complex nature of reversing transverse dunes, initially rounding the crests with focussed shear stress, then eventually reforming into fully transverse dunes in the opposite direction.

[1] Bristow et al. (2010) EPSL, 289, 30-42. Author A. B. and Author C. D. (1997) *JGR*, *90*, 1151–1154. [2] Burkinshaw et al. (1993) Geo. Soc. Lon., 72, 25-36. [3] Jackson et al. 2013 Geomorphology 187, 86-93.