ANOMALOUS SHEAR VELOCITY AT THE BRINK OF A BARCHAN DUNE

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We report transects of aerodynamic roughness z_0 and shear velocity u^* relative to an upwind reference $u^\star_\infty$ on and around a crescent-shaped barchan dune at $25°\,00'\,30''$N, $51°\,20'\,27''$E with 60 m toe-to-brink distance, 80 m horn-to-horn, and 4.5 m crest elevation above a relatively rough Qatar desert ground, using triads of ultrasonic anemometers positioned within the inner turbulent boundary layer [1] at altitudes z = 29 cm, 73 cm, and 115 cm above the sand surface, yielding vertical profiles of mean speed averaged during > 15 min intervals and fitted to the log-law $u = (u^*/\kappa)\ \ln(z/z_0)$, where $\kappa \simeq 0.41$ is Von Kármán's constant. Here, wind blew toward a bearing of 141° close to the 159° historical direction of this mobile dune [2].

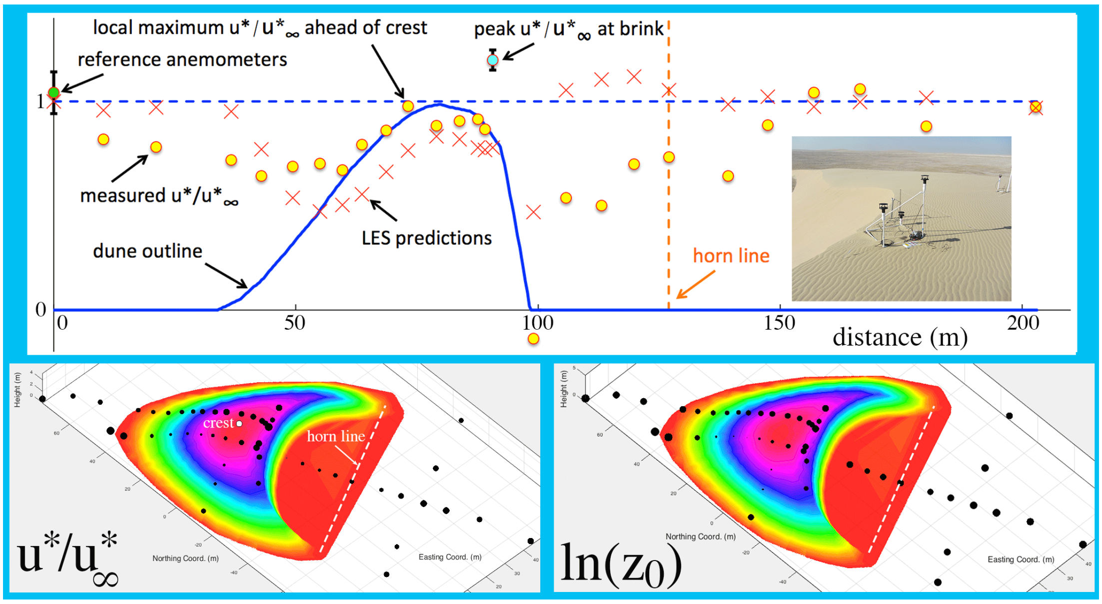

Figure 1. Top: longitudinal transect of u^* (yellow circles) and LES predictions (red crosses) relative to $u^\star_\infty$ at the green circle. Blue line: dune profile at the transect. Dashed lines join horn tips. $u^*/u^\star_\infty$ at the brink (cyan circle) is a factor 1.20 ± 0.05 higher than the local maximum at a distance $L_{\text{sat}} \simeq 6$ m ahead of the crest. Inset: roving anemometer triad near the brink line. Bottom: on the dune surface colored for altitude, the size of black dots grows with $u^*/u^\star_\infty$ (left) and $\ln[z_0(m)]$ (right).

As Fig. 1 shows, z_0 progressively adjusted from its relatively high $z_{0_\infty} = 5.3 \pm 0.5$ mm on hard ground to $z_0 = 0.16 \pm 0.02$ mm at the crest, while u^* first decreased, then progressively recovered as air climbed on the dune. Contrary to earlier models [3], a peak of $u^*/u^\star_\infty$ arose at the brink on the dune centerline. Large-eddy numerical simulations (LES) showed similar trends. However, $u^*/u^\star_\infty$ in the LES recovered closer downstream of the slip face than field measurements, which asymptoted back to 1 twice as far as the line joining horn tips. To the exception of a single wind reversal at the base of the avalanche, all profiles closely conformed to the log-law, and u from all three anemometers in the roving triad rose and fell in unison without discernable mutual lag along the transect [1].

References

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