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Aerodynamic surface stress intermittency and conditionally averaged turbulence statistics: insights for aeolian processes

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Aeolian erosion of dry, flat, semi-arid landscapes is induced (and sustained) by kinetic energy fluxes in the aloft atmospheric surface layer. During saltation – the mechanism responsible for surface fluxes of dust and sediment – briefly suspended sediment grains undergo a ballistic trajectory before impacting and 'splashing' smaller-diameter (dust) particles vertically. Conceptual models typically indicate that sediment flux, q (via saltation or drift), scales with imposed aerodynamic (basal) stress raised to some exponent, n, where $n > 1$. Since basal stress (in fully rough, inertia-dominated flows) scales with the incoming velocity squared, u^2, it follows that $q \sim u^{2n}$ (where u is some relevant component of the above flow field, $\overrightarrow{u}(\overrightarrow{x}, t)$). Thus, even small (turbulent) deviations of u from its time-averaged value may play an enormously important role in aeolian activity on flat, dry landscapes. The importance of this argument is further augmented given that turbulence in the atmospheric surface layer exhibits maximum Reynolds stresses in the fluid immediately above the landscape. In order to illustrate the importance of surface stress intermittency, we have used conditional averaging predicated on aerodynamic surface stress during large-eddy simulation of atmospheric boundary layer flow over a flat landscape with momentum roughness length appropriate for the Llano Estacado in west Texas (a flat agricultural region that is notorious for dust transport). By using data from a field campaign to measure diurnal variability of aeolian activity and prevailing winds on the Llano Estacado, we have retrieved the threshold friction velocity (which can be used to compute threshold surface stress under the geostrophic balance with the Monin-Obukhov similarity theory). This averaging procedure provides an ensemble-mean visualization of flow structures responsible for erosion 'events'. Preliminary evidence indicates that surface stress peaks are associated with the passage of inclined, high-momentum regions flanked by adjacent low-momentum regions. We will characterize geometric attributes of such structures and explore streamwise and vertical vorticity distribution within the conditionally averaged flow field.