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Interactions between surface roughness and airflow turbulence affecting drying dynamics of rough porous surfaces

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Evaporative drying of porous surfaces interacting with turbulent airflows is common in various industrial and natural applications. The intrinsic relief and roughness of natural porous surfaces are likely to influence the structure of interacting turbulent airflow boundary layers, and thus affect rates and patterns of heat and vapor fluxes from the surface. These links have been formalized in new mechanistic models that consider intermittent and localized turbulence-induced boundary layers, resulting in rich surface evaporation and energy exchange dynamics. The models were evaluated experimentally by systematically varying surface roughness elements in drying experiments of wavy and bluff-body covered sand surfaces in a wind tunnel. Thermal infrared signatures of localized evaporative fluxes as well as mean evaporative mass losses were recorded. The resulting patterns were in good agreement with model predictions for local and surface averaged turbulent exchange rates. Experimental and theoretical results suggest that evaporative water losses from wavy sand surfaces can be either enhanced or suppressed (relative to a flat surface), due to the complex interplay between the local boundary layer thickness and internal limitations on water flow to the evaporating surface. For sand surfaces covered by isolated cylindrical elements (bluff bodies), model predictions and measurements show persistent enhancement of evaporative fluxes from bluff-rough surfaces compared to a flat surface under similar conditions. This enhancement is attributed to the formation of vortices that thin the boundary layer over part of the interacting surface footprint. The implications of this study for interpreting and upscaling evapotranspiration rates from terrestrial surfaces will be discussed.