Surface Profiling of Natural Dust Devils

Conference or Workshop Item

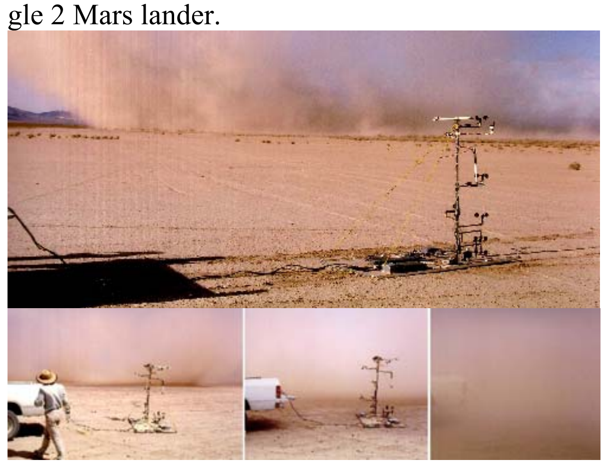
SURFACE PROFILING OF NATURAL DUST DEVILS. S.M. Metzger[1], M. Balme[2], R. Greeley[2], T. Ringrose[3], M. Towner[3], and J. Zarnecki[3], [1] Metzger Geoscience, 2875F Northtowne Ln, #165, Reno, NV 89512-2058, <dustdvl1@yahoo.com>, [2] Arizona State University, Dept. of Geol Sci, [3] PSSRI, Open University, UK.

Introduction: Although once thought of as interesting but inconsequential desert oddities, dust devils are now understood to be a major contributor to airborne dust loading in the arid regions of Earth and Mars. The vortex process(es) responsible for soil erosion, however, remain poorly articulated. Dust devils have complex, intense, and highly variable wind fields at their base due to changes in boundary layer meteorologic, geologic, and surface aerodynamic conditions.

Prior to 2002, the few field research efforts [1,2,3] obtained measurements at a single height, typically 2 m. Beginning in 2002, the authors have refined the chase-and-sample strategy by utilizing, for the first time, a near-surface (1 cm to 3.5 m) profiling array consisting of nearly 2 dozen instruments. Our research is intended to characterize dust devil land-atmosphere interface dynamics. This report will present findings obtained during our 2002 and 2003 field seasons, conducted on a strong mars analog site in southern Nevada. This information will continue to be applied to ground-truth the ASU Vortex simulator, Beagle 2 meteorological suite, and Mars surface observations.

Dust devils often move rapidly (≤10 m/s) over desert surfaces when propelled by ambient winds. Any sampling effort must physically cope with high-speed desert driving (≤ 100 kph) to reach the dust column, while handling rough terrain and protecting the instruments.

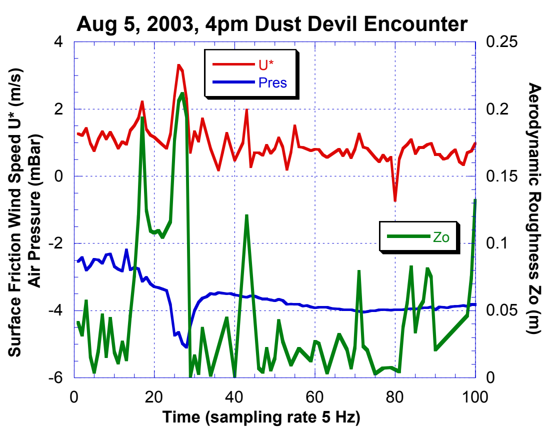
Methods: In 2002, our near-surface profiling array prototype COTBOTT (named for the deployment mode; "chucked off the back of the truck"…) consisted of 22 instruments on a 2 m vertical mast secured to a plywood test bed. COTBOTT successfully engaged over forty dust devils, either with a direct overpass by visible vortices or within effective range of their influence. Profiling capabilities included wind speed, wind direction, pressure, temperature, and electric field strength, in addition to single point measurements with dust and sand impact counters, and a UV photodiode array similar to that on the Beagle 2 Mars lander.



For the 2003 field season, we extended the mast to 3.5 m, refined sensor selection and placement, improved datalogger integration, and prototyped a forward-mounted terrain-following wishbone suspension. Now called the Dynamic Atmosphere-Surface Hardpan Environment Rig (DASHER), this system was able to chase the vortices as they swept rapidly across the playa, then pause and immediately begin data collection, resuming the chase as needed. Unfortunately, uncommonly thick cloud cover during the early monsoon season substantially inhibited thermal vortex production. Regardless, the system provided superb mobility and delivered excellent resolution profile data on the several vortices encountered.

Results: Based on a sampling rate of 5 Hz and a typical dust column-over pass duration of one-to-four seconds, wind profiles were used to determine the surface friction speed (u*) and aerodynamic roughness length (Zo). These calculations were then compared to results obtained from nearby stationary profiling meteorology mast and field wind tunnel data [4].

The following plot was derived from a modestly dusty devil captured over a transition surface between the playa and adjacent alluvial plain. The surface consisted of fine sand, silt, and clay bonded weakly into a friable crust (DASHER's truck tires sank 4 cm), with occasional small pebbles (≤2 cm). The dust column was 10 m wide and well over 200 m tall.



As measured by DASHER prior to the encounter, U* on the site was 1.1 m/s and Zo was 0.03 m. The stationary metmast results indicated the surface to have a surface roughness length (Zo) of 0.04 m. Wind tunnel results indicated an erosion threshold surface friction speed (U*t) of 1.4 m/s. During the dust devil's maximum action, U* rose to over 3 m/s (thus making the vortex "dusty"). Note that Zo increased by an order of magnitude. This is attributed to both the high airborne sediment load (which violates some of the conditions on which the equations are based) and, possibly, the change of wind direction (as Zo is orientation dependent on surface geometry, a factor which results from all the influences that create the surface, including climate and local topography).

Vortex core pressure dropped 3 mbar from ambient (1029 mbar). Furthermore, the pressure effect of the passing vortex took two minutes to return to background conditions. Thus, the influence of such thermal vortices is seen to extend well beyond and long after the visible column passes.

Conclusions: The forward-mounted instrument array has proven effective in sampling highly mobile phenomena over rough natural surfaces. Upcoming field sessions will utilize the suystem on a variety of surface types. The data derived from these encounters is consistent with ancillary data sets from the field area. On-going efforts to correlate encounter data with the extensive analysis of the region's geology will lead to the identification of those factors which inhibit or promote dust devil production. Researchers interested in desert surface process geomorphology and the atmospheric effects that stem from those surfaces are invited to collaborate.

References: [1] Sinclair, 1966, UofA dissert., [2] Ryan and Carroll, 1970, JGR v75, no. 3, [3] Metzger, 1999, UNR dissert., [4] Metzger, unpublished 1995 research

Eldorado Valley, NV field site: