METEOROLOGIC CONDITIONS AND THE FORMATION OF TERRESTRIAL DUST DEVILS. S. Metzger[1], M. Balme[1] and A. Pathare[1], [1]Planetary Science Institute, Tucson AZ (metzger@psi.edu)

Introduction: Dust devils are localized convective vortices which form after insolation bearing upon an arid surface results in a hot layer of ground-level air. In a terrestrial setting, such a hot air layer will persist if local winds do not exceed 8 ms^{-1} (depending on the sheltering effects of surface roughness elements) [1,2,3]. This layer is unstable and generates buoyant thermal plumes. Positive feedback draws in more heated ground-level air which then commonly develops rotational velocities whose ground surface shear stresses are sufficient to entrain particulate material from surfaces otherwise resistant to turbulent wind shear [4]. Of course, dust devils are also effective on the surfaces readily eroded by more familiar turbulent winds. On average, the Eldorado Valley, NV, field site experienced 42 large dust devils per summer day, each lofting over 200 kg for a daily total of 9 metric tonnes from this desert basin. This report concentrates on the ambient weather conditions in place while dust devils were active.

Surface response to solar heating – IR thermometer transects: If dust devils form from the hot air that develops in contact with a solar-heated desert floor, the extent of such heating must be determined. Beginning inn the summer of 1996 through to the most recent field campaign in 2008, a Raynger ST™ handheld Infrared thermometer was used to measure ground surface temperatures along three valley-crossing transects for a total of 74 km; one running N – S, two E – W; one each at either end of the playa. Measurements were repeatedly taken over several days of identical weather in ½ mile increments at marked roadside locations based on odometer readings and verified by GPS. The instrument's coverage area of 0.3 m^2 was sufficient to broadly incorporate soil, small scale vegetation, and rocks, if present. The surveys were conducted as early as 08:20 until as late as 18:30 local time, with each location measured four times.

Early morning ground temperature was 32°C at a time when the air temperature at 2 m was 31°C. The mean high surface temperature of 58°C was reached at 13:20, in some areas lasting until 16:00, when the air temperature was 38°C. Isolated plots of ground were able to achieve surface temperatures of nearly 63°C. By 18:30 the surface temperature had dropped to 40°C when air temperature was 36°C.

Note that air temperatures during the IR survey are higher than those presented on the dust devil frequency vs. valley wind conditions plots (discussed next) because those plots incorporate data from June and July; none the less, the August trends are relevant. These results indicate that desert soils in Eldorado Valley are characterized by low thermal conductivity. This enables them to be strongly heated by solar radiation that is subsequently transferred to the air layer immediately over the ground.

During the 2008 field campaign on the northern end of the playa, central section, wind was recorded using a hand-held hot wire anemometer at 2 m ht. On 6-02-2008, at 13:40, wind speed was 6.6 ms^{-1} and IR thermometer temperature of buff-tan silt/dust playa surfaces was 58.8°C while brown sand/silt patches were 60°C. At 14:20, wind speed was 10.2 ms^{-1} at 2 m ht. and 2.3 ms^{-1} at 0.01 m ht, originating from 220-255° True. At 15:30, buff-tan patches were 52.2°C while brown patches were 53.9°C. At 15:35, air temperature was 35°C (dial thermometer).

On 6-5-2008, playa surface temperatures were 51.1°C at 12:10, 54.4°C at 13:12, 48.9°C at 15:46, 46.1°C at 16:04, and 43.3°C at 16:32.

Dust Devil Activity Characterization: To date, we have systematically logged 844 dust devils in the EV site. It is important to emphasize that a great many small or nearly-transparent dust columns, clearly visible at close range, where not apparent to the spotter and thus are not included in this tally.

Timing, duration, physical features: Although various single factors can impede dust devil formation, a state-wide survey failed to reveal a single Nevada basin or valley in which *some* dust column vortices would not develop, given the prerequisite of dry soil and clear skies. Most dust-laden vortices (over 95%) were V-shaped and attained less than 500 m height (based on a visual estimation of the point where the dust plume was no longer discernible). A minority of dust devils (less than 4%) was sharply defined columns that could reach over 2 km in height (as detected visually with the aid of polarized lenses). On rare occasions two other vortex structures were observed; (1) broad, very diffuse columns of irregular widths but considerable height, and (2) small, sinuous, and highly dynamic "rope" structures of short duration. The largest columns attained widths of 100 m. There was no minimum height nor width and many large vortices went through moments of considerable downsizing and dissipation before rejuvenating into robust vortices.

Dust devil activity extended from 10:00 local time until 18:00, peaking in the early afternoon. Daily tallies ranged from 15 to over 90 dust devils visible to the spotter (located on the valley edge several kilometers from most of the dust plumes), all on the flattest 40% of the valley floor (300 km^2). Whereas some vortices of either the V- or cylindrical-shapes would very rapidly disperse, many dust devils lasted for tens of minutes (average duration was 4 minutes) and traveled several kilometers. Dust devil duration was greatest in the late afternoon (~16:00) but a secondary maximum appears at ~11:30.

Frequency : Dust devils rarely formed on the proximal alluvial plain (2%). The medial plain was highly productive (58%), whereas the basin's center was moderately so (16%). Dust devils that formed over the medial plain displayed a slight tendency toward the less-organized, V-shaped type, whereas those that formed over the playa were slightly more likely to develop the "classic" tubular column. Both column types, however, occurred wherever dust devils were active. Intense dust-free thermal vortices were observed at several locations across Eldorado Valley that did not develop dust columns. Lacking a systematic means to detect such clear vortices, their occurrence could not be quantified.

Local wind conditions during dust devil activity Regional wind speed, direction and temperature were measured with instruments located at 2 and 10 m on a meteorology mast placed mid-valley for the duration of both field seasons. Data was recorded continuously at one second intervals, 24 hrs. per day, for several weeks each season, and then averaged into 15 minute bins.

Dust devils formed under wind conditions that ranged from calm to sustained winds of 8 ms^{-1}, gusting to 16 ms^{-1} (measured at 2 m). Vortices traversed several kilometers, especially on windy days, whereas their upper portions were sheared downwind ahead of their bases. Given that winds are driven by pressure gradients, themselves usually a result of thermal gradients, it is not surprising that daily wind speeds in the Eldorado Valley climb as near-surface (2m) temperatures rise. Until mid-afternoon, the number of dust devils increases in proportion to the rise in temperature but by 15:00 dust devil numbers begin to diminish. Conversely, the duration of the average dust vortex does continue to increase throughout the day as temperature and wind speed rise. The height of the dust columns, however, is likely to be greatest around 11:00 and then settle back to lower levels as the day develops. This period of maximum height also corresponds with the second maximum in dust devil duration. This may indicate that once well-structured thermal vortices are able to form in the morning, they can "punch through" the upper, still cooler levels. The situation should change when higher levels have warmed up later in the day, usually with the help of surface thermals and turbulent mixing from forced convection. In contrast, there is a greater temperature gradient earlier in the day.

References: [1] Sinclair, 1966, PhD dissertation, Univ. of AZ, Tucson [2] Ryan and Carroll, 1970, JGR v75, no3 [3] Metzger and Lancaster, 1995, EOS Transactions AGU, v76, no46, F66 [4] Gillette *et al.*, 1980, JGR v85, noC10