DETAILS IN THE DEVILS: PRELIMINARY RESULTS OF A FIELD INVESTIGATION OF PLANETARY BOUNDARY LAYER TURBULENCE AND DUST DEVIL GENERATION. L. K. Fenton[1], S. Metzger[2], T. I. Michaels[1], S. P. Scheidt[3], T. C. Dorn[4], B. Cole[5], O. Sprau[5], L. D. V. Neakrase[6], [1]SETI Institute, 189 Bernardo Ave, Suite 200, Mountain View, CA, USA, 94043 (lfenton@seti.org), [2]Metzger Geoscience Consulting, [3]Planetary Science Institute, [4]University of California Los Angeles, [5]St. Lawrence University, [6]New Mexico State University

Introduction: Dust-laden vortices (i.e., dust devils) in the buoyantly unstable daytime convective boundary layer of Earth and Mars are thought to be among the few visible markers of the structured turbulent eddies that comprise convective atmospheric motions. Because dust devil occurrence, and likely their spatial and temporal characteristics, are controlled by local environmental conditions, their study has the potential to reveal much about patterns of convective structures and areas of enhanced dust lifting.

We present preliminary results of an analog field campaign during which several suites of instruments simultaneously monitored dust devil activity and measured the local meteorological conditions. We seek to enable dust devil observations to constrain local meteorological conditions, both on Mars and in remote locations on Earth.

Analog field study: The goal of the field study was to obtain time-lapse stereo observations of dust devils simultaneously with high fidelity meteorological measurements, placed in a mesoscale and synoptic context using the North American Mesoscale Forecast System (NAM). Instruments were placed on the north end of the Smith Creek Valley playa in Nevada, aimed to capture dust devil activity both on the playa and the surrounding alluvium (**Fig. 1**). Instruments consisted of: (1) a 10 m weather tower sensor suite from Campbell Scientific® measuring wind and temperature profiles, 20 Hz 3D wind speed/temperature, air pressure, relative humidity, surface temperature, insolation, soil heat flux, and soil water content; (2) a Vaisala® LIDAR ceilometer measuring 910 nm attenuated backscatter ranging from the surface to 15 km; and (3) four Canon EOS digital single-lens reflex (DSLR) cameras. Instruments were operational from 8-20 June 2019. For more detail on the playa and instrumentation, see the companion abstract [1].

Analysis method: The field instruments enabled measurement of temporal variations in dust devil activity (dependent variables: onset time, number density, morphology, and spatial patterns) in the environment around them (independent variables: surface properties, changes in local/mesoscale/synoptic meteorologic conditions). Eddy covariance analysis was conducted using EddyPro® v.7, which de-spikes, rotates, and de-trends 20 Hz sonic anemometer data over a specified averaging interval, and then calculates eddy momentum and heat fluxes, among other parameters (e.g., Monin-Obukhov length). Ceilometer data has been analyzed with BL-View® to conduct range correction and time/height averaging, identify clouds and precipitation, and estimate the planetary boundary layer (PBL) height using a modification of the gradient method [e.g., 2]. To date, camera data has been used to manually survey dust devil activity; forthcoming work will include stereogrammetry to measure dust devil locations, spacing, height, etc.

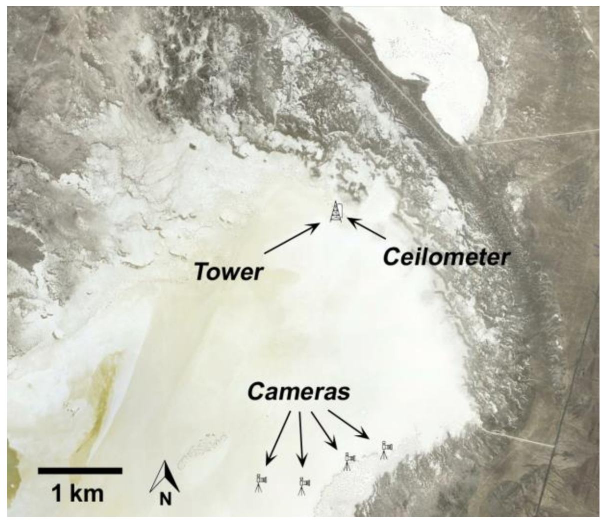

Figure 1. Instrument placement at the Smith Creek Valley playa, NV, USA (tower was located at 39.347°N, 11.463°W).

Results: We present results from 11 June 2019, one of the clearest days of the campaign. Insolation data in **Fig. 2a** show a nearly cloudless sky after 07:30 (spikes after this were from tower shading and field truck headlights). Air temperatures rose after sunrise from ~5 °C to ~28 °C. As expected on a clear day dominated by dry convection, ground temperatures exceeded air temperatures from late morning through the afternoon (**Fig. 2b**). Although sunny, air and ground temperatures remained similar from 07:30 to 10:00, suggesting that some local or mesoscale atmospheric activity might have inhibited growth of the CBL.

Ceilometer backscatter (**Fig. 3**) indicated a PBL height of ~0.5 km until 11:00. Then, rather than smoothly increasing in height as expected when dry convection deepens a CBL, the PBL height jumped to ~1.2 km, slowly growing to ~1.8 km by evening. The conditions responsible for suppressing CBL growth in midmorning may be the same that were responsible for cooler air temperatures during the same period.

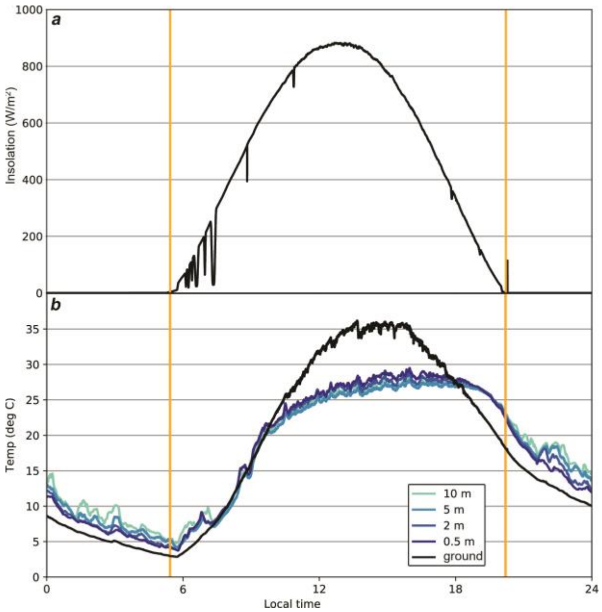

Figure 2. Weather tower data from 11 June 2019, obtained at 0.5 Hz, including (a) insolation and (b) temperature. Yellow lines correspond with local sunrise and sunset.

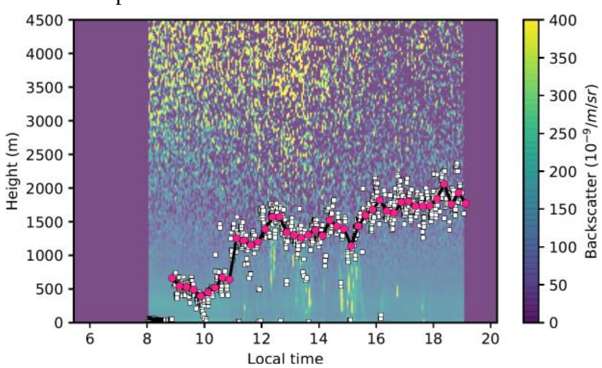

Figure 3. Ceilometer backscatter on 11 June 2019 from sunrise to sunset. White squares show BL-View boundary layer height detections; pink circles are 15-minute median values. Data before 09:00 is contaminated by truck exhaust. Note the afternoon dust devil detections within the PBL.

Dust devils appeared abruptly at 10:22 (**Fig. 4a**), corresponding with an abrupt jump in eddy heat flux in the averaging period from 10:30-10:45 (**Fig. 4c**), a finding consistent with that observed by others [3]. However, dust devil activity fluctuated considerably throughout the day, not correlating with peaks and dips in eddy heat flux. The only parameter dust devil density correlated with was vertical wind velocity (**Fig. 4b**).

Discussion: The correlation between dust devil activity and mean vertical velocity holds for time averaging intervals ranging from 15 to 60 minutes, suggesting that both transient small-scale flows (e.g., convective cell structures) and larger-scale flows (e.g., mesoscale flows over nearby mountain ranges) combine to influence dust devil density.

Conclusion: Preliminary results from our dust devil field survey suggest that dust devil onset times and frequency are highly sensitive both to eddy heat flux and vertical wind speed. Further analysis will involve stereogrammetry to investigate dust devil dimensions and spacing, as well as morphology.

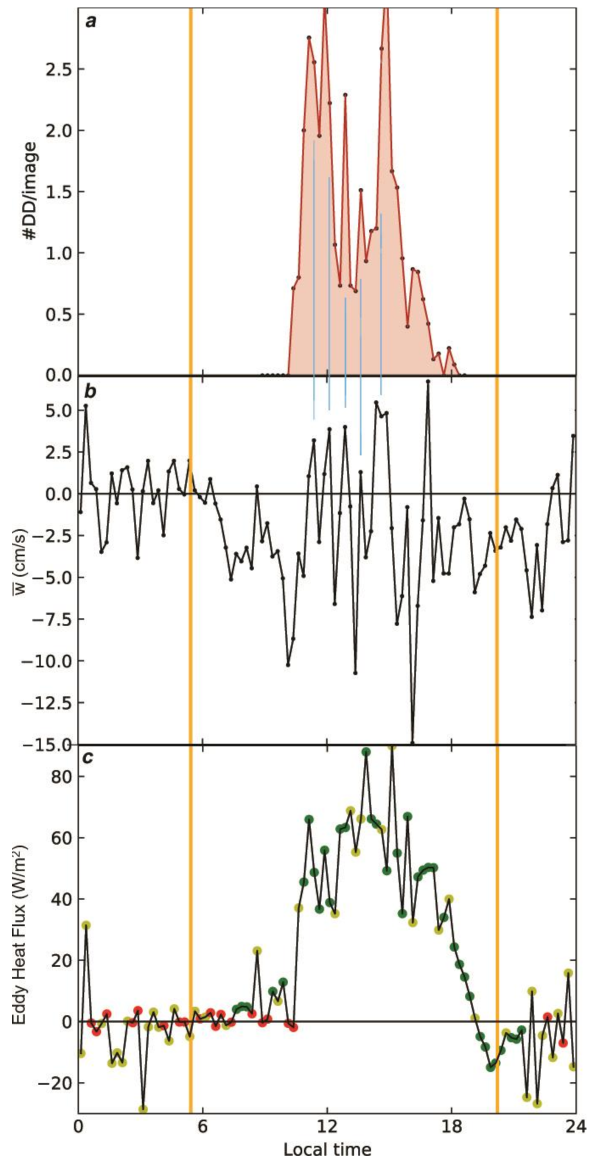

Figure 4. Fifteen-minute interval calculations of (a) average number of dust devils per image, (b) mean vertical velocity at a height of 5 m, and (c) eddy heat flux. Blue lines show the correspondence between $\overline{w}$ and dust devil activity.

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References: [1] Metzger et al. (2020) *LSPC LI*, Abst. #2350. [2] Hayden, K. L. et al. (1997) *J. Atmos. Environ.*, *31*, 2089-2105. [3] Rafkin S. et al. (2016) *Space Sci. Rev.*, *203*, 183-207, doi:10.1007/s11214-016-0307-7.