FUELING DUST DEVILS; INSOLATION-DRIVEN SURFACE HEATING RATES FOR AN ARID TERRESTRIAL MARS-ANALOGUE SITE.

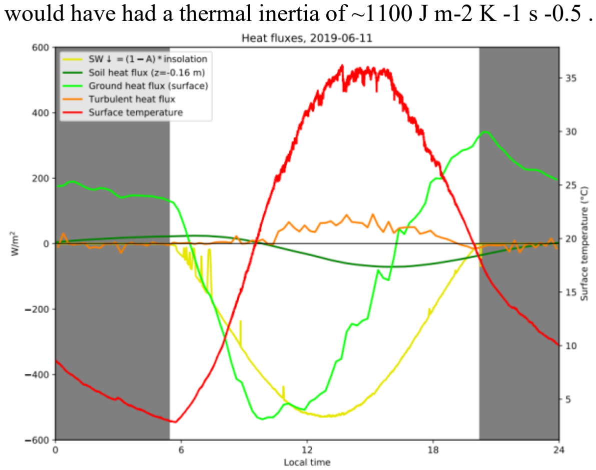
E. Idec[1], S. Metzger[2], L. Fenton[3], T. Dorn[4], T. Michaels[3], S. Scheidt[5], B. Cole[1], O. Sprau[1], L. Neakrase[6]; [1]St. Lawrence University Geology (ehidec18@stlawu.edu), [2]Metzger Geoscience Consulting LLC (metzgergeosci@gmail.com), [3]SETI, [4]University of California Los Angeles, [5]Howard 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 among the few visible markers of the structured turbulent eddies that comprise atmospheric convective motions. Even stark natural deserts have a variety of surfaces whose composition and aerodynamic roughness contribute differently to warming under daily insolation. The general goal of this project is to understand the relationship between dust devil formation, and atmospheric activity at the regional and local scales. In turn, such an understanding will hopefully enable use of surface dust devil images as indicator proxies of the lower atmosphere's structure, especially the Planetary Boundary Layer (PBL). If that relationship is reliably defined, years of archived Mars lander surface images can be utilized to reconstruct circulation models of the lower Martian atmosphere. This report focuses on the rate at which four common ground conditions contribute to surface heating, and consequently fuel dust devil formation.

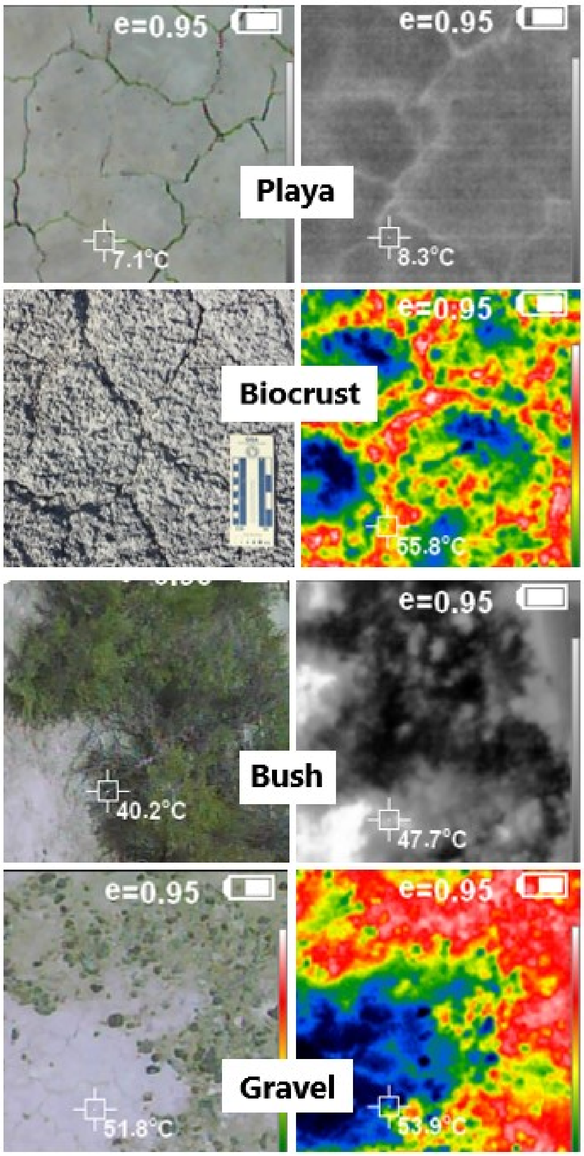
Dust-laden vortices (i.e., dust devils) form as a result of convective heat transfer between the surface and the air in contact with it. This air heats up quickly, and becomes adiabatically unstable, rising to form convection cells. In some settings, formation appears to be favored by aerodynamically large roughness elements, which shields pockets of preferentially heated air [1]. We hypothesize that surfaces which heat up at faster rates and have sufficient roughness elements should spawn greater numbers of dust devils given other necessary factors are met.

Geomorphic Setting: This analogue field program is designed to study a common Mars setting; confined crater and canyon floors. Since those settings require nearby topographic relief, Nevada's Basin and Range Province, climate and our team's previous field experience led to the selection of the Smith Creek Playa Field Site, west of Austin NV. The Basin and Range Province is a Horst and Graben system, and as an ephemeral lake the Smith Creek Playa is biased eastward due to more recent subsidence along the eastern flank. The perimeter alluvial plain basin exhibits low relief and is covered by <1m bushes and sparse grasses. A nestled series of stranded recessional gravel-covered shorelines provide arcuate minor relief (<1-3m) on the northern bounds of the playa (perhaps aerodynamically similar to degraded crater rims). The playa's surface consists predominantly of angular well-sorted coarse silt (0.04mm) and clay, nearly devoid of larger grains except the occasional rounded, frosted quartz fine sand (0.2mm), probably the result of Aeolian saltation across the dry lake bed. Black to grey crenulated biocrusts are found extensively on most topographically elevated surfaces around the playa perimeter and on the flanks of silt-based mounds. Dust devils occurred across the entire valley but mostly closer to and on the playa.

Soil Diurnal heat flux was examined to understand the rate at which solar heating was able to penetrate into the subsurface soil [2]. This heat flux was measured by a soil heat flux plate (placed at a depth of 16 cm). For reference, the ground temperature is also shown, along with the shortwave flux absorbed by the ground, and the turbulent heat flux. Shaded periods correspond with nighttime. The ground heat flux (GHF) was calculated as the sum of the soil heat flux and the heat storage in the soil above it, accounting for the measured volumetric water content (vwc). During the night, the GHF was positive (upward) as the ground radiated its accumulated heat. In the morning, as the sun warmed the surface, the GHF flipped as the soil began to absorb heat from insolation. In late afternoon, the GHF became positive again as the solar influx waned and turbulence mixed heat from the surface to the atmosphere. Because of nearby spring runoff, the vwc was rather high (~0.5 m3 /m3), contributing to a high GHF diurnal amplitude (similar calculations with dry soil reduced the amplitude by ~2.5x). The resulting thermal inertia of ~3000 J m-2 K -1 s -0.5 was correspondingly high (following the methods of Bennett et al. 2008 and Wang et al. 2010); not accounting for vwc, the dry, compact playa surface would have had a thermal inertia of ~1100 J m-2 K -1 s -0.5 .



Surface Heating and Cooling Rates of four distinct geomorphological surface types were measured over three 24-hour cycles. The four prominent surface types identified at the valley floor include silt-dominated playa, gravel-imbedded playa, biocrust covered sediment, and creosote/mesquite bush hummocks. Each surface is represented by 6-7 sample sites, and temperature was measured using both an infrared thermometer and thermal imaging camera. We recorded temperatures at theoretical maximum and minimum times, and subsequent maximum with 2 intermediate time periods over a 24-hour period. For each surface type, we collected representative sediment samples for sieving analysis and color ID from a Munsell color chart.

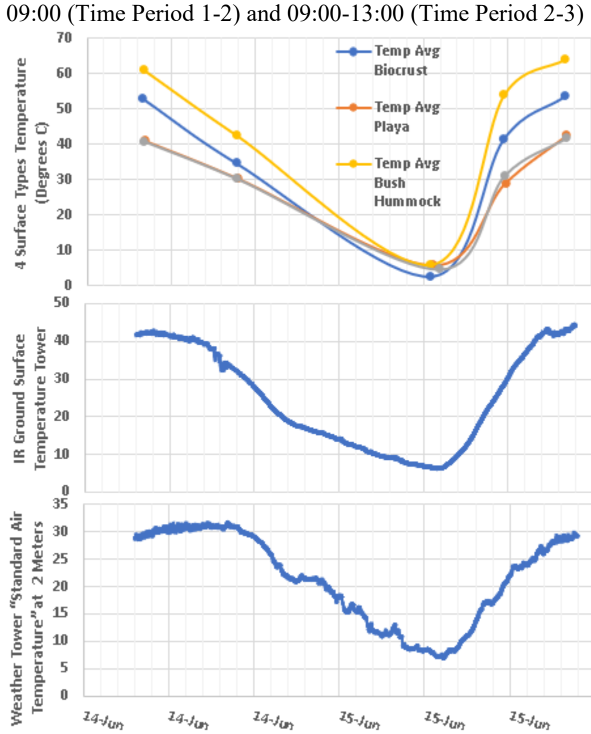


Preliminary results: Bush hummocks and biocrust surfaces had heating rates and maximum temperatures higher than the playa and gravel-imbedded playa. The 5:00-9:00 morning heating rates averaged between all three cycles show bush hummocks heated at 9.9° C/hr, biocrust at 8.25°C/hr, gravel imbedded playa at 5.83°C/hr and playa at 5.17°C/hr. Average maximum temperatures followed the same pattern, with bush hummocks heating to 52.8°C, biocrust heating to 52.9°C, gravel heating to 41.5°C, and playa heating to 40.9°C.

The data suggest that with greater heating rates and maximum temperatures, dust devils should begin forming earlier and form preferentially over bush hummock and biocrust surfaces. The greater "sheltering" roughness elements of these surfaces may also contribute to enhanced dust devil formation. We continue to evaluate the connection between surface types, upwind fetch and atmospheric processes responses in relationship to dust devil production and behavior [3].

Surface Type	Average Heating Rate 0500-0900 (Deg C/Hr)	Average Heating Rate 0900-1300 (Deg C/Hr)	Average Max Temp (Deg C)
Bush Hummock	9.9	2.73	56.88
Biocrust	8.25	3.76	52.9
Gravel	5.83	3.31	41.52
Playa	5.17	3.32	40.99

Table 1-Heating rates of surface types between 05:00-09:00 (Time Period 1-2) and 09:00-13:00 (Time Period 2-3)



The top plot summarizes temperatures measured on the 4 common ground types found around Smith Creek Playa. The middle plot includes the continuous readings from an IR thermometer located on our primary weather tower as it recorded playa surface heating for the same June 14-15, 2021 period. Bottom plot records 2m air temps on that same tower.

Acknowledgments: This project enjoyed crucial support of NASA's Solar Systems Workings program, grant #80NSSC19K0025, and from St. Lawrence University's Internship Program and Geology Department.

References: [1] Metzger S. M., (1999) *PhD Dissertation* [2] Metzger S. M. et al. (2020) *LPS LI*, Abst. #2350. [3] Fenton L. K. (2020) *LPS LI*, Abst. #2567