SURFACE ROUGHNESS LENGTH AS A FUNCTION OF FETCH LENGTH AT A PLANETARY ANALOG FIELD SITE. L. K. Fenton[1], S. Metzger[2], T. I. Michaels[1], S. P. Scheidt[3], T. C. Dorn[4], L. D. V. Neakrase[5], [1]SETI Institute, 189 Bernardo Ave, Suite 200, Mountain View, CA, USA, 94043 (lfenton@seti.org), [2]Metzger Geoscience Consulting, [3]Howard University, [4]Univ. of California Los Angeles, [5]New Mexico State Univ.

Introduction: The aerodynamic roughness length (z_0) is defined as the height above a planetary surface at which the logarithmic wind profile drops to zero; it is approximately proportional to the height of roughness elements on the surface [e.g., 1, 2]. In conditions of neutral stability, the mean wind speed u (at height z) and roughness length together determine the magnitude of the friction speed u_*, and thus the Reynolds wind stress ($\tau = \rho u_*^2$) applied to the surface:

$$u_* = \frac{u(z)}{\left(\frac{1}{k}\ln\frac{(z-d)}{z_0} + \Psi\right)}$$

in which Ψ is a stability-correcting factor [e.g., 1] and the displacement height is d (assumed here to be zero on the flat playa). Because z_0 values in natural settings range over four orders of magnitude (from <0.01 mm to >0.1 m), establishing z_0 is crucial to parameterizing thresholds and fluxes of sand and dust entrainment [3]. Further, spatial variations in z_0 impact wind stress downwind [4], indicating that particle mobilization depends on the heterogeneity of the terrain upwind, which can vary with wind direction at a given site.

Here we determine surface roughness as a function of wind direction over a hard, smooth playa that has been used as a planetary analog site [5, 6]. We find that z_0 varies strongly as a function of playa fetch length. In neutral conditions, wind speed measurements (and therefore shear stresses) do not reflect the pure playa environment for fetch lengths less than ~2-3 km.

Study Area: Smith Creek Valley in central Nevada, USA (39.34°N, 11.46°W) hosts an oblong playa with dimensions 11 km x 4-6 km (**Fig. 1a**). The bare playa surface (**Fig. 1b**) is flat and covered in desiccation cracks, a typical hard impermeable playa crust [7]. Surrounding the playa is a ring of phreatophytic vegetation that has colonized both the playa margin and adjacent hummocks, which are ~100-500 m long and ~2-5 m high.

From 7-21 June 2019, a field campaign obtained nearly continuous data from instruments placed on a 10-m meteorology tower [5, 6]. Examples of the resulting data set include – but are not limited to – profiles of wind speed and air temperature, air pressure, humidity, solar flux, and ground temperature, obtained at a rate of 0.5 Hz. The tower was stationed 50 m within the northern margin of the bare playa (**Fig. 1**). Defining the “fetch length” as the distance along the smooth playa from the tower to the margin of the vegetated area, the tower data sampled a fetch length that varied with the wind direction from 50 m (from NE) to ~10 km (from SW).

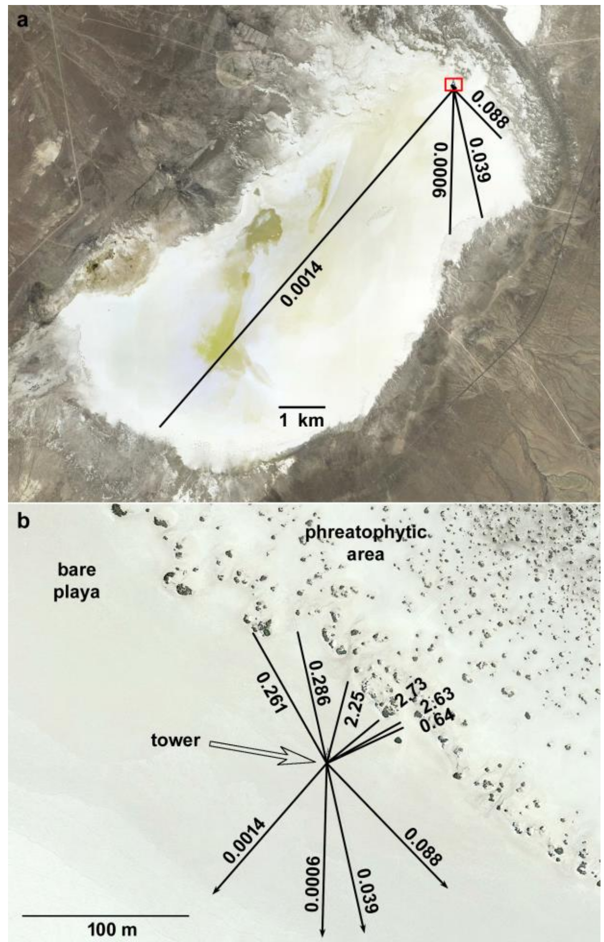

Figure 1. a) The Smith Creek Valley playa of central Nevada, USA. The red rectangle outlines b) a zoomed in view surrounding the meteorology tower, located 50 m from the bare playa edge. Lines indicate directions and numbers indicate values (in mm) of individual z_0 measurements. Note the strong inverse correlation of z_0 with fetch length.

Determination of z_0: Proper estimation of the surface roughness requires either correcting for static stability [e.g., 3] or using data obtained in neutral conditions (this is usually done in windy, overcast weather). Typical of most deserts, Smith Creek Valley was rarely neutrally buoyant during the 2019 field campaign, with typical daytime conditions being sunny and unstable, and typical nighttime conditions being stable. However, there were a few storms during which conditions briefly became statically neutral, and during many late afternoons, conditions were temporarily near-neutral while the convective boundary layer collapsed.

Averaging wind and temperature data over 15-minute periods, the data was scoured for periods during which the following conditions held:

1. Statically neutral: The bulk Richardson number (Ri_b) progressed from negative to positive (unstable to stable), or positive to negative (stable to unstable).
2. Windy: The wind speed at a height of 2 m was >2 m/s, both to remain above the minimum threshold for cup anemometers and to ensure the environment was not dominated by buoyant convection.

For example, **Table 1** shows an example from the evening of 11 June 2019, approximately an hour before sunset. During the two successive 15-minute periods between 19:00 and 19:30, the surface cooled enough that Ri_b crossed from negative to positive (i.e., the atmosphere went from being statically unstable to statically stable). Linearly interpolating between the two Ri_b values where the change occurred, the resulted in z_0 = 0.286 mm at a wind direction of 347.5°.

Table 1. Example of conditions trending from unstable to stable on the evening of 2019-06-11.

Local time	Ri_b	u_{2m} (m/s)	z_0 (mm)	Wind Dir
18:45-19:00	-0.00142	3.14	0.1581	1.6±16°
19:00-19:15	-0.00030	3.83	0.1990	347±12°
19:15-19:30	0.00075	3.50	0.5044	348±16°
19:30-19:45	0.00174	3.55	1.250	337±10°

Ten different instances of such conditions were identified, during which the wind blew from a range of directions (**Fig. 2a**, also labeled in **Fig. 1**). Plotted against the fetch length (**Fig. 2b**), the points fit to a polynomial with a slope of -1 to -1.5. Included in the analysis is a measured point from Lunar Lake in central Nevada [3], in which the surface roughness (0.077 mm) was determined from a weather tower located ~1.3 km from the upwind margin of the playa.

Discussion/Conclusions: With a maximum fetch length of ~10 km, the playa surface roughness drops as low as ~0.001 mm. However, the effect of terrain roughness beyond the playa margin affects z_0 as far away as ~2-3 km. At the location of the meteorology tower, a 10 m/s wind (at z=10 m) blowing across the smooth playa surface from the southwest will produce a friction velocity $u_* = 0.25$ m/s, whereas the same wind blowing across the phreatophytes and hummocks, from the north-northeast, will produce $u_* = 0.48$ m/s. This ~2x difference has the potential to strongly impact sand and dust entrainment rates, as well as the resultant drift direction of sand.

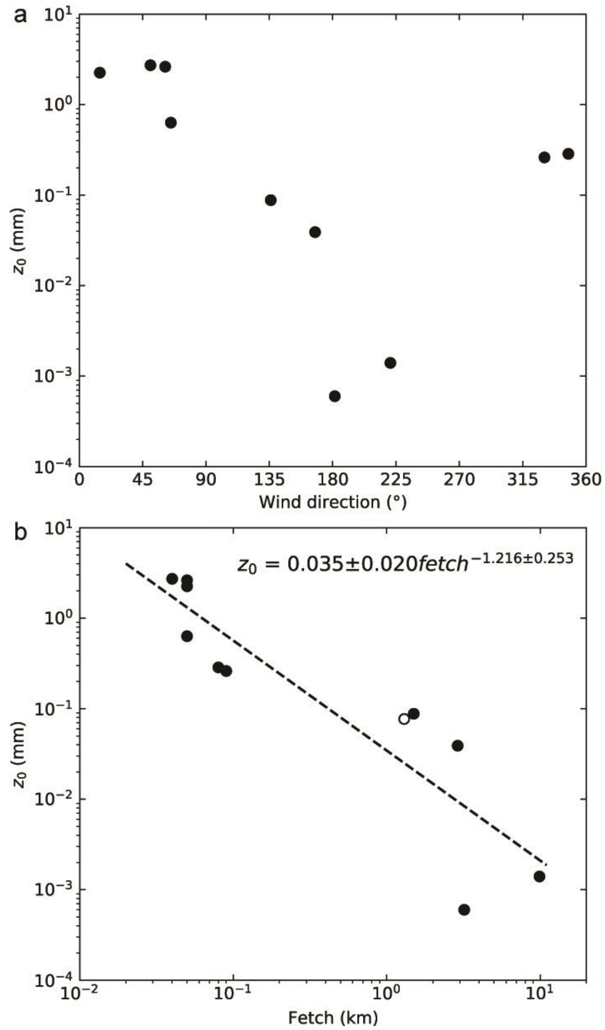

Figure 2. Measured z_0 vs. a) wind direction on the Smith Creek Valley playa (shown in Fig. 1), and b) vs. fetch length, which fits to a power law (the equation applies for z_0 in mm and fetch length in km). The open circle is from [3]'s "Lunar Lake (1)" site.

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References: [1] Stull, R. (1988) *An Introduction to Boundary Layer Meteorology*, 666 pp. [2] Kok et al. (2012) *Rep. Prog. Phys, 75,* doi:10.1088/0034-4885/75/10/106901. [3] Greeley et al. (1995) *Desert Aeolian Processes*, 75-99, doi:10.1007/978-94-009-0067-7_4. [4] Greeley and Ivsersen (1987), *GRL, 14,* doi:10.1029/GL014i009p00925. [5] Metzger et al. (2020) *51st LPSC,* Abst. #2350. [6] Fenton et al. (2020) *51st LPSC,* Abst. #2567. [7] Langer and Kerr (1966) *J. Sed. Petrol., 36*, 377-396.