

New Aerodynamic Roughness Height Results from Wind Profiles for Megaripples in the Puna of Argentina

Abstract 1207

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In Brief:
-The Argentine Andes plateau features gravel-megaripples, likely an analog for martian Transverse Aeolian Ridges.
-We recorded the vertical wind profile in several locations there to measure the aerodynamic roughness heights, z_0 .
- $z_0 \sim 1.1$ -5.3 cm for various locations and wind conditions. Future analysis will refine z_0 .
- z_0 will inform gravel megaripple formation & evolution models.

Introduction: In November of 2018 we collected new wind profile data at several settings within and around fields of megaripples in the Puna high desert of Argentina (see [1] and Fig. 1 for setting). Here we present initial results obtained on the first day at a location called Campo Piedra Pomez (CPP). Wind data were also collected at CPP West, Lago Purulla, Purulla, and Incahuasi, and we also provide some initial results from these locations.

Setting for CPP measurements: On the first day in the field we set up two portable wind towers near the downwind edge of a megaripple field immediately west of the eroded ignimbrite that gives CPP its name. Each tower consisted of connected pole segments that gives a tower height of about 2.8 m, to each of which five data logging anemometers were attached at a logarithmic height spacing (Fig. 2). Tower 1 was positioned 22 m downwind of a 33-cm-high megaripple, part of a field of megaripples extending hundreds of m upwind, with the entire surface covered by dark lithic fragments in the small gravel size range (Fig. 3). Tower 2 was located about 50 m north of Tower 1 where a lithic gravel plain extended hundreds of m upwind (Fig. 4). The tower location and anemometer heights were chosen based on guidelines given by Wieringa (1993 [2], the most important of which are that the tower be located where the upwind fetch is homogeneous in surface roughness elements for >200 m, the tower is downwind >15 times the height of the major roughness elements, the lowest anemometer is positioned at a height above the surface at least 20 times the expected roughness length, and the entire region is not on a prominent regional slope. Each anemometer recorded wind speed at a 2 sec interval.



Figure 1 (left). Screen shot from Google Maps showing the general setting for the wind measurements collected in the Puna of Argentina. The five study locations are indicated by the letters C (CPP, 11-19-18), W (CPP West, 11-20-18), L (Lago Purulla, 11-21-18), P (Purulla, 11-21-18), and I (Incahuasi, 11-22-18). We were based out of Antofagasta de la Sierra, located about 2 hours drive north of the study area.

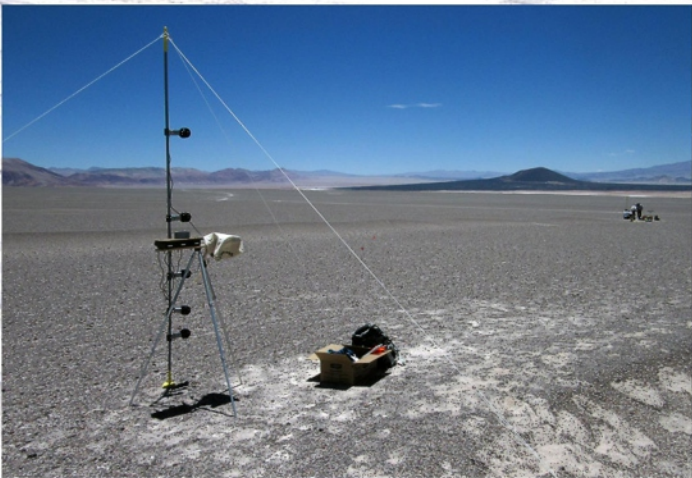


Figure 2. Context for the tower locations at the CPP site, before commencement of data logging. Tower 1 (near field) is 2.8 m tall. Anemometer controllers were mounted on a tripod downwind of the tower. Tower 2 is ~50 m away at right. JRZ, 11/19/18.



Figure 3. Vertical view of lithic fragments near crest of the megaripple upwind of Tower 1 (see Fig. 2). JRZ, 11/19/18.

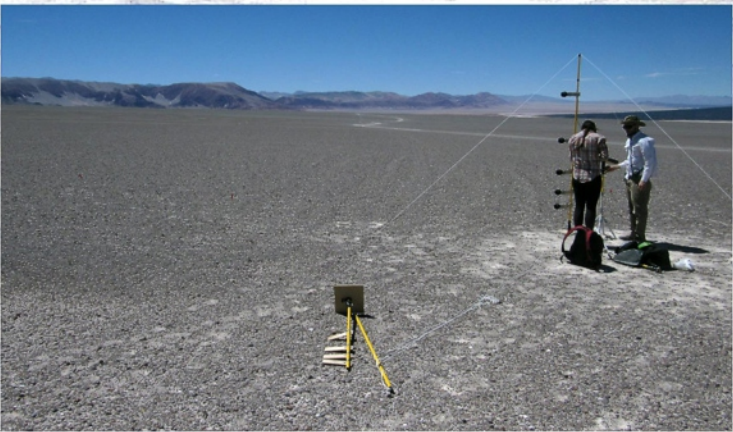


Figure 4. Tower 2 during setup, with a flat gravel surface for hundreds of m upwind of the tower. JRZ, 11/19/18.

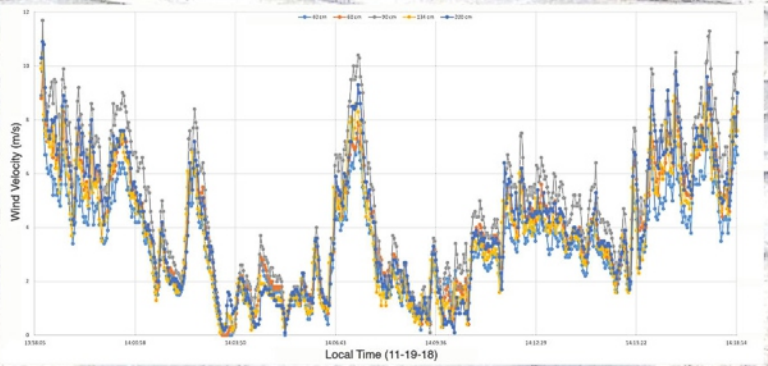


Figure 5. Tower 1 wind speed coincident in time with Tower 2 (Fig. 6).

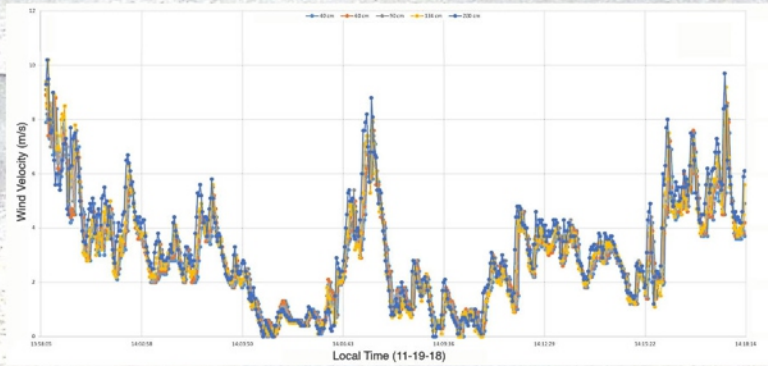


Figure 6. Tower 2 wind speed coincident in time with Tower 1 (Fig. 5).

CPP wind data: Tower 1 started data logging slightly before Tower 2, but the distinctive recorded wind gust patterns allowed us to correlate data from both towers to within one 2-sec recording interval (Figs. 5 and 6). Here we present results for the first coincident 20 minute time period (600 data points) recorded at both towers; data records extend >40 min beyond this initial period; these data will be addressed in subsequent analyses. Previous studies indicated a roughness length of about 1.5 cm for the CPP area [3], so the bottom anemometer was mounted 40 cm above the surface. Wind data were averaged for each anemometer over the 20 min period in order to investigate wind conditions that ranged between 0 and 12 m/s (see Figs. 5 and 6 and Table 1). Tower 2 showed a good progression of wind speed with height, but anemometers 2 and 3 on Tower 1 were consistently higher than anticipated from winds documented at the other three anemometers; this trend continued through the entire record from the CPP site. We were concerned that the two anemometers may have not been operating correctly, but a controlled comparison conducted after the field work showed that all anemometers reported consistent wind speeds within a 0.15 m/s standard deviation, which is less than the 0.2 m/s accuracy of the instruments. We determined a best-fit logarithmic profile for the data in Table 1, from which we projected zero wind velocity at a height of 4.3 cm for Tower 1 (with a correlation coefficient r of 0.37), interpreted to be the roughness length, and 1.4 cm height for zero velocity for Tower 2 ($r = 0.89$). Removing anemometer 2 from the fit for Tower 1 gives a roughness length of 7.69 cm with $r = 0.72$, but removing both anemometers 2 and 3 from a fit for Tower 1 gives an unrealistic roughness length of only 0.02 cm ($r = 0.98$). Using only the top two anemometers at Tower 1 gives a roughness length of 1.0 cm ($r = 1.00$), a value consistent with the roughness length of the gravel plain at Tower 2. Averaging over the entire 1.5 hr recorded period at the CPP site, the five anemometers of Tower 1 give a roughness length (z_0) of 3.3 cm ($r = 0.49$). The megaripples appear to add several cm to the roughness length represented by the gravel particles alone at Tower 2.

Initial results from four other sites: One megaripple location near a western exposure of CPP ignimbrite bedrock we called CPP West (Fig. 1). Towers were set up expecting ‘normal’ afternoon winds perpendicular to megaripple crests. Instead, the strongest winds experienced during the 2018 trip blew parallel to the megaripples crests (see Table 2); z_0 was 1.4 cm ($r = 0.98$), identical to the Tower 2 result at CPP. We conclude that this value is a good representation of z_0 for a gravel lag surface without input from megaripple bedforms. At Lago Purulla we measured wind perpendicular to small (<15 cm height) megaripples, resulting in $z_0 = 0.02$ cm ($r = 0.43$); if anemometer 2 is ignored, z_0 becomes 0.98 cm ($r = 0.95$). At Purulla we had multiple issues with the anemometers, but from several minutes of useful data we obtained $z_0 = 1.4$ cm ($r = 0.60$), and if the low anemometer 3 is ignored, then $z_0 = 1.1$ cm ($r = 0.99$). The final profiling site was at Incahuasi where we collected the longest continuous record of the trip, totaling >2.9 hr (Fig. 7). This full record gives $z_0 = 5.3$ cm ($r = 0.91$), and skipping low anemometer 3 gives $z_0 = 5.0$ cm ($r = 0.99$).

Discussion: Why are the recorded wind speeds at CPP high for anemometers 2 and 3 of Tower 1? Given our post-trip tests we do not think this is the result of malfunctioning instruments, unless somehow the conditions at the Puna altered only those two instruments relative to their function under normal conditions. If the instrument accuracy is taken as the probable standard deviation, the values from anemometers 2 and 3 are three and five sigma, respectively, above what would be expected from the other three anemometers on Tower 1. Perhaps some form of wave phenomenon developed downwind of the megaripple field, somewhat analogous to atmospheric lee waves downwind of mountain ranges [4], although it is difficult to extrapolate atmospheric conditions present at multi-km scale to near-surface conditions at decameter scale. We will explore additional possible explanations as we process the rest of the wind data collected during the 2018 trip, but we point out that field notes indicate unusual values, either higher or lower than expected, for anemometers 1 to 3 for observations within other megaripple locations in the Puna. Since the anemometers do not appear to be malfunctioning, we think it is prudent to explore possible unexpected wave phenomena downwind of some long fetches of large megaripples in the Puna. As more data are evaluated, we hope that the situation will become more clear.

Acknowledgements: This work was supported by a NASA Solar System Workings grant 80NSSC17K0759 to Oregon State University, S. de Silva PI.

Table 1. Average and standard deviation for anemometers on two towers at CPP during a concurrent 20 minute interval (13:58:16 to 14:18:16) on 11/19/18.

Height (cm)	40	60	90	134	200
Tower 1					
Ave	3.32	3.96	4.86	3.76	4.07
Std Dev	1.79	2.15	2.64	2.25	2.39
Tower 2					
Ave	2.92	2.98	3.00	3.04	3.28
Std Dev	1.76	1.82	1.90	2.00	2.05

Table 2. Average and standard deviation for anemometers at locations after CPP.

CPP West, 11-20-18 (17:10:18 to 17:36:10)					
Height (cm)	40	60	90	134	200
Ave	7.07	7.56	8.11	9.07	10.38
Std Dev	1.62	1.86	1.97	2.10	2.39
Lago Purulla, 11-21-18 (12:23:46 to 12:46:00)					
Height (cm)	40	60	90	134	200
Ave	7.07	7.56	8.11	9.07	10.38
Std Dev	1.62	1.86	1.97	2.10	2.39
Purulla, 11-21-18 (15:45:30 to 15:52:21)					
Height (cm)	80	101	127	160	200
Ave	3.12	3.22	2.65	3.64	3.74
Std Dev	0.71	0.70	0.68	0.89	0.95
Incahuasi, 11-22-18 (11:13:16 to 14:04:18)					
Height (cm)	80	101	127	160	200
Ave	1.32	1.37	1.34	1.62	1.73
Std Dev	0.84	0.86	0.88	1.03	1.05

References: [1] de Silva S. L. et al. (2013) *GSAB*, 125, 11/12, 1912-1929. [2] Wieringa J. (1993) *Boundary Layer Met.*, 63, 323-363. [3] Zimbelman J. R. et al. (2016) *Icarus*, 266, 306-314. [4] Wurtele M. G. et al. (1993) *NASA Contractor Report 186024*.

Figure 7 (left). Complete wind record from Incahuasi, covering more than 2.9 hours. Although the winds were somewhat variable and gusty, a roughness height of 5 cm was obtained from this long record (see text).

