DUNE AND WIND OBSERVATIONS AND PREDICTIONS IN GALE CRATER ON MARS.

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Introduction: Recent measurements by the Mars Science Laboratory (MSL) rover in the Bagnold Dune field in Gale Crater provided the first *in situ* wind data for planetary dunes [1]. Orbital observations indicate that much of this dune field is currently active, with some dunes / ripples observed to move a good fraction of a meter per Mars year. Measuring the wind field for present day conditions is thus very valuable for understanding how the dunes formed and continue to evolve, and to provide ground truth data for validating atmospheric models that can be used to predict the dune-forming winds at other times, locations, and epochs.

We will describe the wind measurements made near the dunes and their impact on understanding and predicting dune-forming winds on Mars.

REMS wind measurements: As described in [2,3,4,5], the Rover Environmental Monitoring Station (REMS) wind sensor consisted of two horizontal 'booms' mounted on MSL's Remote Sensing Mast (RSM) at a height of ~1.5m, one pointing forward and one pointing at 120° to the side/rear. The original retrieval scheme first determined which boom was least affected by flow around the RSM, then used its measurements to retrieve wind direction and speed.

Loss of the side/rear pointing boom. Unfortunately, the side/rear-pointing boom was found to be largely non-functional after landing [4,5]. Since the retrieval then relied entirely on data from the front-facing boom, which sits in the RSM's wake for winds from the hemisphere to the rover's rear, it is not possible to properly retrieve ambient wind directions or speeds for winds coming from the hemisphere to the rear of the rover.

For 'front' winds, however - i.e., winds coming from the hemisphere in front of the rover - both wind direction and wind speed can be retrieved. During the Bagnold Dunes Campaign, optimum rover headings for wind measurements were prioritized over other science and engineering constraints, due to their importance for better understanding the aeolian processes responsible for forming the dunes.

Loss of nighttime wind measurements. The remaining boom also experiences significant electronic noise during cold periods, which causes further difficulties in obtaining useful data for a portion of each night.

Wind Investigations: During the Bagnold Dunes Campaign, good rover headings for obtaining wind measurements were prioritized in three investigations:

The Wind Characterization Investigation. This was designed to characterize the wind field just outside the dunes in N. late spring. Wind direction changes by 180° over each sol but the wind sensor can only measure winds coming from the hemisphere in front of the rover, multiple rover headings were needed. Wind was measured in five very different directions for several sols each, to build up a full picture of the wind field.

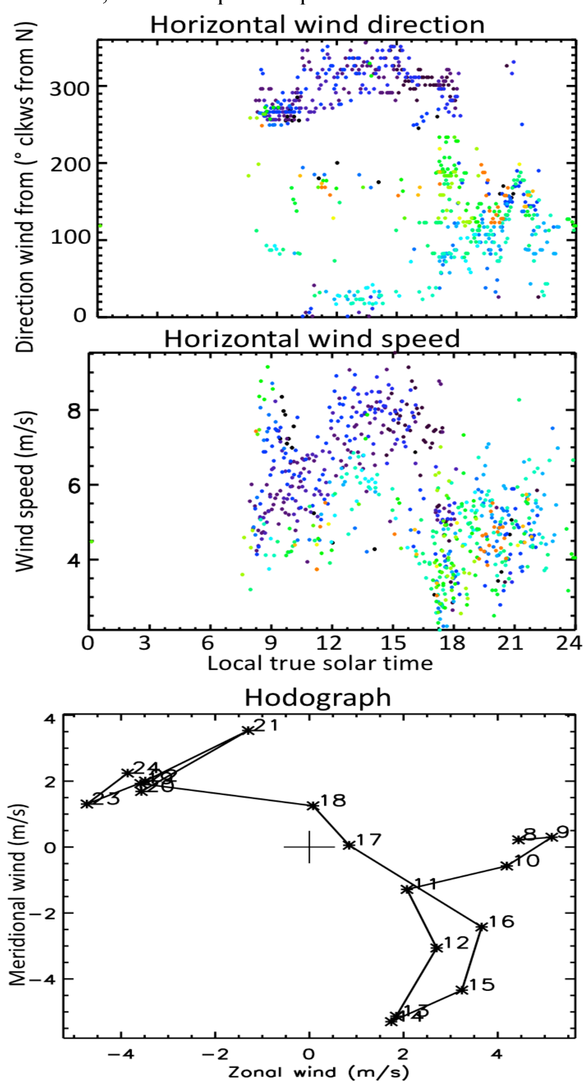

Figure 1: 5-minute median horizontal 1.5m wind directions and speeds for all 'front' winds measured during the Wind Characterization Investigation at Ls~67-75°. Colors indicate measurements made on different sols. Hodograph shows winds averaged over all 19 sols. Top two panels are from [5].

Figure 3 shows the 5-minute median wind speeds, directions, and wind hodograph over the 19-sol period. Wind direction shifts from westerlies before ~10:00 to northwesterlies with occasional northerlies, with peak wind speeds in the early afternoon. At ~17:00 or 18:00 the wind direction changes again to easterlies then to predominantly southeasterlies/southerlies, although the timing of the wind reversal and the duration of the easterlies varies greatly from sol to sol. There is generally clockwise turning of the wind direction between the upslope/downslope periods, particularly in the morning. The loss of overnight hours to noise makes it impossible to form a full picture of the circulation, particularly the strength and direction of downslope nighttime winds, for this location and season. However, the ~08:00 to midnight dataset is extremely useful for validation of mesoscale models.

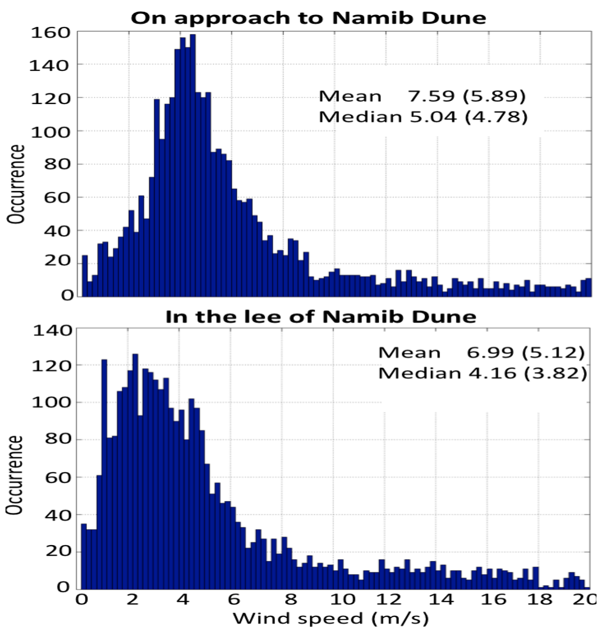

Figure 2: 1Hz 'front' wind speed distributions at 2pm during the Wind Characterization Investigation (top) and in the lee of Namib Dune (bottom). From [5].

The Namib Lee Investigation. This occurred while the rover spent several sols facing ~WNW while in the lee of Namib Dune, thus measured changes to the daytime wind pattern in the lee of a large dune on Mars. Figure 2 shows broadening of the wind speed distribution when in the lee of Namib Dune. This is consistent with an increase in wind variance resulting from the development of turbulent structures, as in high resolution simulations of dunes on Earth and Mars [6,7].

The Namib Side Investigation. This occurred while the rover spent several sols facing ~NNW sitting on the western side of Namib Dune, facing a heading of either -14° or -20°, thus measured daytime winds in order to support aeolian change detection experiments.

Implications for understanding dune formation: Using the Wind Characterization wind data as ground truth for Ls~67-75°, we adjusted the setup and assumptions made in the MarsWRF atmospheric model until it best reproduced the results shown in Figure 1. We then ran the model over 1 Mars year and used the predicted wind field to predict sand transport directions and dune orientations assuming ample and limited sediment availability, i.e., using respectively the Gross Bedform-Normal Transport [8] and Fingering Mode [9] hypothesis. Figure 3 shows the best fit results in each case.

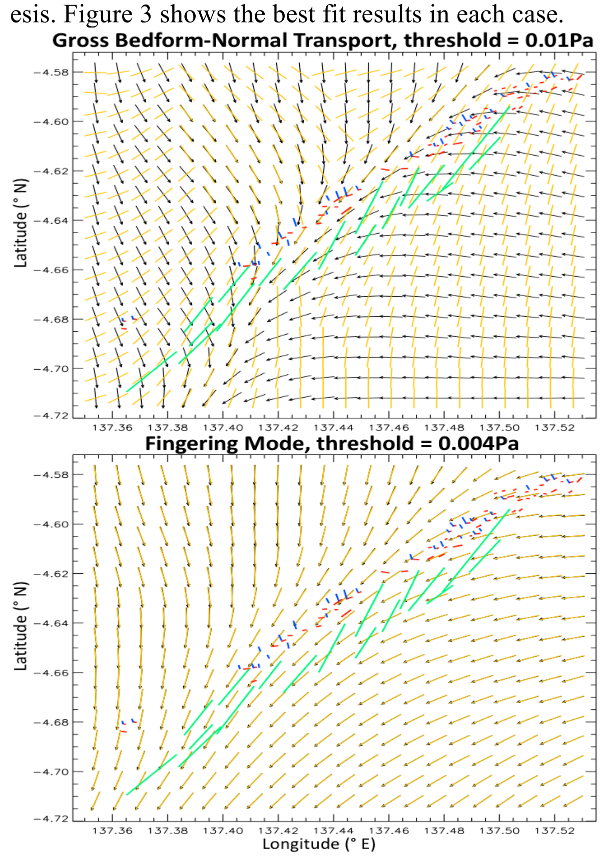

Figure 3: Dune predictions in Gale Crater using MarsWRF winds. Black arrows show predicted net transport direction, orange lines predicted dune orientation, blue and red lines observed Barchanoid dune orientations, green lines observed linear dune orientations. Note that for the Fingering Mode the predicted orientation is that of the dune train for Barchanoid dunes, thus is not parallel to individual dune crests.

References: [1] Silvestro et al. (2013) *Geology*, 41(4), 483-486. [2] Domínguez et al. (2008) *Plan. Space Sci.* 56, 1169-1179. [3] Gómez-Elvira et al. (2012) *Space Sci. Rev.* 170, 583-640. [4] Gómez-Elvira et al. (2014) *J. Geophys. Res.* 119, 1680-1688. [5] Newman et al. (2017) *Icarus*, in press. [6] Omidyeganeh et al. (2013) *J. Geophys. Res. Earth Surf.* 118, 2089-2104. [7] Jackson et al. (2015) *Nat. Comm.* 6, 8796. [8] Rubin and Hunter (1987) *Science* 237(4812),276-278. [9] Courrech du Pont et al. (2015) *Geology* 42(9),743-746.