INVESTIGATING THE INFLUENCE OF DUST STORM DIRECTIONS ON SURFACE WINDS VIA SAND DUNE MORPHOLOGIES IN THE NORTHERN MID-LATITUDES OF MARS.

J. M. Widmer[1] and L. K. Fenton[2], [1](previously at) University of Maryland (jwidmer@terpmail.umd.edu), [2]SETI Institute.

Introduction: Wind and ice are currently hypothesized to be the two major factors actively shaping the martian surface. Few in-situ measurements exist for near-surface martian winds except those collected by several landers and rovers. These measurements are all constrained to localized regions and are unable to accurately depict atmospheric circulation patterns on regional or global scales.

Dune fields reside at the surface-atmosphere boundary and cover approximately 1.025×10^6 km^2 of the martian surface [1-2]. The abundance of dune fields on Mars, combined with their ability to physically record information of the winds that created them makes dune fields ideal tools for understanding present-day atmospheric conditions.

Previous works have used indirect methods such as modeling and interpretations of surface morphological features (i.e., sand dunes, ripple marks, yardangs, windstreaks, etc.) to infer wind directions in the martian north polar region and southern hemisphere [e.g., 3,4]. Studies conducted in the northern mid-latitude region (MLR) of Mars, defined here as 30-65° N, have shown that dune fields in this region are smaller in size and number compared to the north polar region and southern hemisphere [1,2,4,5]. As a result, most dune studies conducted at regional and global scales have overlooked the MLR.

However, regional and global dust storms have been detected starting in and/or passing though the MLR, sweeping southward through low-lying terrain in distinct corridors [e.g., 6]. The degree to which these events dominate sand transport is not known but the presence of these large regional to global scale storms may influence present-day wind directions.

This investigation will interpret sand dune morphologies to infer wind directions (and their relative sand transporting capability) in order to determine if regional frontal dust storms influence dune morphologies in the MLR. Results from this investigation will provide the opportunity to ground-truth climate models and a glimpse into a long-term (10s-100s yrs) record of martian weather patterns.

Framework: For simplicity, this investigation can be divided into two parts: 1) inferring wind directions from sand dune morphologies and 2) comparing inferred winds to major dust storm tracks.

Inferring Wind Directions: Two modes of dune construction have been found to create distinct dune morphologies based on the angle that wind interacts with the crest of a dune and the amount of sediment available for dune building. Bedform instability mode occurs when crestlines form as perpendicular as possible to sand-transporting wind directions, and a large supply of sediment is available for transport [7-10]. Fingering mode occurs when crestlines align closely with the resultant drift direction of sand transport, and a small supply of sediment is available [11,12]. For the purpose of this investigation, we will focus on bedform instability mode.

Using HiRISE images of the MLR dune fields, crestlines of each dune (that can be determined) were traced as line segments in the JMARS GIS software [13]. Each line segment records the orientation of the crestline and the length of the segment. Once all of the crestlines within a field were traced, line segments were grouped by similarities in orientation (i.e. N-S oriented crestlines may be color coded green while E-W crestlines may be blue).

Using the orientations and lengths of each line segment in a group, a weighted average was computed to approximate the mean crestline orientation for that group. To approximate a first order wind direction, 90° was added or subtracted to the mean crestline orientation (based on the location of the stoss and lee slopes of the dune morphology) in order to account for the perpendicular wind flow expected in bedform instability mode of dune construction. This methodology has been adapted from [10].

Comparing Inferred Winds with Storm Directions: Once all of the crestlines have been mapped and a first order wind direction has been identified, a comparison between the direction of inferred winds and major storm events can be made. The primary interest in this comparison is to determine if the dune morphology is consistent with winds expected from major dust storms. It should be noted that this is currently a qualitative comparison but quantitative methods are being explored for future work.

Study Area: For the purpose of this investigation, we chose a study area based on several characteristics: clustered dune fields, proximity of dune fields to a major dust storm track, and flat/ simple terrain. Dune fields that are clustered, or grouped together in a small area, are beneficial for obtaining multiple sources of measurements that share similar environmental characteristics. The proximity or distance of dune fields in the study area to a major dust storm corridor is crucial for comparing inferred winds in and out of a storm corridor. In order to avoid any issues during the comparison process, choosing a study area devoid of major topographic formations was also important.

With these criteria, a rectangular study area was identified in the NW region of Utopia Planitia bounded by 55-90° E and 51-62° N. This area includes 12 newly documented dune fields [2] inside craters: 4 clustered inside/ near the Utopia storm corridor [6] (which passes north to south at ~100° E), 6 clustered ~1400 km west of the storm corridor, and 2 between those groups. Figure 1 shows a detailed look at the study area and dune field locations.

Preliminary Results and Discussion: Initial results have been recorded for four dune fields in the study area, two inside/ near the storm corridor (i.e. NML086 and NML042) and two outside of the storm corridor (i.e. NML020 and NML067). A first order approximation of wind directions at each field and a qualitative comparison with the storm tracks is shown in Table 1. Directions were derived from the dominant group of crestlines in each field, that is, the crestline group that best represented the majority of the dune field. These preliminary results suggest that dune fields inside/ near major dust storm corridors in the MLR are being influenced by the southern moving dust storms.

However, as all of the dune fields in the study area reside in the bottom of craters, it is possible that the morphology of the crater (i.e. crater rim topography, slope of the crater walls, depth of the crater, etc.) affects how winds interact with each dune field.

Future Work: As this investigation continues to progress, we will look to 1) analyze additional MLR dune fields and storm corridors, 2) obtain new HiRISE images for the last of the MLR dune fields without high-resolution image coverage, 3) incorporate crater characteristics (i.e. dimensions, morphology, etc.) into our wind direction analyses, and 4) develop a quantitative method for comparing dune morphologies with dust storm corridors.

Acknowledgments: We would like to thank Philip Piccoli for his insight and comments. We also thank the JMARS team for maintaining their GIS software and the HiRISE science team for providing high quality data for public use.

References: [1] Hayward R. K. et al. (2014) *Icarus, 230*, 38-46. [2] Fenton L. K. (2020) *Sixth International Planetary Dunes Workshop 2020*, 3013. [3] Fernandez-Cascales L. et al. (2018) *Earth and Planet. Sci. Letters, 489*, 241-250. [4] Fenton L. K. and Hayward R. K. (2010) *Geomorphology, 121*, 98-121. [5] Widmer J. M. and Diniega S. (2018) *LPSC 49*, 1651. [6] Wang H. and Richardson M. (2015) *Icarus, 251*, 112-127. [7] Rubin D. M. and Hunter R. E. (1987) *Science, 237*, 276-278. [8] Rubin D. M. and Ikeda H. (1990) *Sedimentology, 37*, 673-684. [9] Fenton L. K. et al. (2014a) *Icarus, 230*, 5-14. [10] Fenton L. K. et al. (2014b) *Icarus, 230*, 47-63. [11] Reffet E. et al. (2010) *Geology, 38*, 491-494. [12] Courrech du Pont S. et al. (2014) *Geology, 42*, 743-746. [13] Christensen P. R. et al. (2009) *AGU*, IN22A-06.

NML Dune ID	MGD^3 Dune ID	Crestline Groups	Approx. Wind Dir.	Near Storm Track	Match Storm Dir.
NML086	0896+583	3	N-NW	Yes	Yes
NML042	0873+588	3	N	Yes	Yes
NML020	0623+581	4	SW	No	No
NML067	0561+558	2	NW	No	Yes

Table 1: *Preliminary results from 4 dune fields in the NW region of Utopia Planitia. Wind directions are presented using the upwind convention (i.e. the direction that winds are entering dune fields.) For consistency with previous studies, 2 types of dune IDs are provided using the Northern Mid-Latitude (NML) and MGD^3 [1] naming schemes.*

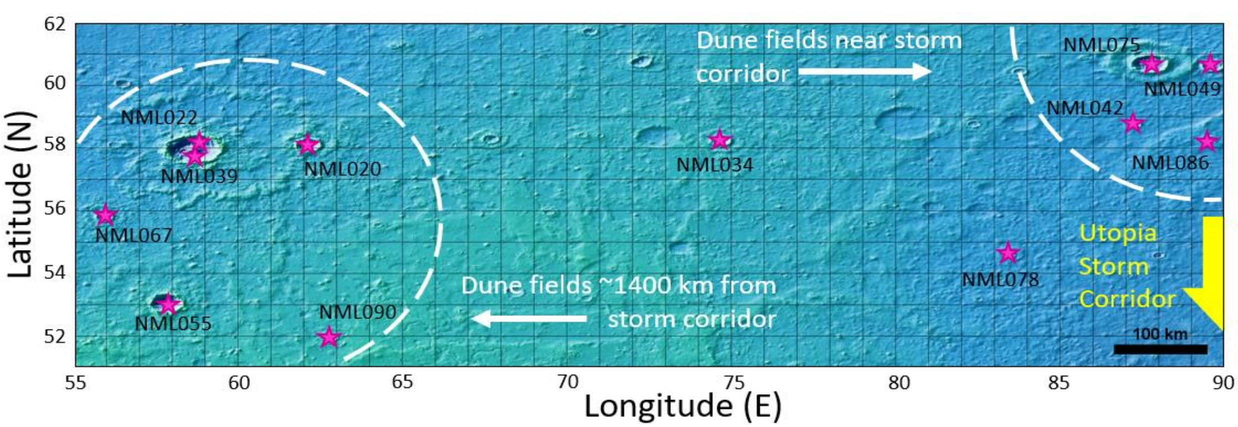

Figure 1: *The study area for this investigation overlaid on a MOLA colorized elevation map. Dune fields are indicated by pink stars, clustered dune fields by white dashed circles, and the location/ direction of the storm corridor in yellow (just off the map).*