COMPARISON OF VENTIFACT ORIENTATION AND RECENT WIND DIRECTION INDICATORS ON THE FLOOR OF JEZERO CRATER, MARS. K. E. Herkenhoff[1], R. J. Sullivan[2], C. E. Newman[3], G. Paar[4], M. Baker[5], D. Viúdez-Moreiras[6], J. W. Ashley[7], A. Bechtold[8], and J. I. Nuñez[9], [1]USGS Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001 (kherkenhoff@usgs.gov), [2]Cornell University, Ithaca, NY 14853, [3]Aeolis Research, Chandler, AZ 85224, [4]Joanneum Research, 8010 Graz, Austria, [5]Smithsonian National Air and Space Museum, Washington, DC 20560, [6]Centro de Astrobiologia, Madrid, Spain, [7]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91101, [8]University of Vienna, Austria, [9]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723.

Introduction: Ventifacts are eroded rocks that have been abraded and shaped by wind-blown, sand-size particles. The abrasion process forms flutes, pits, and grooves that typically align along the flow direction of strong, sand-driving winds on Earth and Mars [1]. Abundant evidence shows that aeolian abrasion modifies exposed rock surfaces on Mars, based on observations of ventifacts at previous landing sites [2]. Ventifacts also are present on the floor of Jezero crater, as observed by the *Perseverance* rover during the first 400 sols (Martian days) of the Mars 2020 mission [3] and are thought to record the direction of the winds that formed them. Here we report orientation measurements of ventifact textures on the floor of Jezero and compare these with orientation measurements of recent wind direction features (regolith wind tails, i.e., sandy drifts behind obstacles). Similar comparisons of wind direction inferences at previous landing sites have shown significant differences in recent and paleowind indicators, suggesting significant changes in wind directions. We discuss the implications of our observations in Jezero crater for paleoclimatic variations along with similar results at other Martian landing sites. Atmospheric circulation modeling results are then compared with the measured orientations.

Observations: Ventifacts and other wind-formed features were identified and measured in stereo data derived from images acquired by the Navcam [4] and Mastcam-Z [5] cameras on the *Perseverance* rover. We measured only aeolian abrasion textures with clearly expressed orientations; features that appeared to be aligned along bedding or other primary structures were not analyzed further. Once linear abrasion features of interest were identified, their orientations were measured in Mastcam-Z-derived digital ordered point cloud (OPC) datasets using the PRo3D software package [6]. Measurements of features that were questionable or poorly resolved in the OPC were not included in statistical analyses. The three-dimensional locations of the upwind and downwind ends of wind tails were measured using Mars 2020 flight operations ASTTRO software (Advanced Science Targeting Toolkit for Robotic Operations [7]), allowing the slope and azimuth (clockwise from north) of each feature to be derived.

Discussion: The wind tail orientations (mean azimuth of 285° ± 15°) indicate that they were formed by winds blowing toward the WNW while the orientations of ventifact features suggest formative, sand-driving winds blowing toward a mean azimuth of 94° ± 7°, almost in the opposite direction (Fig. 1). The inferred direction of recent winds that formed the wind tails is very similar to the orientation of the dunes measured by Day & Dorn [8], which indicate that they were formed by winds trending toward 263° ± 8°.

Evidence for changes in strong (sand-transporting) wind directions has been noted at other locations on Mars [13]. Collectively, all these examples indicate the potential of aeolian abrasion textures to preserve records of past wind conditions for relatively long surface exposure times under arid Martian conditions.

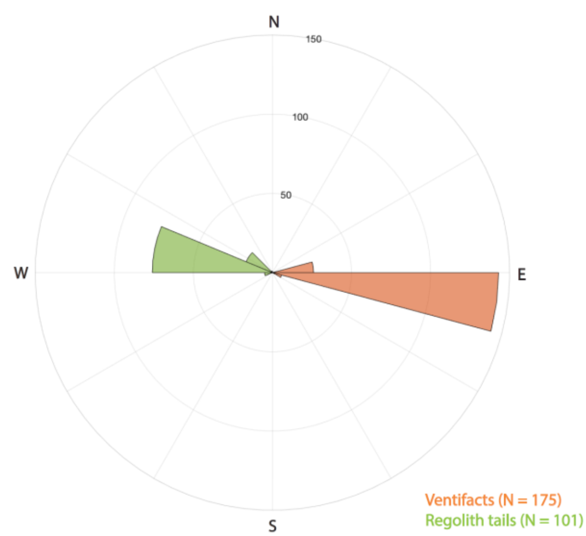

Figure 1. *Orientations of linear ventifact features (orange) and regolith wind tails (green) averaged over 15-degree azimuth bins. In both cases downwind azimuths are shown.*

Comparison with wind observations and models. Winds measured in Jezero crater by the Mars Environmental Dynamics Analyzer (MEDA) [9] to date show good agreement with the predictions of some atmospheric models that resolve the crater topography, and are consistent with measured wind tail orientations. These results lend greater confidence to Mars Weather Research and Forecasting (MarsWRF) model predictions of how the circulation may differ at other seasons, as shown in [10] and in the high-resolution modeling results of [11]. While there are subtle differences, those predictions show a lack of significant seasonal variation in diurnal wind patterns, except for a reduction in wind speeds at aerographic solar longitude (L_s) ~270° compared to other seasons. Hence, it appears unlikely that seasonal changes can explain the difference between ventifact and wind tail orientations.

Other than seasonal changes, there are two other possibilities for producing the observed ventifact orientations. One is that they are formed predominantly during dust storms, when winds could potentially be stronger and thus reflect the altered wind patterns during such events. Unfortunately, the MEDA wind sensor was damaged during the early part of the January 2022 regional dust storm, and although data from right beforehand does indicate a shift in the wind, it is very difficult to determine whether storm winds are consistent with the observed ventifact orientations [12].

A second possibility is that they formed during a different orbital epoch, such as one with a very different obliquity compared to the present day (25.2°) or a different seasonal timing of perihelion. Stronger background northerlies might enhance and/or push nighttime downslope winds from the northwest/west-northwest deeper into the crater, possibly resulting in stronger wind speeds from this direction at the rover's location. High-obliquity simulations generally predict a balance between daytime and nighttime sand flux magnitudes similar to that found for the present day. The exception is near the northern autumnal equinox in the high-obliquity simulation, when the peak flux across all sols at ~23:00 LTST is comparable to the peak mid-sol. However, the sand transport direction in that particular sol (at ~23:00) is from the northeast. Further, peak fluxes during this simulation are lower than those predicted during the daytime for the present-day L_s ~270° simulation and are *much* lower than those predicted in the late afternoon at L_s ~0° for both the present-day and 45° obliquity simulations. In all cases the predicted sand transport is from between the east and southeast. These preliminary results do not support the idea that higher obliquities could explain the observed ventifact orientations. However, far more study is needed, including the idea that at L_s ~270° at higher obliquity the atmosphere might have much greater dust content due to feedback between winds and dust lifting, driving a stronger zonal mean circulation, although this may not occur if the dust supply is limited. This preliminary investigation barely scratches the surface of exploring past orbital configurations.

Conclusions: A major change in the direction of strong winds in Jezero crater is recorded by surface features of different ages. In the past, sand-driving winds consistently from the WNW prevailed long enough to establish ventifact textures on rock exposures throughout the study area, but the strongest winds of the current wind regime have not prevailed long enough, with whatever sand supply exists upwind, to leave a comparable ventifact record. Current nighttime wind directions are similar to the paleowind direction inferred from the ventifact orientations, so a past wind regime that causes nighttime wind speeds to increase and dominate over daytime winds may explain the formation of the ventifacts. Further work is needed to determine what changes in orbital/axial parameters might cause such a wind regime.

Acknowledgments: The authors thank the Mars 2020 science and engineering teams for their excellent support. The data and associated metadata used in this study are available at the Geosciences node of the PDS: https://pds-geosciences.wustl.edu/missions/mars2020/. OPCs processed by PRoViP from all PDS-released Mastcam-Z stereo and monoscopic data sets are available from sftp://PRoViP-Mastcam-Z-PDS-Released@digsftp.joanneum.at:2200 – with username PRoViP-Mastcam-Z-PDS-Released and password MQRr63hJdUzVFHYc!.

References: [1] Laity J. E. and Bridges N. T (2009), *Geomorphology*, doi:10.1016/j.geomorph.2008.09.014. [2] Bridges N. T. et al. (2014) *JGR-Planets, 119*, 1374-1389. [3] Farley K. A. et al. (2020) *Space Sci. Rev., 216*, 142. [4] Maki J. M. et al. (2021) *Space Sci. Rev*. *216*, doi:10.1007/s11214-020-00765-9. [5] Bell J. F. et al. (2021) *Space Sci. Rev*. *217*, doi:10.1007/s11214-020-00755-x. [6] Barnes R. et al. (2018) *Earth and Space Sci.*, *5*(7), 285-307. [7] Abercrombie S. P. et al (2019) *LPS L*, Abstract #2268. [8] Day M. and Dorn T. (2019) *Geophys. Res. Lett*., *46*, doi:10.1029/2019GL-82218. [9] Rodriguez-Manfredi J. A. et al. (2021), *Space Sci. Rev.*, *217*, 48. [10] Newman C. E. et al. (2021) *Space Sci. Rev.*, *217*, 20. [11] Pla-Garcia J. et al. (2020) *Space Sci. Rev*., *216*, doi:10.1007/s11214-020-00763-x. [12] Lemmon M. T. et al. (2022) *Geophys. Res. Lett.*, *49*, e2022GL100126; Viudez-Moreiras D. et al. (2022) *JGR-Planets*, *127*, doi:10.1029/2022JE007522. [13] Bridges N. T. et al. (1999) *JGR.*, *104*, 8595; Sullivan R. et al. (2005) *Nature*, *436*, 58–61; Bridges N. T. et al. (2014) *JGR*, *119*, 1374–1389; Favaro E. A. et al. (2021) *JGR-Planets*, *126*, e2020JE006723.