COLLEGE OF SCIENCE
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Research and Creative Experience for Undergraduates Program (RCEU) Summer 2022

Utilizing NASA/Ames Global Circulation Model to Locate Low-Level Jets on Mars

Sydney Rau, Udaysankar Nair

Department of Atmospheric and Earth Science

Overview

Low-Level Jets (LLJs) are local maxima of wind speeds occurring in the boundary layer, a layer sensitive to surface friction. On Earth, these jets tend to build overnight in the absence of friction as turbulence wanes. This absence, combined with the pressure gradient force, accelerates a belt of winds, forming the LLJ. Further, the inertial oscillation with friction adds momentum for winds to surge faster than geostrophic. In the Great Plains, LLJs tend to take on their strongest form due to its broad, gently-sloped landscape. On Mars, limited knowledge of their nature leads to questions of where, when, and how they form. Our motivation: characterize LLJs on Mars as a function of geography and topography, and compare or contrast their characteristics to LLJs on Earth. This study is applicable for the plans of future missions with landers and sailplanes since LLJs can negatively affect landers' descents while the high wind shear environments can be favorable for the operation of sailplanes (*1*).

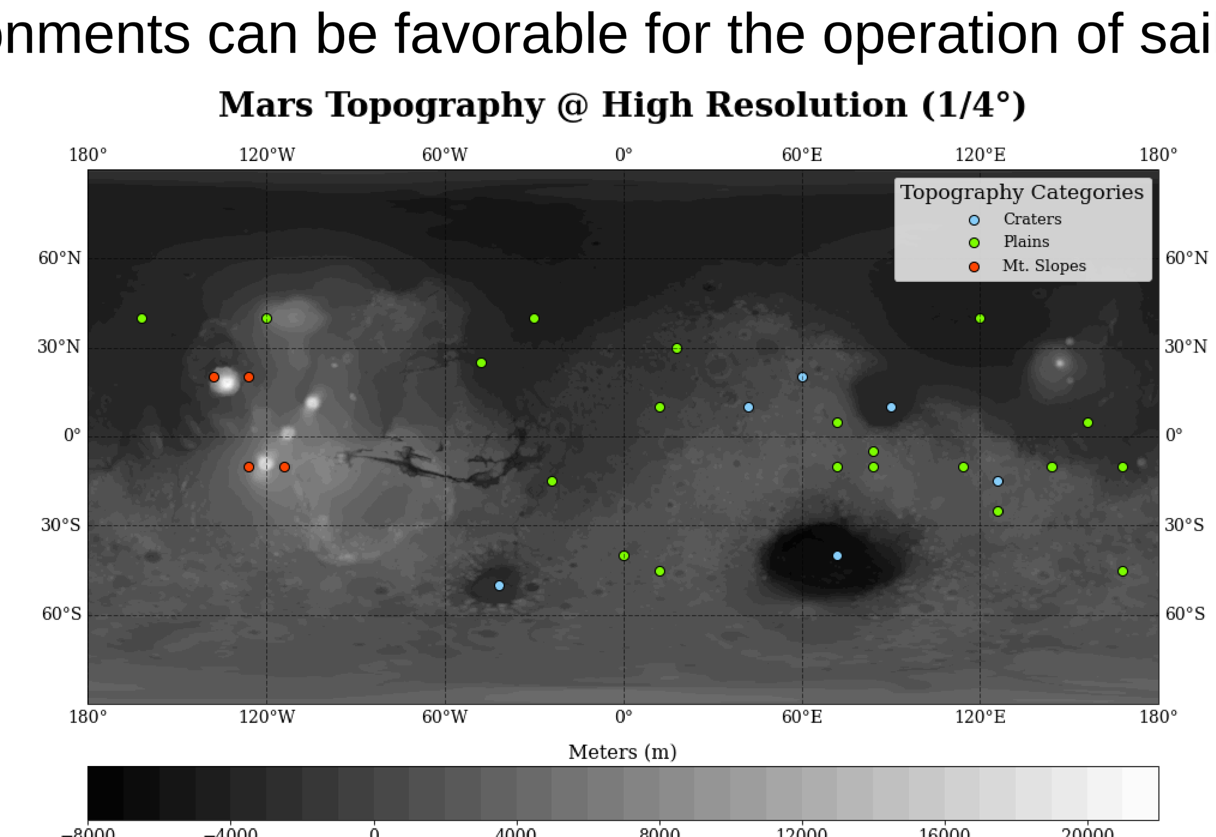


Figure 1 Topographic map of 30 locations either at Mt. Slopes, Plains or Craters.

Methodology

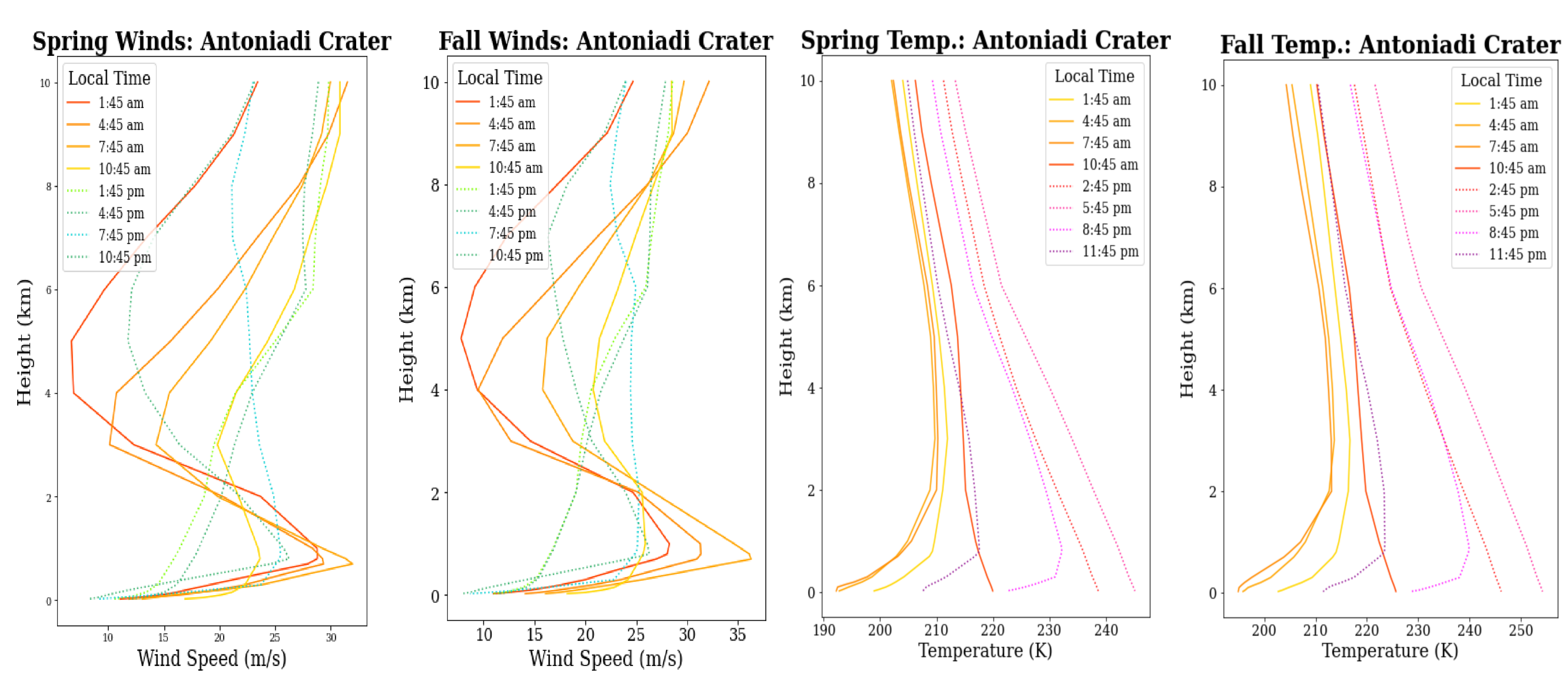
In this project, NASA/Ames Legacy Mars Global Circulation Model (MGCM) was utilized, a 3D numerical model of governing equations of atmospheric flow to simulate circulation. Through python software implemented in Google Colab, MGCM output on the cloud was processed to generate mean seasonal vertical profiles of temperature and wind. Mean vertical profiles were computed by first determining pressure at each terrain-following sigma coordinate level and then using hypsometric equation to interpolate horizontal wind components (U and V) and temperature to specified height levels between 0.025 and 10 km. U and V were then used to calculate mean wind speed profiles at 3-hour intervals and averaged for 40-day window (Fig. 2-3) centered on solar longitude values per season (i.e. Winter = 270°). Temperature profiles were also computed in a similar manner (Fig. 4-5). Both profiles were then examined over various topographic features such as plains, craters, and mountain (mt.) slopes to characterize geographic and topographic variability of LLJ's (Fig. 1). *Note: All profiles were shifted to local time.* (*2*)

References

1. Haberle, et al. (2019) "Documentation of the NASA/Ames Legacy Mars Global Climate Model: Simulations of the present seasonal water cycle". Icarus 333, 130-164.
2. Blackadar, Alfred K. "Boundary Layer Wind Maxima and Their Significance for the Growth of Nocturnal Inversions". Bulletin of the American Meteorological Society 38.5 (1957): 283-290. <https://doi.org/10.1175/1520-0477-38.5.283>. Web.
3. Rife, Daran L., et al. "Global Distribution and Characteristics of Diurnally Varying Low-Level Jets". Journal of Climate 23.19 (2010): 5041-5064. <https://doi.org/10.1175/2010JCLI3514.1>. Web.

Key Findings

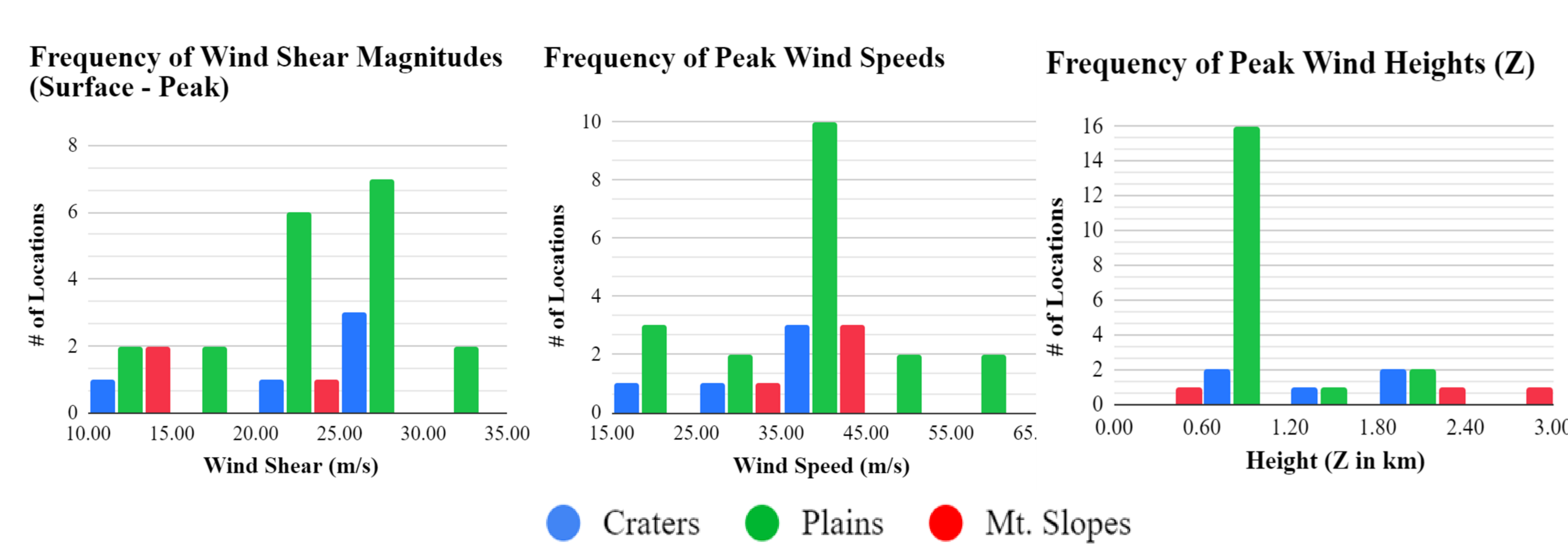
In the assessment of 120 wind profiles between 30 locations, LLJs were found in all locations, but were the most prominent, frequent, and well-timed in the mid-high plains and craters, peaking in strength during the Fall/Winter seasons. Mt. slopes did have low-level maxima and were still included, but this was hypothesized to possibly be slope winds rather than jet cores. In comparison to Earth's LLJs, the mean LLJ heights on Mars reached about 1.2 km, about thrice the 0.44 km average on Earth (*3*). For timing, 17 locations had LLJ peaks at dawn, local time (around 3:00 to 7:00 am), which is synonymous to the nature of Earth's nocturnal LLJs (NLLJs) in the Great Plains. The mean wind speeds of all locations came out to be 38.3 m/s, a higher speed than Earth's average of 13.2 m/s (Fig. 6-8) (*3*).



Figures 2-5 Left-Right: Mean vertical profiles of Fall/Spring wind speeds and temperature at Antoniadi Crater: A depression of "flat" terrain located at 20°N, 60°E.

Conclusions

This comprehensive survey of LLJs on Mars was conducted for the first time using MGCM, where LLJs were found to occur frequently at all geographic locations. However, their behavior and nature varied with topography. According to key findings, LLJs on Mars turned out to be more intense, have higher wind shear magnitudes, and form at higher altitudes than LLJs on Earth. In the future, mapping this zone of high wind shear would prove to be an essential aspect to the planning of lander and sailplane missions since their operations are dependent on their environment.



Figures 6-8 Left-Right: Histograms of three main characteristics to LLJs (from left-right): wind shear magnitude, peak (maximum) wind speeds, and peak winds' height levels in the atmosphere.

Acknowledgements

I give a special thanks to Chris Phillips, Alexandre Kling, Ankur Kumar, George Priftis, Michael Yurovchak, Nick Perlaky and Adam Weiner. In the toughest moments, you all played an essential role in providing unconditional support on this project. I gratefully appreciate the UAH Office of the President, Office of the Provost, Office of the Vice President for Research and Economic Development, The Dean of the College of Science, the Dean of the College of Engineering, and the Alabama Space Grant Consortium for allowing me this opportunity.