National Aeronautics and Space Administration

Characterizing Small Martian Dust Storms with Data Science for Mission Planning and Climate Modeling

Principal Investigator: Mark Wronkiewicz (398); Co-Investigator: David Kass (322); Collaborator: Marek Slipski (322)

Program: FY22 R&TD Innovative Spontaneous Concepts

Objectives

We sought to better understand small dust storms and their effect on the Martian climate. Specifically, our scientific objective here was to explain variability (e.g., size, duration, lifecycle) in several thousand small dust storm using atmospheric measurements. **This is crucial to better interpret, model, and eventually predict dust events for future robotic or crewed exploration.**

Background

Dust storms are critical to the circulation of materials (e.g., dust, H 2O, CO2) through the Martian atmosphere. **Small dust storms (occurring thousands of times/year) are difficult to investigate** due to limited spatial/temporal extent. Mars Reconnaissance Orbiter (MRO) has collected ample data on these small storms and analysis in aggregate may provide insights.

Approach

We studied small dust storms by harmonizing data across two different Martian datasets. The MDAD [1] is a catalog of 14,974 dust storm instances and properties (e.g., size, duration, traveled distance). MCS [2] retrievals provide vertical profiles of temperature and dust opacity through the atmosphere [3]. **We examined thousands of storms using data science techniques** (like Principle Component Analysis (PCA) and K-Means clustering) to explain variability in known storm characteristics.

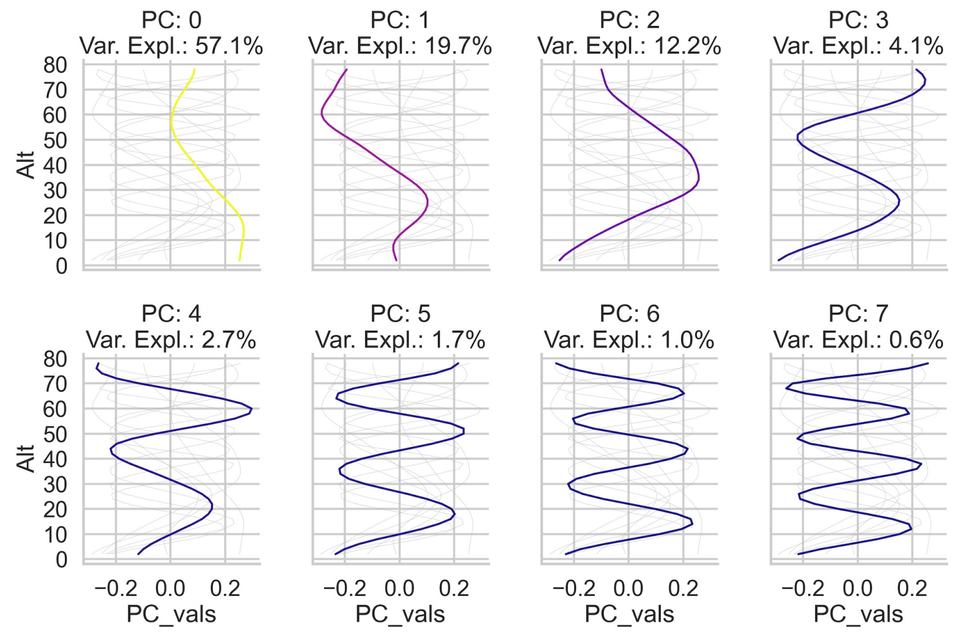

Figure 1. Principal components after applying PCA to the full set of storm temperature profiles. These 8-traces represent a set of basis vectors that capture the majority of the variability in measured storm temperatures.

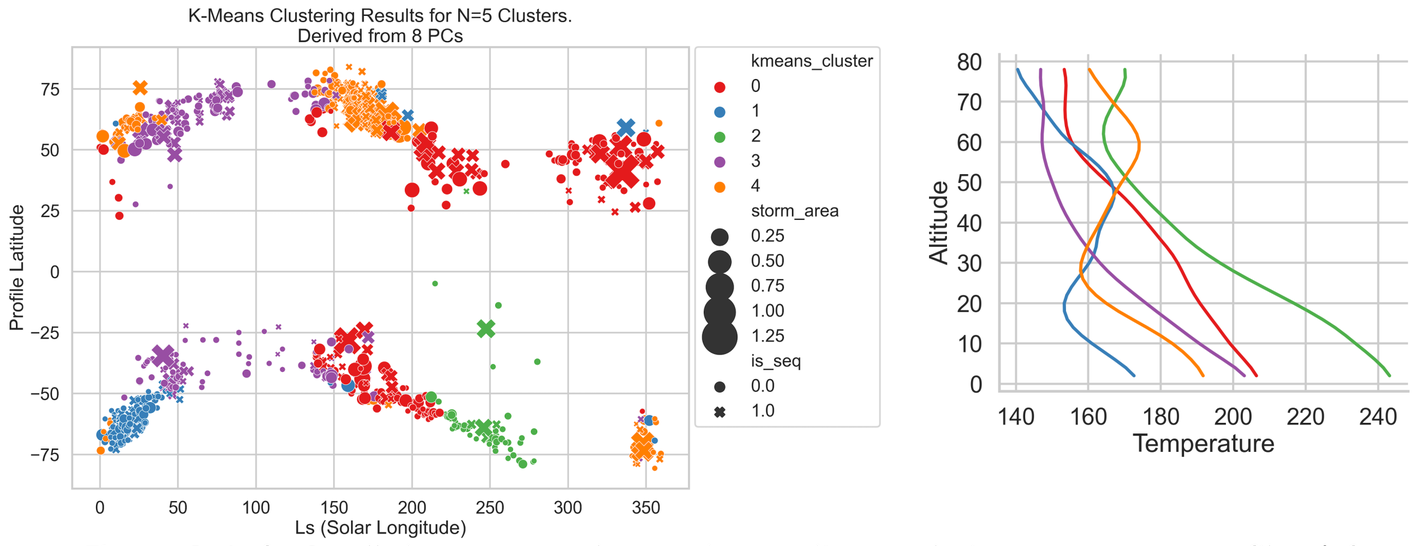

Figure 2. Left: Small dust storms clustered according to their temperature profiles (after PCA decomposition). Right: Storm archetypes representing the "average" temperature profile for each of the storm clusters.

Results

- We identified one storm cluster (#4 in Fig. 2, left) **with longer average duration and larger size than any other storm cluster**
- The average profile (or “archetype”) for this storm cluster has a temperature inversions with warm temperatures peaking at 60km above the a colder trough at ~30km
- Correlations exist between individual PCA components and storm size, duration (Fig. 1, 3)
- We were not able to identify clear differences between measured storms and matched control profiles **suggesting that seasonal climate variations (and not individual storm variability) drive storm differences**

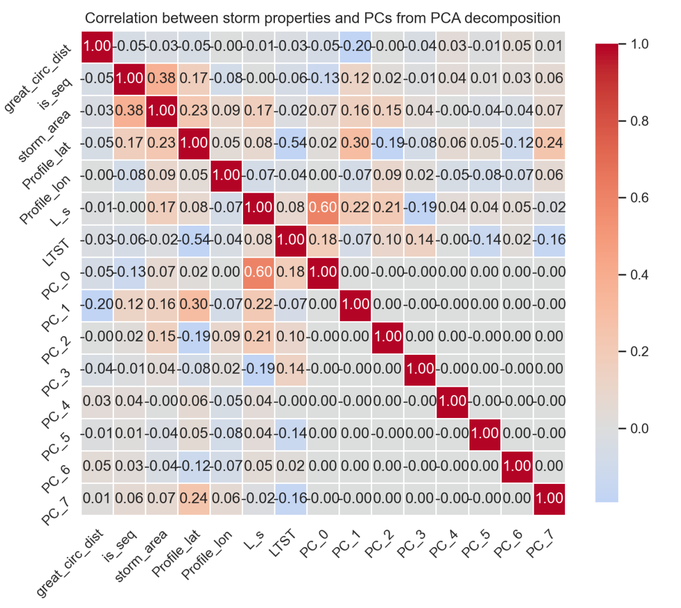

Figure 3. Correlations between physical measured properties (from the MDAD) and PCs. Note that some PCs correlate with whether the storm was a sequence (lasted multiple days) and storm area.

Significance to JPL and NASA

We must better understand **dust events as they affect important mission phases like aerocapture, EDL, and surface operations.** Preliminary results from this work are being submitted as a ROSES MDAP proposal to further address these needs. This project is also working example of the **Scientific Understanding through Data Science (SUDS)** effort to bridge JPL’s physical science and data science communities.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

References:

[1] Battalio, M., & Wang, H. (2021). The Mars Dust Activity Database (MDAD): A comprehensive statistical study of dust storm sequences. In Icarus (Vol. 354, p. 114059). Elsevier BV. https://doi.org/10.1016/j.icarus.2020.114059

[2] McCleese, D. J., Schofield, J. T., Taylor, F. W., Calcutt, S. B., Foote, M. C., Kass, D. M., Leovy, C. B., Paige, D. A., Read, P. L., & Zurek, R. W. (2007). Mars Climate Sounder: An investigation of thermal and water vapor structure, dust and condensate distributions in the atmosphere, and energy balance of the polar regions. In Journal of Geophysical Research (Vol. 112, Issue E5). American Geophysical Union (AGU). https://doi.org/10.1029/2006je002790

[3] Kleinböhl, A., Schofield, J. T., Kass, D. M., Abdou, W. A., and McCleese, D. J. (2007). MARS ATMOSPHERIC PROFILES OF TEMPERATURE AND DUST RETRIEVED FROM MARS CLIMATE SOUNDER MEASUREMENTS. Workshop on Planetary Atmospheres (#9015). https://www.lpi.usra.edu/meetings/patm2007/pdf/9015.pdf

PI/Task Mgr. Contact Information:

Email: wronk@jpl.nasa.gov