National Aeronautics and Space Administration

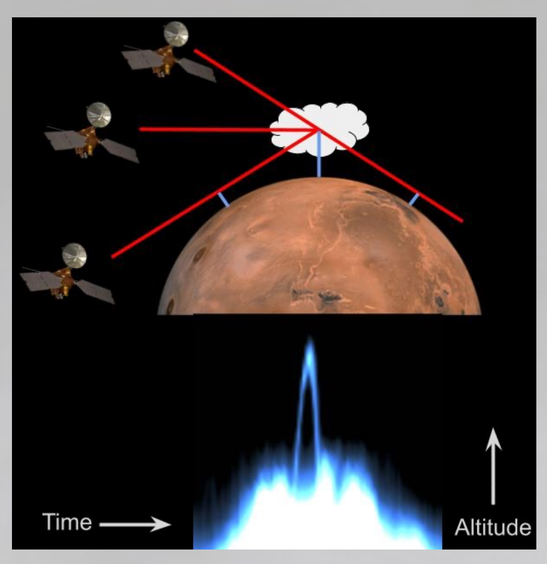
Cloudspotting on Mars: Exploring Mars's atmosphere through citizen science

Marek Slipski, JPL Postdoctoral Fellow (3222)
Armin Kleinböhl (3222), Steven Dillmann (Imperial College London),
Jason Reimuller (International Institute for Astronautical Sciences),
Mark Wronkiewicz (398J), Gary Doran (398J)

Observing clouds at high altitudes can help us better understand the major volatile cycles and climate of Mars.

- How is water transported to the upper atmosphere where it can be broken apart and lost to space? How does dust influence this process?
- How do planetary scale oscillations (thermal tides) and small-scale perturbations (gravity waves) enable cloud formation?
- Here, we probe these questions by identifying clouds in Mars Climate Sounder (MCS) observations through a NASA citizen science project on the Zooniverse platform, *Cloudspotting on Mars*.

Mesospheric clouds appear as arch-shaped features in MCS limb observations.



- MCS is an infrared limb sounder onboard Mars Reconnaissance Orbiter (MRO).
- The changing geometry during an orbit causes the apparent altitude of the cloud to rise until its true altitude at the tangent point before declining again.

Fig 1: (Top) Schematic of how mesospheric clouds appear as arches (not to scale). (Bottom) Radiance measurements spanning an hour are shown from near the surface to about 80 km.

To aid in analysis of 15 years of observations, the Cloudspotting on Mars project launched on 6/28/2022.

- Users identify the peaks of arches in MCS "images" using a point-and-click tool on Zooniverse.
- The labeled data set produced by citizen scientists provides ground truth for an automated cloud detection algorithm.
- We hold monthly webinars to share research findings, help participants use the tool, and build connections with citizen scientists.

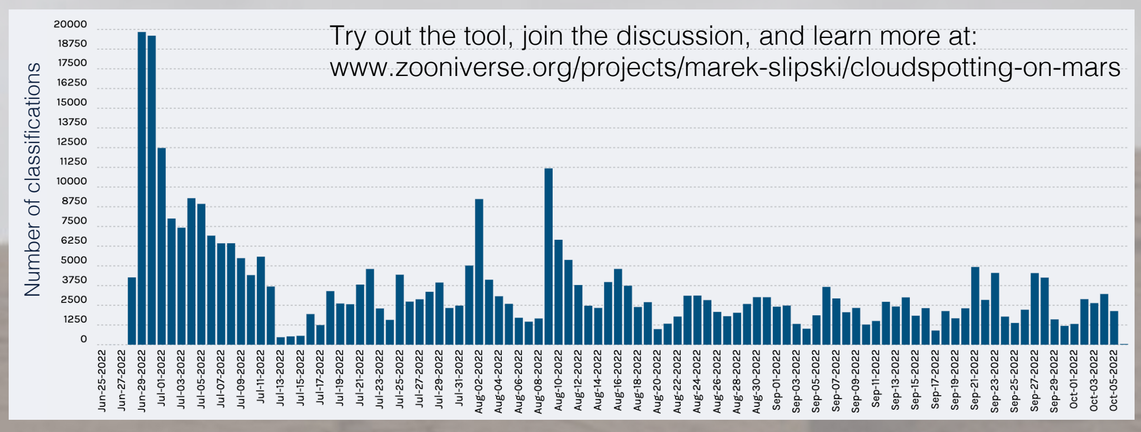


Fig 2: Number of classified subjects per day since launch.

Using a clustering algorithm, we aggregate the citizen scientist annotations into cloud locations.

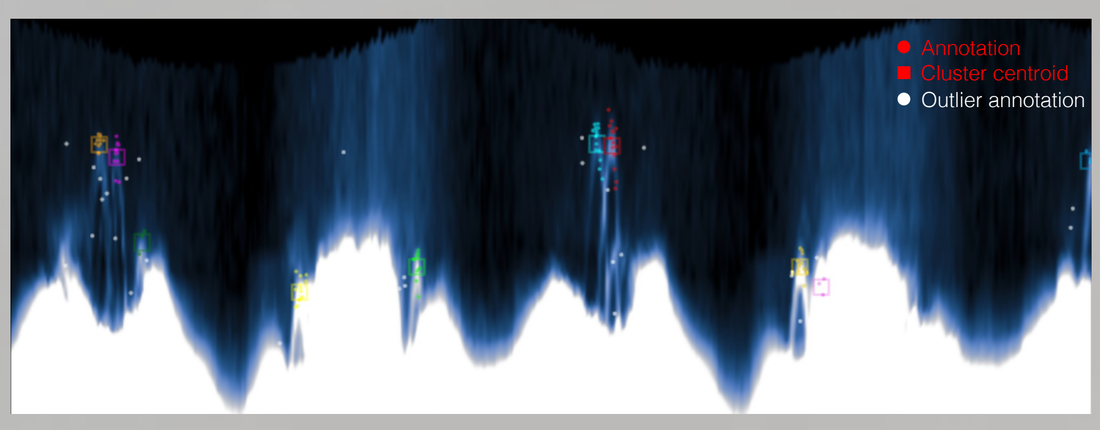
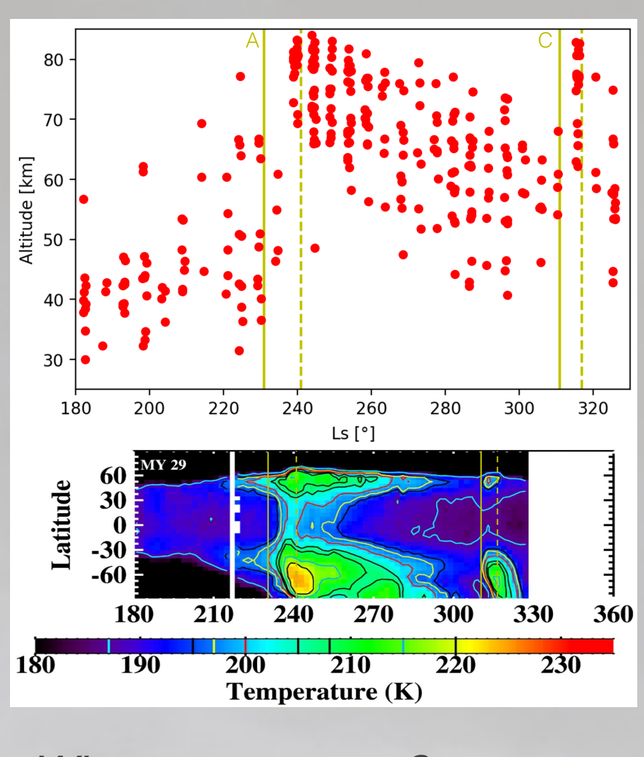


Fig 3: Individual cloud markings (points) are clustered together (squares). In this example 4-hour image, there are 10 identified clouds.

We find that water-ice clouds in the southern hemisphere quickly jump to 80 km due to regional dust storms.



- Regional dust storms (here, the A and C events) cause significant warming of the lower atmosphere.
- These events lead to the formation of high altitude water-ice clouds.

Fig 4: (Top) Altitudes of individual clouds in the A6 channel poleward of 50°S during southern summer of MY29. (Bottom) Daytime zonal mean temperatures at 50 Pa (~25 km) observed by MCS covering the same time period (Kass et al., 2016).

What comes next?

- Citizen scientists have nearly retired every image from Mars Year 29 (MY29). Upon completion, we will analyze MY30—a year that was much less dusty than MY29.
- We will determine the composition and particle sizes of clouds by fitting the output of a radiative transfer model to cloud radiances.

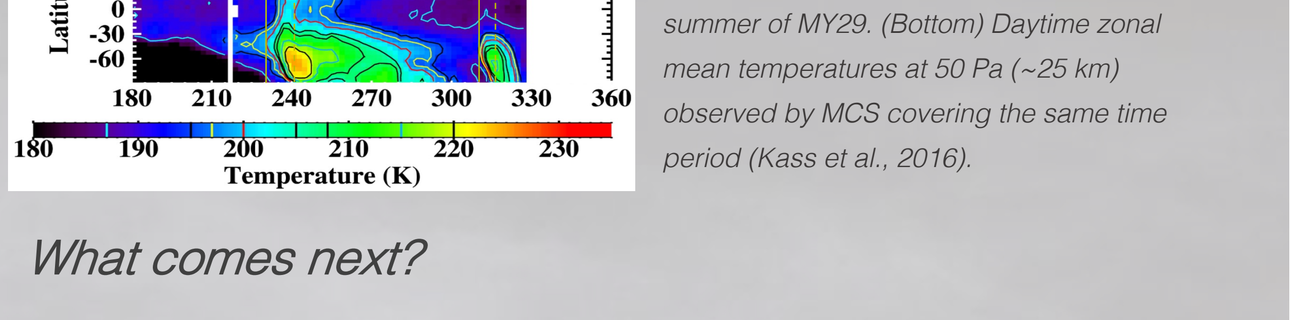


Fig 5: Diagram indicating how we will find cloud compositions. The plot above shows radiances consistent with a CO_2-ice cloud.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Publications and Press:

- *WIRED:* NASA Is Crowdsourcing Cloud Research—on Mars (https://www.wired.com/story/nasa-is-crowdsourcing-cloud-research-on-mars/)
- *Planetary Radio Podcast:* Citizen Science: Join the search for Martian clouds (https://www.planetary.org/planetary-radio/2022-cloudspotting-on-mars)
- *NPR Morning Edition:* NASA scientists need your help finding clouds on Mars (https://www.npr.org/2022/08/09/1116455607/nasa-scientists-need-your-help-finding-clouds-on-mars)
- *Past work on MCS clouds:* Slipski, M., Kleinböhl, A., Kass, D. M., "Role of thermal tides and gravity waves in Mars equatorial mesospheric cloud formation revealed by Mars Climate Sounder observations." *Geophysical Research Letters* (in revision).

Author Contact Information:

Phone: 818-393-4828
Email: marek.j.slipski@jpl.nasa.gov