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# Conditions and dynamics in the active region of a regional Mars dust storm

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## Abstract

The conditions within and nearby the active lifting region of a dust storm have never been observed in situ. The unobserved conditions are modeled with the Mars Regional Atmospheric Modeling System using a fully interactive dust cycle. The storm is found to be extremely dynamic, with deep and vigorous vertical plumes of dust that exhibit a life cycle and mesoscale organization.

## 1. Introduction

The active regions of Mars dust storms may present some of the most challenging operational environments for human and robotic exploration. Visibility is likely to be substantially reduced. Winds, although lacking meaningful momentum, can pick up large quantities of dust causing it to abrade or enter mechanical elements. The large amount of dust may also induce strong electric fields, possibly sufficient to induce breakdown (i.e., lightning) or arching within electronics. The thermal environment is likely to also change dramatically. But all of these conditions are hypothesized; there have never been in situ observations at or near the active lifting center of a regional or larger dust storm on Mars. Landed meteorological packages have recorded the atmospheric environment during large and global dust storms, but only at a distance from the presumed active areas.

## 2. Numerical Experiment

In support of the Mars 2020 Rover mission (hereafter M2020), mesoscale modeling of 11 landing sites with high science potential have been modeled to characterize and identify possible hazardous atmospheric conditions during entry, descent and landing (EDL) operations. Substantial effort has gone into simulating both nominal (non-dust storm) conditions as well as those conditions that might be expected in a dust storm. For the purposes of this study, the results of dust storm scenarios in the vicinity of the landing sites at Syrtis (lat/lon) and Jezero Crater (lat/lon) are presented.

One method to investigate dust storm conditions is to utilize a fully interactive dust cycle. In this scenario, surface winds are allowed to lift dust, the lifted dust is permitted to radiatively perturb the thermal structure of the atmosphere, and the dynamics (the winds) evolve and transport the lifted dust according to the radiative forcing. The Mars Regional Atmospheric Modeling System (MRAMS [1]) is configured with a fully interactive dust cycle that evolves according to the model-predicted winds and diffusion. Dust also undergoes sedimentation. The simulation has five grids, and dust lifting is permitted only on grids two through four.

## Results

During the afternoon on the sol 2, the first day of dust lifting, two primary areas of lifting develop (Fig. 1). The first area is in the northeast region of the grid, and is already organized into a linear feature that becomes more disorganized through the day. The second area is on the southeast rim of the Syrtis impact basin. The Syrtis area organizes into a linear feature roughly aligning with the daytime upslope flow.

A cross-section showing different atmospheric fields at x=85 and ~1400 local is displayed in Fig. 2. The dust mixing ratio shows a deep (> 6 km) plume just to the north of the Isidis crater rim. The mixing ratio peaks near the surface and drops off with height. This dust profile is consistently seen in active lifting regions. The surface maximum is partly due to the surface being the source of dust, with entrainment of less dusty air as the plume rises. However, it is also because the mixing ratio can be dominated by a few large dust aerosol, since the mass is proportional to the cubed of the radius.

In the plume near the surface, the air temperature is as much as 20K colder than nearby areas. This is due to solar absorption higher in the dust column limiting direct heating deeper into the atmosphere. Overall, within the plume, there is an inversion, and although the top of the plume is warmer than below, it is near neutral buoyancy compared to the less dusty air on either side. Apparently, adiabatic cooling nearly offsets the expected positive heating perturbation at the top of the dusty plume.

Turbulent kinetic energy is confined to a much shallower layer near the surface in and around the dust plume. This structure is consistent with the thermal structure—an inversion—that will tend to suppress buoyancy of generation of turbulence. In contrast, near the middle of the grid where a more traditional steep lapse rate is present, deep convective, but non-dusty plumes are present.

Finally, a very strong (>60 m/s) low level jet forms in the vicinity of the dusty plume. This structure results entirely from the dust storm distribution, which can be seen by examining the model solution when lifted dust (foreground dust) is not radiatively active (Fig. 3).

## 3. Figures

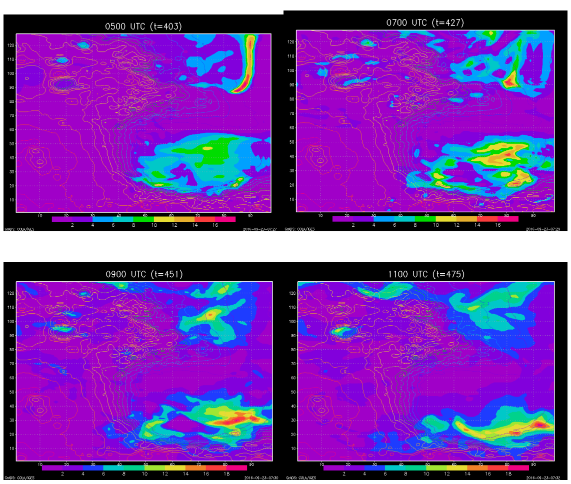


Figure 1. Column visible dust opacity (shaded) and topography (contours) on grid 3 during the afternoon. Times are given in Mars UTC. Add ~5 hours for local time. Axes are labelled by grid point (~27 km spacing).

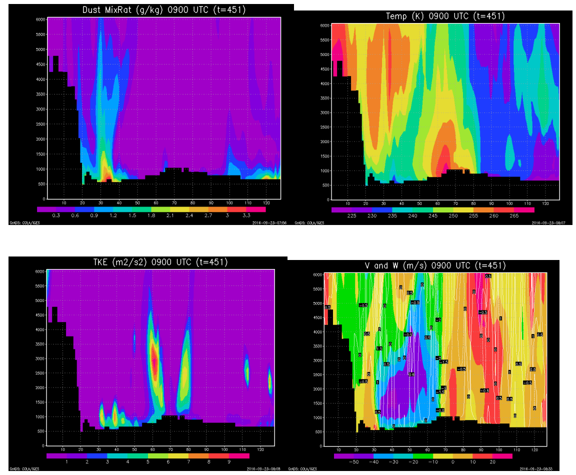


Figure 2. Dust mixing ratio (top left), temperature (top right), Turbulent kinetic energy (bottom left) and v (shaded) and w (contoured) wind (bottom right) on grid 3 at x=85 during the afternoon.

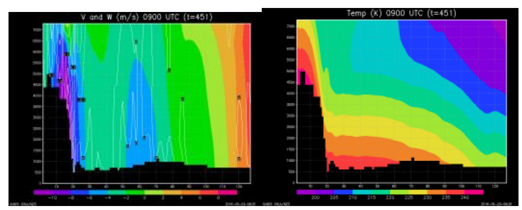


Figure 3. Temperature (left) and winds (right) for the same cross-section as in Figure 2, but for the case of radiatively passive dust.

## Acknowledgements

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## References

[1] Rafkin, S. C., Haberle, R. M., & Michaels, T. I. (2001). The Mars regional atmospheric modeling system: Model description and selected simulations. Icarus, 151(2), 228-256.