Inside the Belly of a Mars Dust Storm

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There have never been in situ observations at or near the active lifting center of a regional 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. In the absence of in situ data, it is common to employ numerical models to provide guidance on the physical processes and conditions operating in an unobserved location or weather system. This is a reasonable approach assuming the model has been adequately validated at other locations. Consequently, the Mars Regional Atmospheric Modeling System (MRAMS) is employed to study the structure and dynamics of a simulated large regional storm in the Isidis Basin area, and to provide the first ever glimpse of the conditions that might occur inside one of these storms.

The simulation has five grids, and dust lifting is permitted only on grids three through five. Limiting the dust lifting to the three highest resolution grids forces the model to produce a dust storm no larger than the size of the third grid domain. The simulation is run for a total of five sols with the simulations starting at ~0500 (local time). Dust lifting is activated at ~0500 local on the second sol, and continues through sol 3. Lifting is deactivated on sol 4 in order to force dust storm decay.

The simulated storm shows extremely complex structure, highly heterogenous lifting centers, and a variety of deep dust transport circulations. The active lifting centers show broader organization into a mesoscale system in much the same way that thunderstorms on Earth can organize into mesoscale convective structures. In many of the active dust plumes, the mixing ratio of dust peaks near the surface and drops off with height. The surface mixing ratio 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. Once lifted, the largest dust tends to sediment out while the smaller dust continues to be advected upward by the plume. This size-sorting process tends to drive the mixing ratio profile to a maximum near the surface. In dusty plumes 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. A very strong low level just forms in the vicinity of the storm, accompanied by system-wide negative pressure deficits and circulation patterns strongly suggestive of the wind-enhanced interaction of radiation and dust (WEIRD) feedback mechanism.

Keywords: Mars, Atmosphere, Dust Storm, Dynamics, Aerosol

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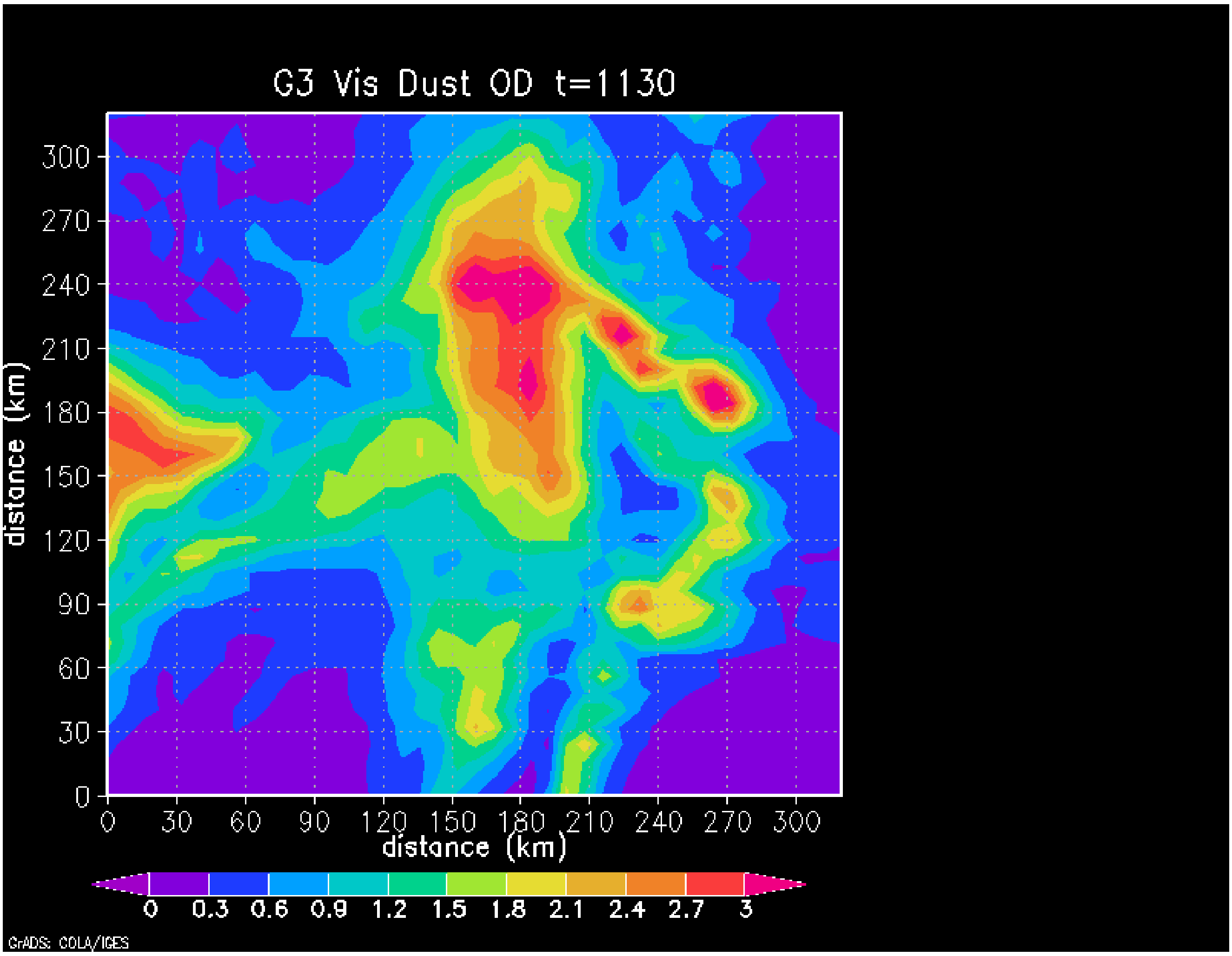

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