The circulatory impact of dust from dust profile assimilation

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The circulatory impact of the vertical dust structure
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Dust Profile Assimilation
- Mineral dust is the key radiative forcer in the martian atmosphere.
- Data assimilation: LMD-UK MGCM + observations = best estimate of state (e.g. [1]).
- Vertical dust structure shown by MCS to be more complex than previously assumed [2].
- MCS dust profiles and columns are assimilated to examine impact on the circulation and transport (“3D”), and compared to a MCS column-only assimilation (“2D”) for MY 31.

Zonal Temperatures and Winds

Major difference between assimilation cases is significantly warmer lower-middle atmosphere for the 3D case, due to greater dust representation above 10 km, and enhanced polar warming. Northern polar warming is also shifted higher, potentially heating the lower thermosphere.

In general, 3D case shows strengthened circulation, including as a strengthened southern polar jet; however, northern polar jet mostly unaffected, although strengthened at very high altitudes.

Asymmetry implies vertical dust distribution (i.e. more dust higher up) has most significant effect around “clear” season, when insolation is lower and middle atmosphere as observed by the Mars Climate Sounder: Seasonal variations in zonal mean temperature, dust, and temperature structure, global warming. Northern polar warming is shifted higher, potentially heating the lower thermosphere.

Seasonal asymmetry also related to topography: elevated dust layers act to mitigate topographic asymmetry [3,4] by providing elevated heating source in northern hemisphere.

Figures:

Transport

3D assimilation shows lower dust mass in southern polar vortex despite higher overall. Better fit with observed dust exclusion over southern polar vortex [5], suggesting dynamical explanation.

Mean meridional circulation (MMC) structure sees greatest difference around southern winter, with dramatically intensified Hadley cell. Suggests extra high-altitude dust mitigates topographic effects, as high dust loading can [6]. This has implications for long-term inter-hemisphere transport.

3D case sees some reduced surface eddy activity (Ferrel cells) due to greater lower-atmosphere static stability, which could impact eddy dust transport into polar regions. However, also see increased eddy activity at higher altitudes, due to increased thermal contrast at dust layer top.

Summary
- Vertical dust structure has significant impact on temperature structure, global circulation, and transport.
- Circulatory impact of increased elevated dust presence appears greatest during low-insolation times of year: mitigates effect of hemispheric topographic asymmetry and dramatically strengthen the N→S Hadley cell. Stronger Hadley cells overall.
- Reduced near-surface eddy activity; possible explanation for southern dust exclusion.
- TGO will offer a new dataset of dust profiles across a range of martian local times.

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