EPSC Abstracts
Vol. 7 EPSC2012-272 2012
European Planetary Science Congress 2012

Dust rocket storms, gravity waves and their impact on the martian troposphere and thermosphere

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Background Recent studies have shed light on mesoscale phenomena in the Martian atmosphere, unresolved by global climate models [6]. A particular emphasis was put on near-surface circulations, less so on dynamical phenomena in the upper troposphere and mesosphere. This aspect is in need to be further investigated to better understand recent observations and, more generally, the martian climate.

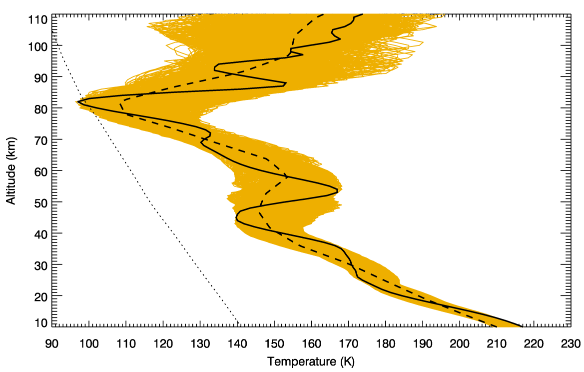

Figure 1: Gravity waves, mesospheric cold pockets and CO_2 clouds. *Results from idealized mesoscale simulations carried out in [7]. Vertical profiles of temperature in the vicinity of the domain center are shown : dashed line represents initial GCM profile, solid line represents predicted mesoscale profile after 3 simulated hours, orange "envelope" represents a larger set of predicted profiles ranging $2-4$ simulated hours and 20×20 grid points around domain center. CO_2 condensation profile T_c is superimposed.*

Gravity waves Many independent measurements have shown that extremely low temperatures ("cold pockets") are found in the Martian mesosphere. Recent observational achievements also hint at such cold pockets by revealing mesospheric clouds formed through the condensation of CO_2 [e.g., 5]. Large-scale meteorological conditions are key factors to account for the presence of those cold pockets in the Martian mesosphere [2]. Yet we show through multiscale meteorological modeling (Figure 1) that mesoscale gravity waves too could play a key role in the formation of mesospheric cold pockets propitious to CO_2 condensation [7]. Gravity waves are not detectable only through temperature disturbances. Wave patterns in the southern polar region of Mars were found in O_2 dayglow maps obtained with MEx/OMEGA. We show through mesoscale modeling (Figure 2) that the propagation of gravity waves in the Martian troposphere explains these patterns and that model predictions match spatial variability and dayglow fluctuations observed in the OMEGA maps [1].

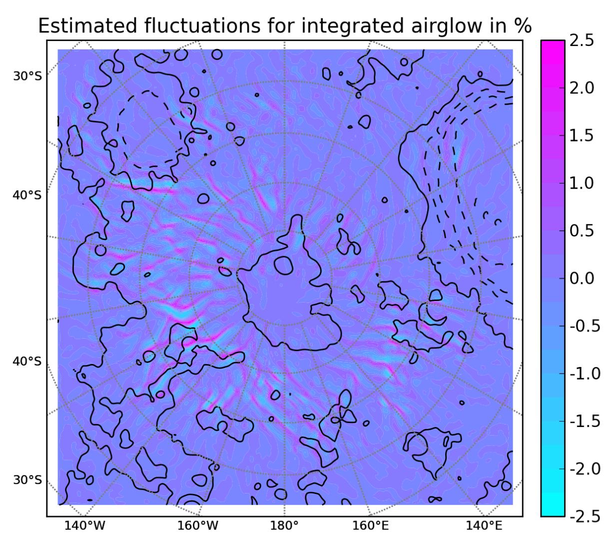

Figure 2: Airglow and gravity waves. *Estimated fluctuations of integrated airglow intensity in %, derived from predictions with mesoscale model by [6] for southern polar regions around spring equinox. See [1] for further details.*

Dust rocket storms We use atmospheric mesoscale modeling with radiatively-active transported dust to predict the evolution of a local dust storm monitored by OMEGA onboard Mars Express [4]. In the afternoon, dust transport within storm is governed by deep convective motions (Figure 3). The vast majority of convective energy supply originates in the absorption of incoming sunlight by dust particles, mostly in the visible. What we propose to name a "dust rocket storm" subsequently forms and injects dust particles at high altitudes in the Martian troposphere (30 to 40 km above the surface). Combined to advection by horizontal winds, this contributes to form detached layers of dust reminiscent of those observed e.g. with instruments onboard Mars Reconnaissance Orbiter [3]. Such detached layers are stable over several days. We checked the robustness of our conclusions by performing sensitivity simulations without the radiative effect of transported dust, with various sizes and properties of dust disturbance and with lifting activated in a more realistic setting. Our conclusions (manuscript to be submitted to JGR planets) have strong implications for the Martian dust cycle and advocate for further studies of dust storms (including global dust storms) at finer scales than usually assumed in global climate models.

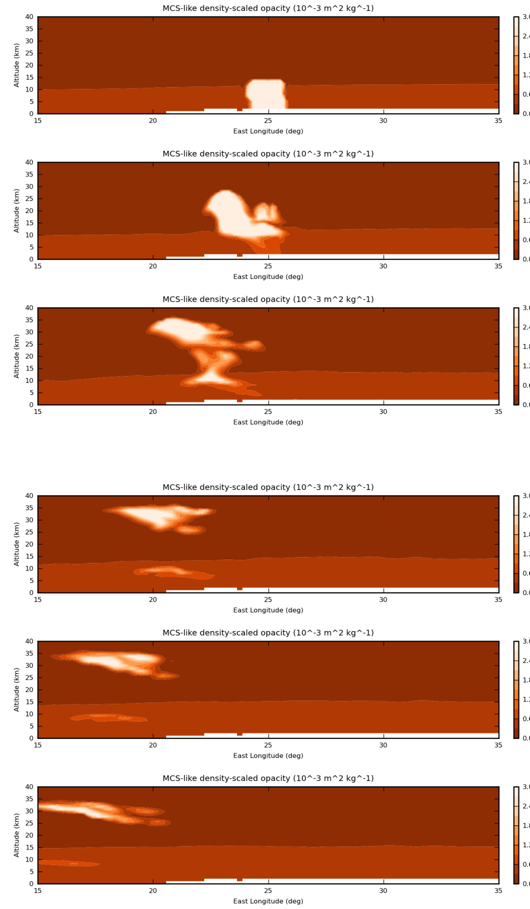

Figure 3: From dust rocket storms to detached layers of dust. *Longitude-altitude sections of "MCS-like" density-scaled dust optical depth predicted with our mesoscale model every two hours from local time* 14 : 00 *to* 00 : 00. *Initial state defined according to [4].*

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