EXISTENCE OF SUPERCOLD ATMOSPHERIC LAYERS IN THE MARTIAN MESOSPHERE

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Introduction:

The SPICAM experiment onboard Mars Express has produced to date several thousands stellar occultation sequences yielding atmospheric transmission in the UV from 10 to 120 km of altitude. In this spectral range, CO_2 is strongly absorbing and its concentration profile can be retrieved by spectral inversion. Hundreds of profiles have been obtained this way from SPICAM stellar occultation data for two and half Martian years with a consistent spatial coverage. One of the most striking features emerging from this dataset is the frequent occurrence (□10% of cases) of vertical portions of the atmosphere exhibiting temperature well below CO_2 condensation point. Seasonal and latitudinal distribution of these mesospheric supercold pockets will be presented and discussed in the context of GCM and meso-scale results.

Observations:

Before Mars Express and Mars Climate Sounder missions, the state of the Martian atmosphere above 40 km was poorly constrained. Interestingly, the EDL-phase measurements performed by the ASI/MET experiment onboard Pathfinder revealed that the temperature around 80 km was below the freezing point of CO_2. Several observations since then have shown the existence of mesospheric CO_2 ice cloud layers ([1,2,3,4]), consistent with the earlier findings of Pathfinder.

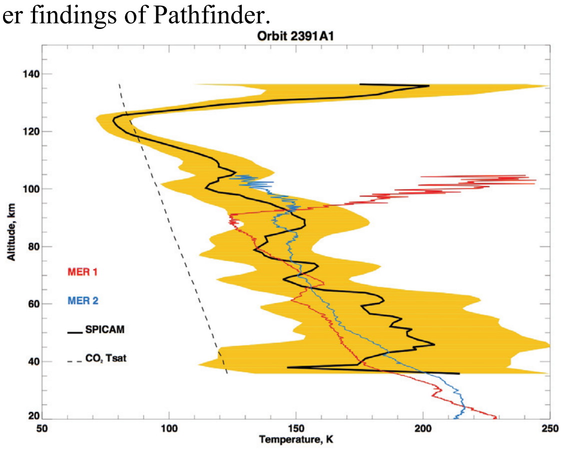

Figure 1: A SPICAM temperature profile obtained during orbit #2391, showing a significant portion of the atmosphere around 120 km below the freezing point of CO2. The yellow envelope indicates the 3-sigma uncertainty range associated with these measurements.

The SPICAM instrument, onboard Mars Express, is a dual UV-near-IR spectrometer that enables profiling of the Martian atmosphere by stellar occultation. CO_2 possesses a strong absorption band shortward of 200 nm that allows further quantification of CO_2 abundance as a function of altitude (Figures 1 and 2). By assuming simple hydrostatic law, temperature profile can be retrieved.

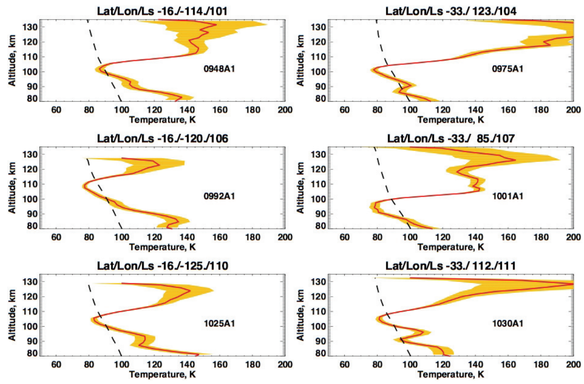

Figure 2: A subset of SPICAM temperature profiles consistently showing portions of the meosophere colder than CO_2 freezing temperature (dashed line).

While CO_2 inversion is usually possible from 30 to 140 km, temperature is confidently retrieved above 70 km.

Previous work:

Preliminary results were presented in [1] that showed the detection of cloud layers above 80 km concomitantly with detection of sub-freezing temperature in the same altitude range. Analysis of mesospheric temperature profiles was later extended to a complete Mars Year of observations [5]. The presence of supercold (*i.e.* below CO_2 condensation point) was noted for a large number cases, especially during the post-aphelion season (Figures 3 and 4).

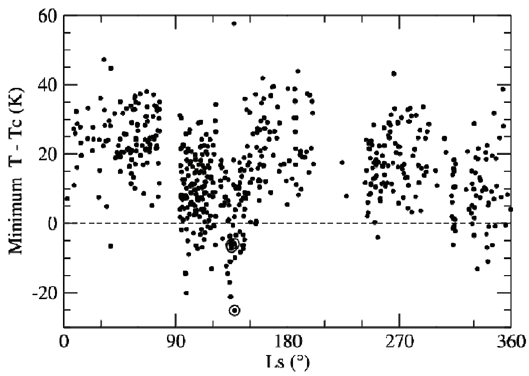

Figure 3: (from [5]) The minimum temperature T (related to the CO2 frost point T_c) encountered in each SPICAM profiles as a function of season (Ls). A negative value corresponds to a subfreezing profile. The four mesospheric clouds reported in [1] are shown by circles.

Comparison with LMD/GCM predictions showed the overall inability of Global Climate model to predict such levels of CO_2 saturation [4,5].

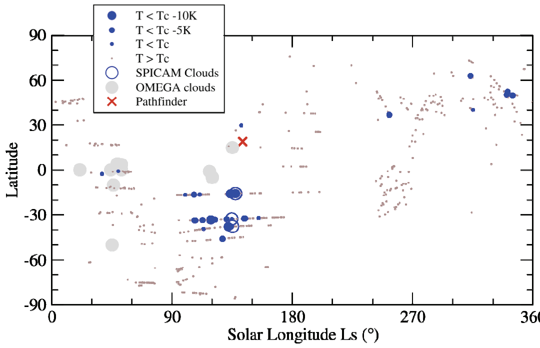

Figure 4: (from [5]) Seasonal and spatial distribution of the SPICAM temperature profiles exhibiting temperature below the CO_2 frost point. The four mesospheric clouds detected by SPICAM and thought to be high altitude CO_2 ice clouds [1] are shown by blue circles. The location of the dayside CO_2 ice clouds imaged by OMEGA [3] are identified by grey shaded circles. The Pathfinder entry profile which also exhibited subfreezing temperatures is marked by a red cross.

The existence of saturation raises a number of issues related to its origin and consequences for our understanding of the thermodynamical state of the upper Martian atmosphere, affecting predictions used for EDL preparation. CO_2 saturation has been also observed closer to the surface. Detection of supercold temperature profiles in the troposphere of the south polar night with concomitant observations of thick CO_2 polar clouds have been explained by [6] as the manifestation of storm events triggered by sudden release of latent heat.

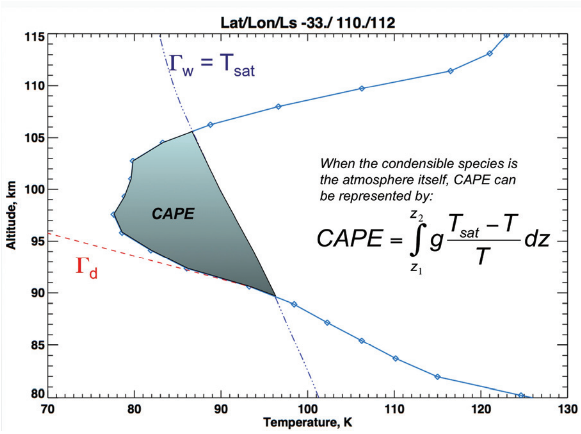

Figure 5: A typical SPICAM profil showing a saturated portion between 90 and 105 km, containing CAPE.

Considering the amount of supersaturation (S > 1,000) encountered in the SPICAM profiles, moist convection potential is also to be expected in the mesosphere, possibly explaining the cumuliform appearance of several occurrences of CO_2 clouds observed by OMEGA. A representative quantity of the moist convection potential is illustrated in Figure 5. The CAPE represents the amount of buoyant energy available to accelerate a parcel vertically. The higher the CAPE value, the more energy available to foster storm growth. CAPE is especially important when air parcels are able to reach the Level of Free Convection (LFC).

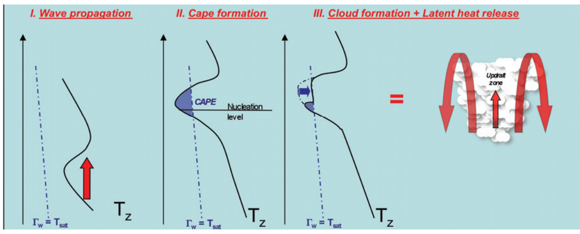

Figure 6: A possible scenario for the build-up and release of convection potential in the mesosphere.

In the mesosphere of Mars, the build-up and further activation of moist convection may occur as follows (see Figure 6):

1. Temperature inversion propagates upward
2. Inversion reaches the colder mesospheric region and creates supercold atmospheric pockets thereby forming CAPE
3. At some point, nucleation threshold is exceeded, CO_2 condensation follows with subsequent latent heat release, convection is activated

The absence of supersaturation at high altitude in the LMD GCM may point to the importance of subscale processes. One possibility that is currently investigated is the role of gravity waves [7] and their representation at meso-scale.

References:
[1] Montmessin et al., *Icarus*, 2006
[2] Clancy et al., *JGR Planets*, 2007
[3] Montmessin et al., *JGR Planets*, 2007
[4] Maattanen et al., *Icarus*, 2010
[5] Forget et al., *JGR Planets*, 2009
[6] Colaprete et al., *JGR Planets*, 2003
[7] Spiga et al., AGU Fall meeting, 2010