# OBSERVATIONS OF THE MARTIAN ATMOSPHERE WITH THE MARS CLIMATE SOUNDER

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**Introduction:** The Mars Climate Sounder (MCS) has obtained measurements of the Martian atmosphere for one Mars year. Onboard the Mars Reconnaissance Orbiter (MRO), MCS continues to acquire high vertical resolution profiles of temperature, dust, condensates of $CO_2$ and $H_2O$, and water vapor by observing the limb of the atmosphere from the surface to 80 km in the spectral intervals 0.3 – 3 µm and 11.5 – 45 µm [1]. This paper describes the investigation and introduces some of the observations being studied by the MCS science team. Other presentations by the team at this workshop will describe in greater detail results of ongoing research using MCS data.

**Investigation Approach and Objectives:** Table 1 presents the names, spectral bandpasses, and measurement functions for each of the nine spectral channels that comprise MCS. All channels move together from limb to surface observations, as well as viewing a blackbody, a solar target (both are external to the optical housing) and to space at regular intervals for the purpose of radiometric calibration. The nominal limb- and nadir-staring observing geometries are illustrated in Fig. 1.

Soundings of vertical profiles of atmospheric temperature are made using three channels located in the 15 µm band of $CO_2$, each chosen to provide sensitivity over a part of the vertical range of interest at the limb. The lower boundary for each of the three 15 µm channels is determined by line-of-sight opacity due to $CO_2$.

**The Observations:** MRO arrived at Mars in March 2006, and MCS acquired its first atmospheric measurements in September 2006 on Ls=111°. MCS measurements continued uninterrupted, apart from regular short intervals of calibration and MRO rolls for off-nadir views by other elements of the payload, until instrument scanning was interrupted by actuator missteps on December 10, 2006. Difficulties with this actuator have persisted, although the interruptions to the limb measurements have been infrequent. Observations directed at the surface of Mars, utilized in retrievals of near-surface atmospheric properties and polar radiative balance, have not fully recovered since December 2006. By means of adjustments to flight operations schemes, the science team maintains near continuous operation of MCS with minimal data gaps.

The MCS investigation builds upon a decade-long climatology of Mars obtain by the Mars Global Surveyor, Thermal Emission Spectrometer (TES)[2]. MCS extends the data record, vertical range and resolution of TES. Figure 2 illustrates the extended vertical range of retrieved temperatures in a cross-section from a single orbital transect from MCS. A cross-section of temperature from TES in an orbit from an ealier year is shown in the lower panel in the figure. The suborbital track closest approach to the South pole is at the center of both panels.

Figure 2 also illustrates another interesting features of the polar middle atmosphere that is not visible in nadir-only data. The middle atmosphere over the winter pole is unexpectedly warm, suggesting a more vigorous "Hadley"-type circulation than had been predicted. The poleward warming of the middle atmosphere is shown in greater detail in MCS zonal mean profiles of temperature in Fig. 3. Retrieved temperatures at the further point south follow the $CO_2$ condensation profile (dashed black line). The warm middle atmosphere was not captured fully observed in the TES observations, and although present in model data the intensity of the warming is underestimated and it extends further poleward than predicted.

Vertical profiles of dust and water ice retrieved

| Telescope/ Channel # | Bandpass $cm^{-1}$ | Band Center µm | Measurement Function |
|---|---|---|---|
| A1 | 595 - 615 | 16.5 | Temperature 20 to 40 km |
| A2 | 615 - 645 | 15.9 | Temperature 40 to 80 km and pressure |
| A3 | 635 - 665 | 15.4 | Temperature 40 to 80 km and pressure |
| A4 | 820 - 870 | 11.8 | Dust & Condensate (D&C) extinction 0 to 80 km |
| A5 | 400 - 500 | 22.2 | Temperature 0 to 20 km, D&C extinction 0-80 km |
| A6 | 3300 - 33000 | 1.65 | Polar Radiative Balance |
| B1 | 290 - 340 | 31.7 | Temperature 0 to 20km and D&C extinction 0 to 80 km |
| B2 | 220 - 260 | 41.7 | Water Vapor 0 to 40 km and D&C extinction 0 to 80 km |
| B3 | 230 - 245 | 42.1 | Water Vapor 0 to 40 km and D&C extinction 0 to 80 km |

Table 1. Mars Climate Sounder spectral channels and measurement functions.

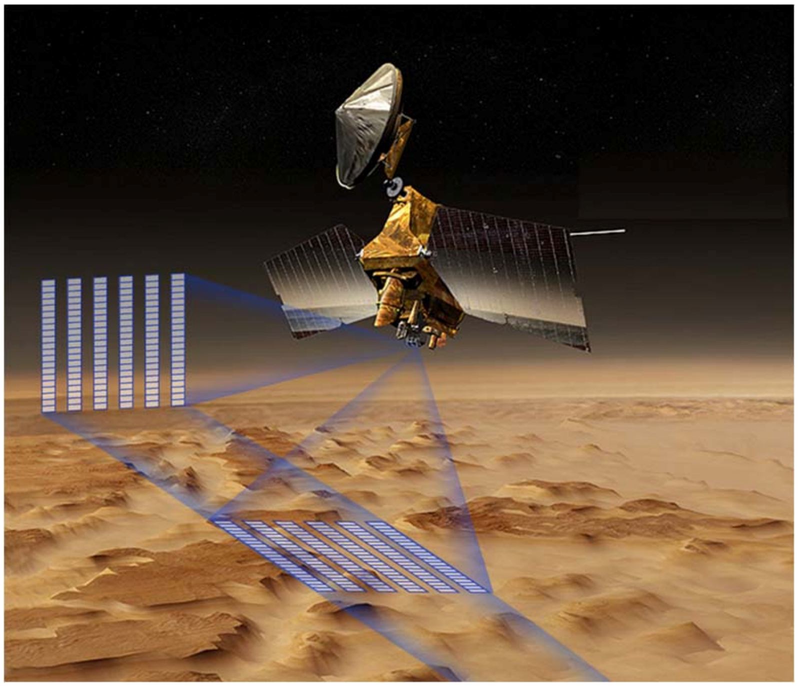

Figure 1. Viewing geometry for MCS limb and nadir observations. MCS is onboard the Mars Reconnaissance Orbiter.

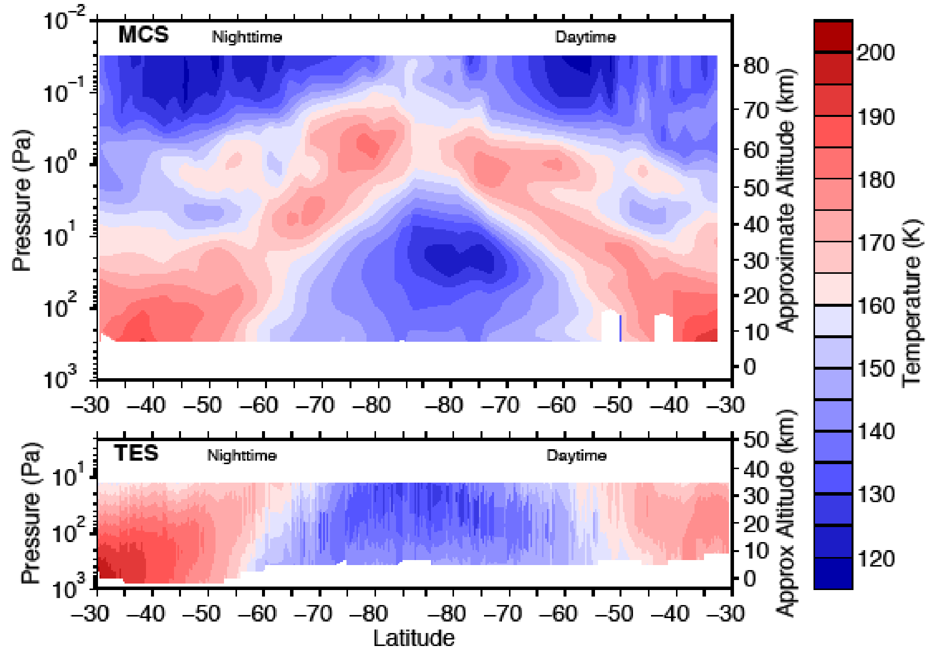


Figure 2. The upper panel is a cross-section of atmospheric temperature obtained from MCS limb soundings in the southern hemisphere of Mars on Ls=136°, November 16, 2006 (mid-southern winter). The lower panel is a cross-section from TES nadir soundings Ls=136.15° to 136.16°, May 1999 [3]. Both transects extend from the night to the day side (left-to-right), with a mean local time for MCS of approximately 03:00 LST to 15:00 LST, and for TES approximately 02:00 LST and 14:00 LST. Due to differences in the horizontal resolution at the limb and in nadir views, the MCS cross-section includes 45 vertical profiles while the TES cross-section includes more than 900.

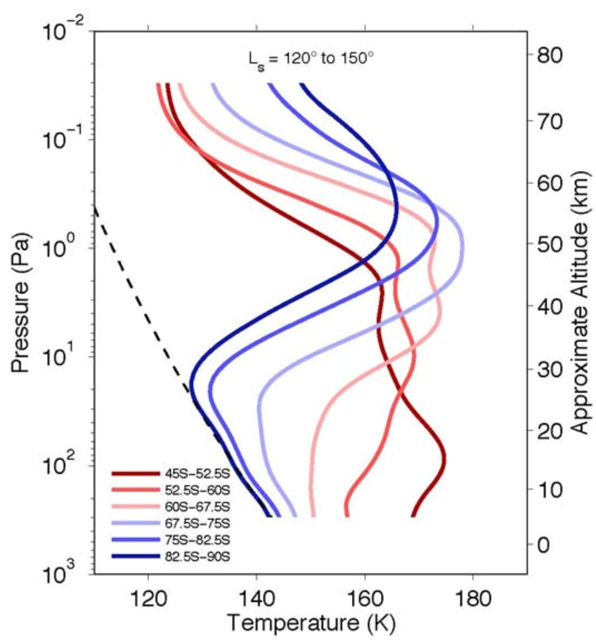


Figure 3. Measured mean vertical profiles of atmospheric temperature at latitudes from 90-45°S, in 7.5° latitude bins, including all soundings (day and night) within $L_s$ = 120-150°.

from MCS limb data demonstrate the value of the extended vertical range, higher resolution, and the long limb path. We will present results, based on the first Mars year of observations that suggest that the standard model of the vertical distribution of dust requires modification.

Recently, MCS data were used to assist engineers with the entry of the Phoenix Lander near in the north polar region. This effort required the intercomparison of multiple data sets, a process that demonstrated good agreement among climatology, Mars Express instruments and MCS.

**Conclusions:** MCS continues to return atmospheric data, concluding its first Mars year of operation and extending the existing decade-long climatology into the middle atmosphere. At the time of the Workshop, MCS will have delivered to the Atmospheres Node of the Planetary Data System the first five months of vertical profiles of retrieved temperature and dust.

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