One Mars year of atmospheric temperature, dust, and water ice profiles retrieved from Mars Climate Sounder measurements.

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Introduction

Mars Climate Sounder (MCS) is a mid- and far-infrared thermal emission radiometer on board the Mars Reconnaissance Orbiter. It measures radiances in limb and nadir/on-planet geometry from which vertical profiles of atmospheric temperature, water vapor, dust and condensates can be retrieved in an altitude range from 0 to 80 km and with a vertical resolution of $\sim$ 5 km. MCS has been taking measurements of the Martian surface and atmosphere since Sep. 2006 so the currently available dataset comprises about one Mars year. Here we present results of combined pressure, temperature, dust and water ice profile retrievals from limb measurements during this period. We show examples of latitudinal cross-sections of these quantities and discuss seasonal differences.

MCS instrument

The Mars Climate Sounder is a passive infrared channel radiometer [1]. It consists of two telescopes that are designed to be slewed in azimuth and elevation to view the Martian atmosphere in limb, nadir, and on-planet geometries. MCS has 8 mid- and far-infrared channels and one visible/near-IR channel. Three channels cover frequencies around the 15 micron CO_2 absorption band and are used for pressure and temperature sounding. A channel centered around 22 microns gives information about dust opacity while a channel centered at 12 microns covers a main absorption feature of water ice. In the far-IR three channels are designed to give information about water vapor abundance and dust and condensate opacities. Each channel consists of 21 detectors which observe the atmosphere simultaneously. Their angular separation provides an altitude resolution of $\sim$ 5 km at the Mars limb. MCS is an instrument on the Mars Reconnaisssance Orbiter spacecraft currently in orbit around Mars. It was powered on in September 2006 and performed nominal limb/nadir scanning of the atmosphere until January 2007. Due to an anomaly in one of the actuators the instrument took measurements in limb staring geometry between February and May 2007 during which the quality of the calibration is reduced. Since June 2007 the instrument has resumed scanning between limb, space, and the internal calibration target. Since October 2007 also on-planet measurements are taken again with every limb scan.

Radiative transfer

The radiative transfer for the gases (CO_2 and H_2O) is based on the HITRAN 2004 linelist [2]. As the line-by-line calculation of transmissions would be too time consuming we use a Curtis-Godson approximation with precalculated transmissions for each channel. The errors introduced due to the approximation are generally below 1% for the mid-IR channels in typical martian atmospheric conditions. Concerning aerosols, currently dust and water ice absorption is considered. No scattering parameterization has been implemented yet. Both dust and water ice absorptions are described by extinction efficiencies derived from Mie-calculations spectrally integrated for each channel. The Mie-calculations for dust assumed a gamma distribution with an effective particle radius of 1.54 microns and are based on the refractive indices for Mars dust by Wolff et al. [3]. For the water ice Mie-calculations a gamma distribution with an effective particle radius of 1.36 microns was used, with refractive indices taken from Warren [4].

Retrieval approach

The retrieval is based on Chahine's method [5], which is an iterative relaxation method that calculates a solution from radiance residuals using weighting functions. In the present stage of the retrieval only limb measurements are considered. For pressure the radiance ratio between the channels centered at 15.4 and 15.9 microns is analyzed. These channels also provide the information for the temperature profile, together with the channel at 16.5 microns for low altitudes. For dust the channel at 22 microns is used, while the water ice part uses the 12 micron channel. Both dust and water ice feed back into the pressure/temperature channels according to their relative extinction efficiencies. Pressure, temperature, dust, and water ice are retrieved simultaneously in a combined iteration loop.

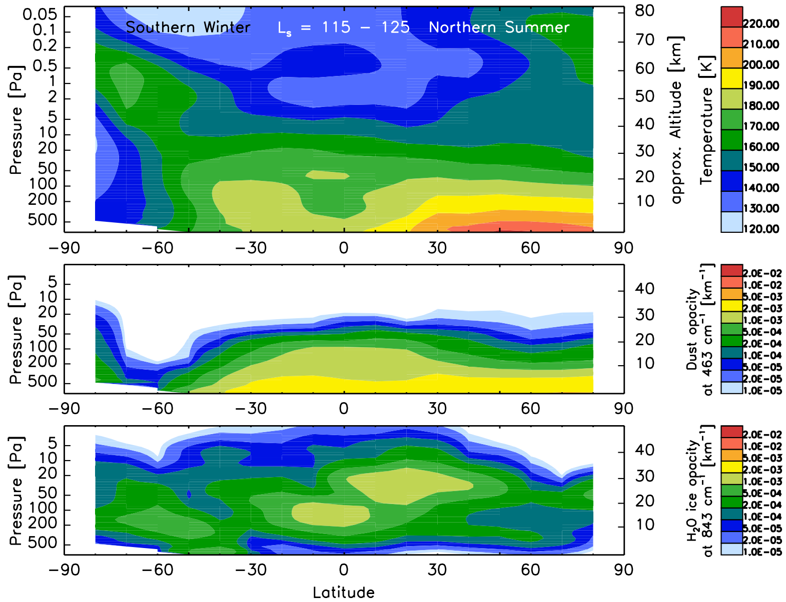

Figure 1: Cross-section of temperature, dust opacity, and water ice opacity profiles from MCS retrievals between L_s 115° and 125°. The profiles have been zonally averaged in 10° latitude bins.

Results

Fig. 1 shows cross-sections of temperature, dust opacity, and water ice opacity profiles for an L_s range between 115° and 125°, which corresponds to the southern winter season. In the northern hemisphere, temperatures up to $\sim$ 210 K are observed in the lower atmosphere. Note that in the equatorial region retrievals are rather sparse and typically from nighttime measurements because the retrieval algorithm has not yet been optimized for the high ice opacities found in the equatorial cloud belt. In the southern hemisphere, temperatures down to $\sim$ 130 K are measured in the lower atmosphere, while at higher altitudes a temperature maximum is observed and temperatures higher than 170 K are reached. This warming is likely to have a dynamical origin as there is no direct solar heating in the winter polar atmosphere. The structure is not dissimilar to limb/nadir observations by TES from an earlier Mars year [6], although MCS provides a better altitude coverage and vertical resolution.

The dust distribution shown in the second panel of Fig. 1 is rather homogeneous with latitude between the north polar region and the southern mid-latitudes. Between 50°S and 70°S though a region with very low dust opacities is apparent. We note that in the same region a local maximum in water ice opacity at low altitudes (100-200 Pa) is shown in the third panel of Fig. 1. However, at 50°S and $\sim$ 50 Pa a local minimum in ice is observed. Other regions with high water ice opacity are found around the equator. It is noted, however, that retrievals in the equatorial cloud belt are still sparse at this stage so that the maximum water ice opacities are likely to be higher than the ones shown in Fig. 1.

Fig. 2 shows cross-sections of the same quantities as Fig. 1 but for an L_s range between 325° and 335°. This period corresponds to the northern winter season and is the end of the decline of a large duststorm that was present during several months before. Note that temperatures below $\sim$ 40 km altitude ($\sim$ 10 Pa) tend to be significantly higher at most latitudes compared to the season shown in Fig. 1. In addition the dust content is higher the atmosphere. While dust opacities higher than 10^{-3} km^{-1} at 463 cm^{-1} are hardly found above 20 km altitude ($\sim$ 100 Pa) around $L_s = 120°$, this level of opacity is found around 30 km altitude ($\sim$ 40 Pa) at $L_s = 330°$. Common to both seasons is the minimum in dust in the winter polar region, located in Fig. 2 between 50°N and 70°N.

The most remarkable feature in the water ice distribution in Fig. 2 is probably the lack of water ice in a

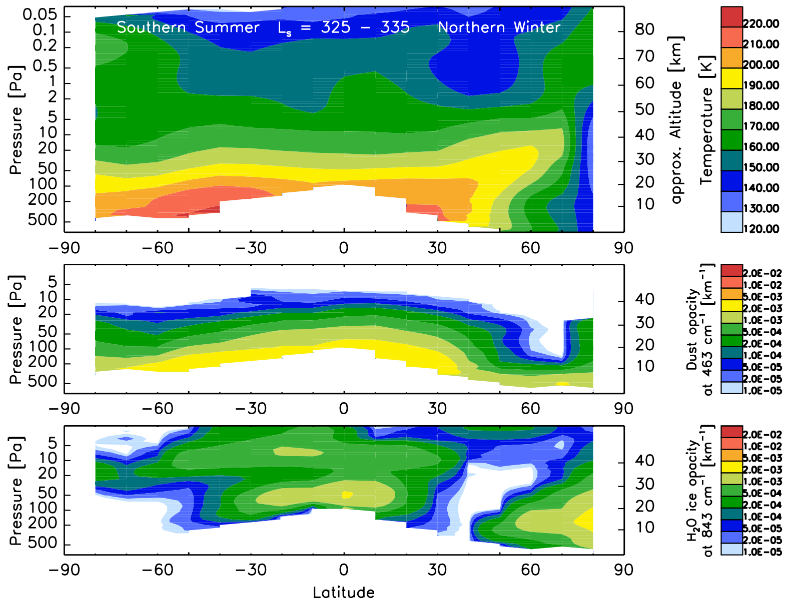

Figure 2: Cross-section of temperature, dust opacity, and water ice opacity profiles from MCS retrievals between L_s 325° and 335°. The profiles have been zonally averaged in 10° latitude bins.

strip from 80°N at 2 Pa down to 30°N at 200 Pa. The occurrence of this feature coincides with the warm temperatures stretching from high altitudes in the northern polar region to low altitudes in the northern mid-latitudes and it is much more pronounced than the feature in the southern polar region in Fig. 1.

Conclusions

We present profiles of temperature, dust opacity, and water ice opacity retrieved from Mars Climate Sounder measurements which cover one Mars year by now. Dust and temperature in the lower atmosphere are elevated at $L_s = 330°$ compared to $L_s = 120°$. Regions of strong middle atmospheric warmings are apparent at both the northern and southern winter pole. Areas of low water ice opacity seem to be associated with these regions, in particular in the northern polar winter.

Acknowledgments

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