MCS MEASUREMENTS OF TEMPERATURE AND AEROSOLS AT MULTIPLE LOCAL TIMES IN THE MARTIAN ATMOSPHERE.

Armin Kleinböhl, David M. Kass, John T. Schofield, Daniel J. McCleese, *Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA, 91109, USA***.**

Introduction

The Mars Climate Sounder (MCS) [1] is a mid- and far-infrared thermal emission radiometer on board the Mars Reconnaissance Orbiter (MRO). Using a detector array MCS performs measurements of radiance profiles by nominally looking at the forward limb. From the measured radiances, vertical profiles of atmospheric temperature, dust and water ice opacity are retrieved up to altitudes of about 80 km [2]. As MRO is in a sun-synchronous orbit around Mars [3], forward limb looking measurements sample the atmosphere predominantly at two local times. For MRO this is around 3 AM and 3 PM Martian Local Time (MLT). While the sun-synchronous orbit is advantageous for mapping, studies of temporally varying features like atmospheric tides typically benefit from measurements at multiple local times to avoid aliasing of diurnal variations into other modes [4]. MCS can use its azimuth actuator to perform cross-track or off-track measurements which give observations at different locations as well as different local times than in-track measurements. During the Phoenix landed mission in 2008, several of these off-track measurements were performed on a campaign basis to observe the atmosphere over Phoenix at different local times. We present analyses of these measurements. Furthermore, we give an preview on new cross-track measurement campaigns which started in Sep. 2010.

Measurement concept

MCS can slew in azimuth in order to perform measurements at different locations and local times. A typical measurement sequence is shown in Fig. 1. It alternates forward in-track measurements with off-track measurements, in this case to obtain a measurement at a given local time above the Phoenix landing site. MCS performed several of these off-track observations on a campaign basis during the Phoenix landed mission to sample the atmosphere at different local times above the Phoenix landing site. In total 17 of these campaigns were performed between June and Nov. 2008, covering an L_s-range between 75° and 160°.

Results

Fig. 2 shows results of MCS retrievals from 7 off-track measurement campaigns close to the Phoenix landing site in northern summer ($L_s = 105° - 135°$). The data has been averaged into bins with a width of 3 hours local time. In the high atmosphere around 0.1 Pa a temperature maximum can be seen at 3 PM MLT. As the day progresses this maximum moves to lower altitudes. At 4 AM MLT it is found around 2 Pa. A temperature minimum with a similar behavior but offset by roughly 12 hours is also evident in Fig. 2. This is the behavior expected to be caused by the diurnal thermal tide [5]. However, we note that features of higher order are also present in the data, e.g. a temperature maximum around 2 Pa at 3 PM MLT, which leads to a semi-diurnal pattern.

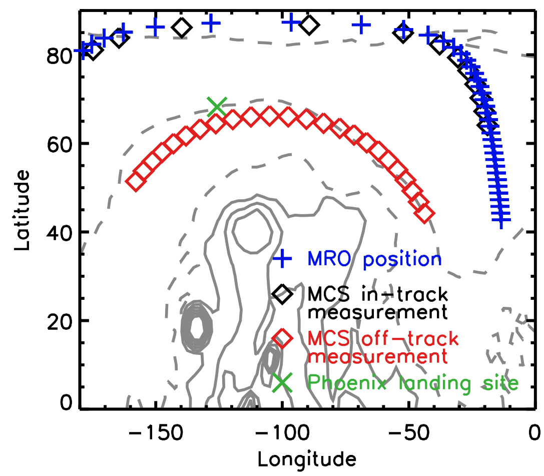

Figure 1: Example of an MCS measurement sequence alternating forward in-track and 74° off-track measurements on June 4, 2008 in the vicinity of the Phoenix landing site.

At lower altitudes (20 – 50 Pa) a diurnal pattern is dominant again, with a temperature minimum around 6 AM and a temperature maximum around 6 PM MLT. The temperature minimum in the morning is coincident with the occurrence of water ice around 50 Pa. In the afternoon no water ice clouds are present at these altitudes. Note that in the morning also the dust seems to reach up to lower pressures than in the afternoon.

Fig. 3 shows results of the in-track temperature measurements between $L_s = 105°$ and 135° from the nightside of the orbit (2 – 5 AM MLT). Profiles were selected from a band between 66°N and 71°N latitude, and binned in 30° longitude. Temperatures in the mid-

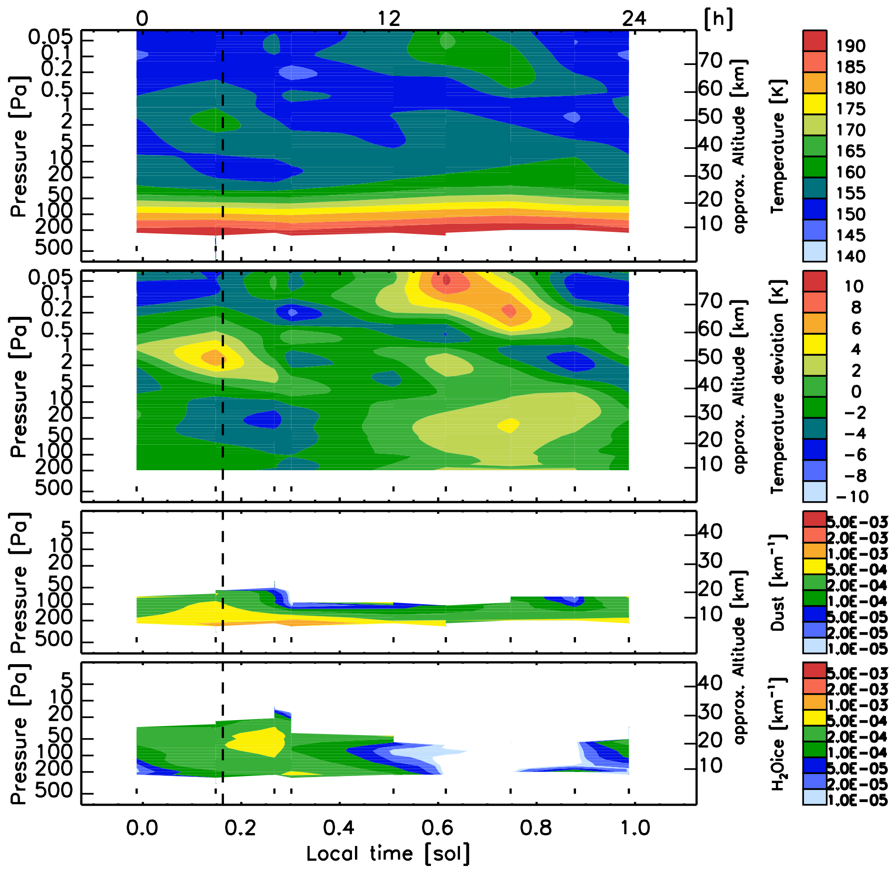

Figure 2: MCS retrieved prof les between $L_s = 105°$ and $135°$ in the vicinity of the Phoenix landing site, averaged into bins of 3 hours MLT. The top panel gives temperature, the center top panel gives temperature deviation from an average temperature prof le calculated from the temperatures in the top panel, the center bottom panel gives dust extinction, and the bottom panel gives water ice extinction. The small black dashes indicate the center of each local time bin, while the dashed line gives the typical local time of nighttime in-track measurements at the Phoenix latitude.

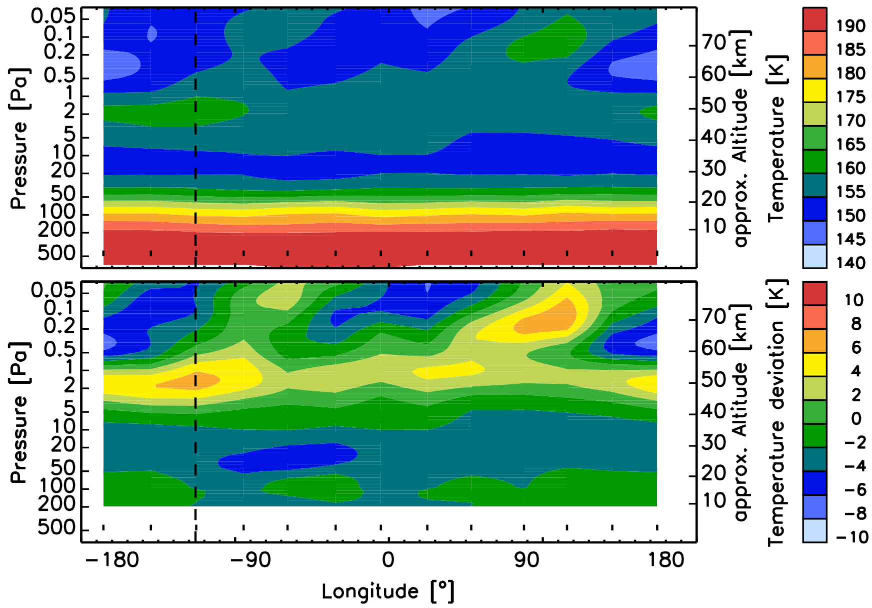

Figure 3: MCS retrieved profles between $L_s = 105°$ and $135°$, $66°$N and $71°$N, and 2 and 5 AM MLT, averaged into bins of $30°$ longitude. The top panel gives temperature while the bottom panel gives temperature deviation from an average temperature profle calculated from the temperatures in the top panel of Fig. 2. The small black dashes indicate the center of each longitude bin, while the dashed line gives the Phoenix longitude.

dle atmosphere reach a minimum around 20 Pa and a maximum at 2 Pa as expected from the diurnal tide. Higher in the atmosphere, however, one can see a zonal wavenumber 2 pattern develop with temperature maxima around $70°$W and $110°$E longitude. The phase seems to shift slightly eastward with higher altitudes. These features are likely related to non-migrating tides, which are created by the interaction of the thermal tide with topography. The zonal wavenumber 2 of the Martian topography is likely to give rise to non-migrating tides of the same zonal wavenumber, and wave 2 density variations were observed previously in upper atmosphere of Mars [6,7]. This suggests that some of the temperature variability shown in Fig. 2 is caused by these non-migrating tides interacting with the diurnal tide pattern. An example would be the temperature maximum found at 2 Pa around 4 AM in Fig. 2. A comparison with Fig. 3 shows that the temperature at 2 Pa at the Phoenix location is higher than at any other longitude in this latitude band.

Outlook

The MCS off-track measurement campaigns during the Phoenix landed mission provide valuable information about the atmospheric structure at different local times. To obtain measurements at multiple local times with a global coverage a cross-track measurement sequence has been developed. The sequence alternates in-track and cross-track measurements in the following way:

in-track $\rightarrow$ 90° **cross-track left** $\rightarrow$ **in-track** $\rightarrow$ 90° **cross-track right** $\rightarrow$ **in-track** $\rightarrow$ **...**

The frst of these cross-track observation campaigns was performed between Sep. 13 and Oct. 11, 2010, ($L_s = 148° - 162°$) in support of the preparation for the entry, descent, and landing of the Mars Science Laboratory. Fig. 4 shows the measurement coverage in latitude and local time that was achieved during one day of observations. In the equatorial region the 90° cross-track observations yield a local time offset of ± 1.5 hours from the regular 3 AM - 3 PM pattern. This offset increases away from the equator. In the polar regions additional off-track measurements give extra local time coverage.

In the future it is planned to alternate these cross-track observation campaigns with standard in-track viewing in cycles of four weeks each.

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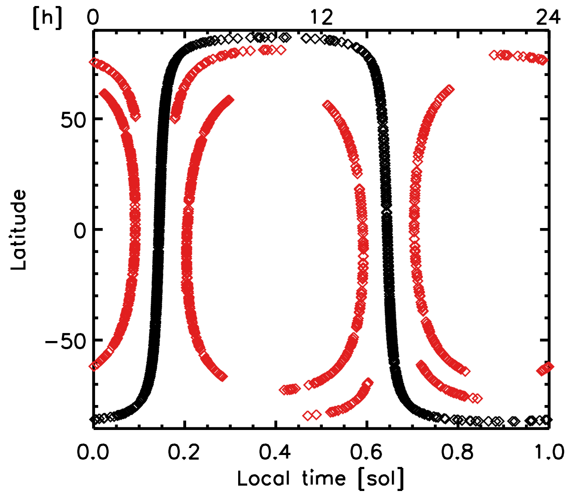

Figure 4: Example of the MCS measurement coverage in latitude and local time during one day (Sep. 14, 2010) of alternating in-track/cross-track measurements. Black symbols indicate an in-track, red symbols indicate a cross-track or off-track measurement.

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