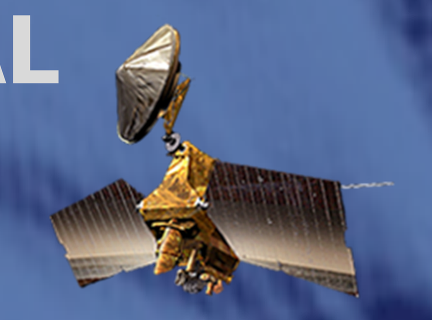
# THE MARS CLIMATE SOUNDER—SIX MARTIAN YEARS OF GLOBAL ATMOSPHERIC OBSERVATIONS READY FOR ASSIMILATION

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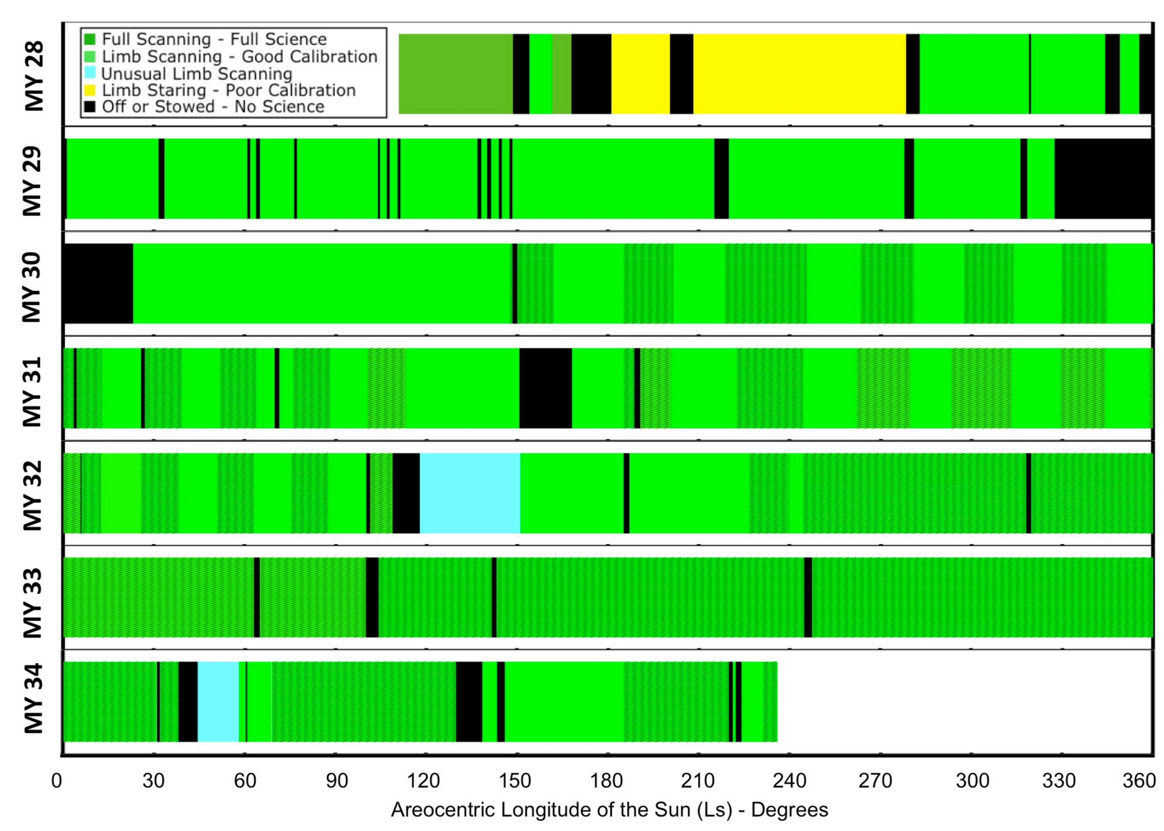
MCS Investigation Timeline




## MCS Observations:

MRO is in a sun-synchronous polar orbit [2] and provides global observations at 3 AM and 3 PM. In addition, MCS uses azimuth scanning to observe at four additional local times: 1:30 AM, 4:30 AM, 1:30 PM and 4:30 PM [3] (figure 1). The polar MRO orbit covers all longitudes in 13 orbits (each separated by ~27°) over 24 hours 20 minutes (figure 3). Each day, the ground track "walks" ~5° to the east.

The MCS mission (see the timeline above) now spans over six complete Mars Years. MCS has predominantly performed forward in-track limb scanning through the six years (bright and dark green). This is the "standard" MCS observation and is used to build and extend the climatology. The additional local time coverage is added to the standard coverage (by reducing the latitudinal oversampling). It was initially used intermittently (alternating ~4 week periods with and without additional local time coverage). The MCS observations then transitioned to continuously include the additional local time coverage.

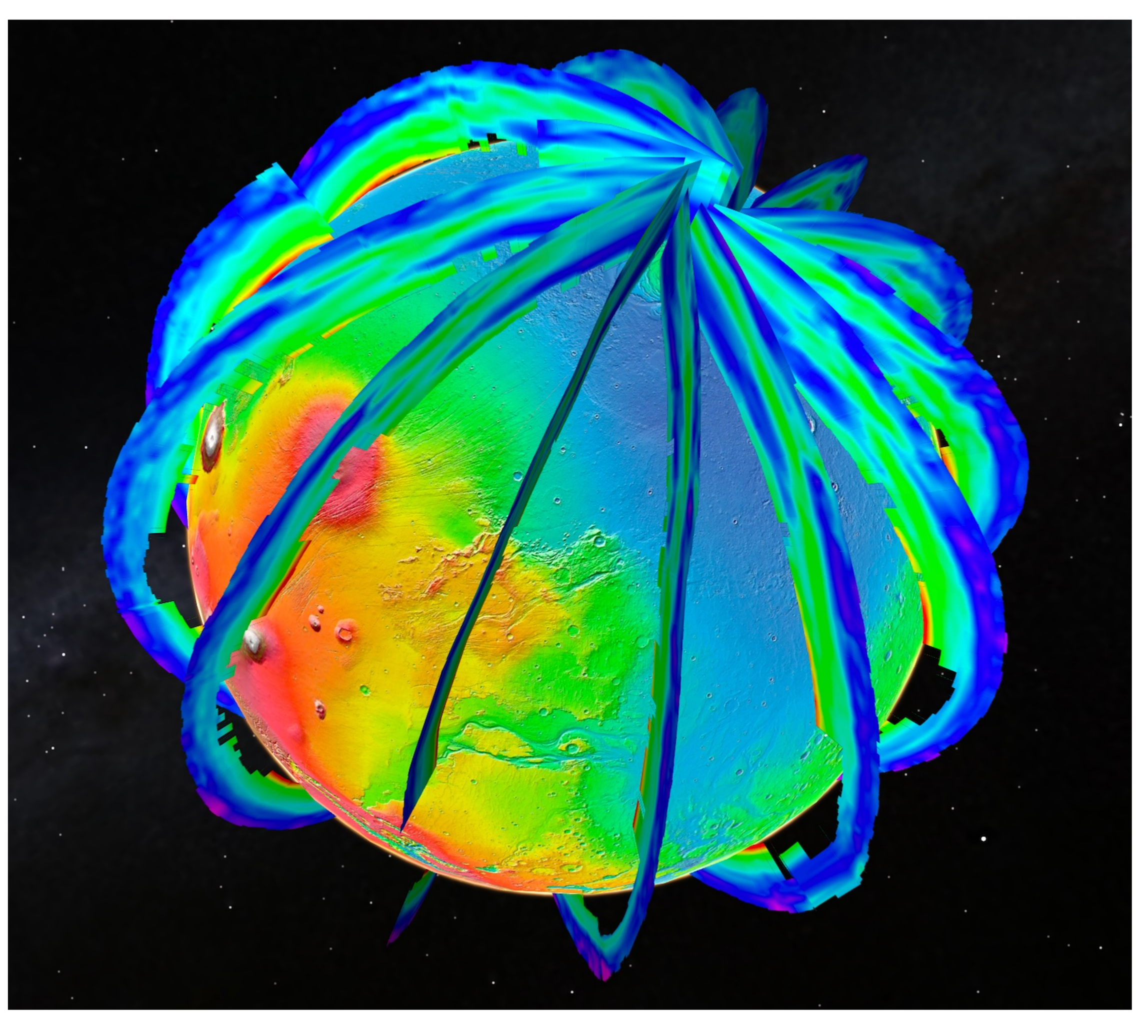


*Figure 3: One day of daytime (15:00) MCS temperature coverage. June 1, 2018, Ls = 185.3*

## Mars Climate Sounder (MCS):

MCS provides daily global observations of dust, temperature and water ice clouds in the martian atmosphere. MCS results include:

- A decade long global climatological record that identifies the seasonal behavior of the atmosphere
- Identification and characterization of large dust storms, especially the 2007 and 2018 global dust storms

## MCS Description:

MCS is a passive 9-channel radiometer on the Mars Reconnaissance Orbiter (MRO) that is optimized for atmospheric observations [1]. It uses limb staring to obtain atmospheric profiles from the surface to ~80 km. MCS has 8 mid- and far-infrared (IR) channels and one visible/near-IR channel, ranging from 0.3 to 45 µm (see table below). Three channels cover frequencies around the 15 µm $CO_2$ absorption band and are used for pressure and temperature sounding. One centered around 22 µm gives information about dust opacity while another centered at 12 µm provides water ice. Each channel consists of 21 detectors, which observe the atmosphere simultaneously. Their angular separation provides an altitude resolution of ~5 km (half a scale height) at the Mars limb.

| Telescope/ Channel # | Bandpass $cm^{-1}$ | Band Center - µm | Measurement Function |
|---|---|---|---|
| A1 | 595 - 615 | 16.5 | Temperature 0-20 km |
| A2 | 615 - 645 | 15.9 | Temperature 20-40 km, Pressure |
| A3 | 635 - 665 | 15.4 | Temperature 40-80 km, Pressure |
| A4 | 820 - 870 | 11.8 | Water ice extinction 0-80 km |
| A5 | 400 - 500 | 22.2 | Dust extinction 0-80 km |
| A6 | 3300 - 33000 | 1.67 | Polar Radiative Balance |
| B1 | 290 - 340 | 31.7 | Aerosol extinction 0-80 km |
| B2 | 220 - 260 | 41.7 | Water Vapor 0-40 km, Aerosol extinction 0-80 km |
| B3 | 230 - 245 | 42.1 | Water Vapor 0-40 km, Aerosol extinction 0-80 km |

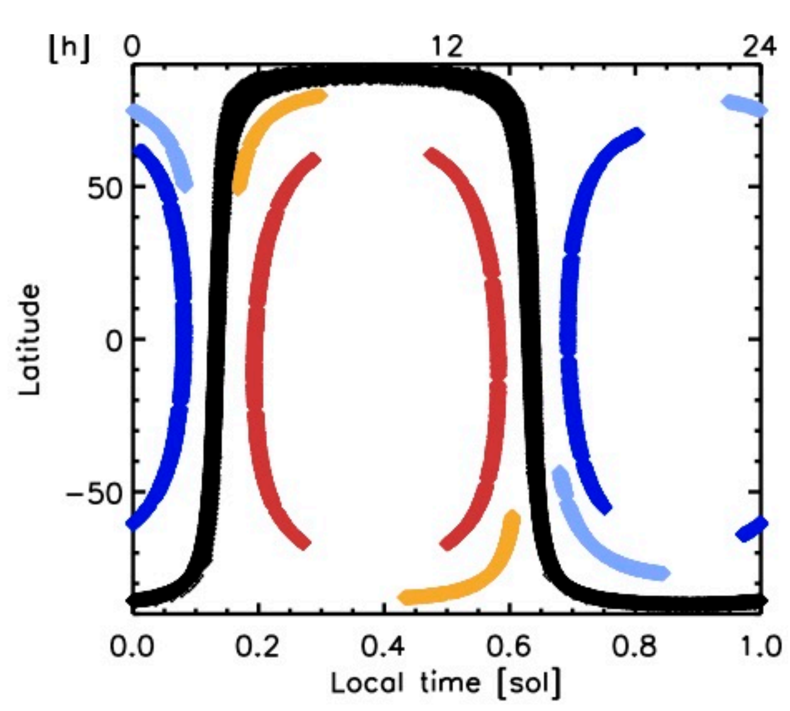



*Figure 1: Positions of MCS atmospheric limb observations vs. latitude and local time. Black symbols indicate measurements along the orbit track, while red and dark blue symbols indicate measurements 90° perpendicular to the orbit track. Pale symbols indicate off-track measurements at other angles.*

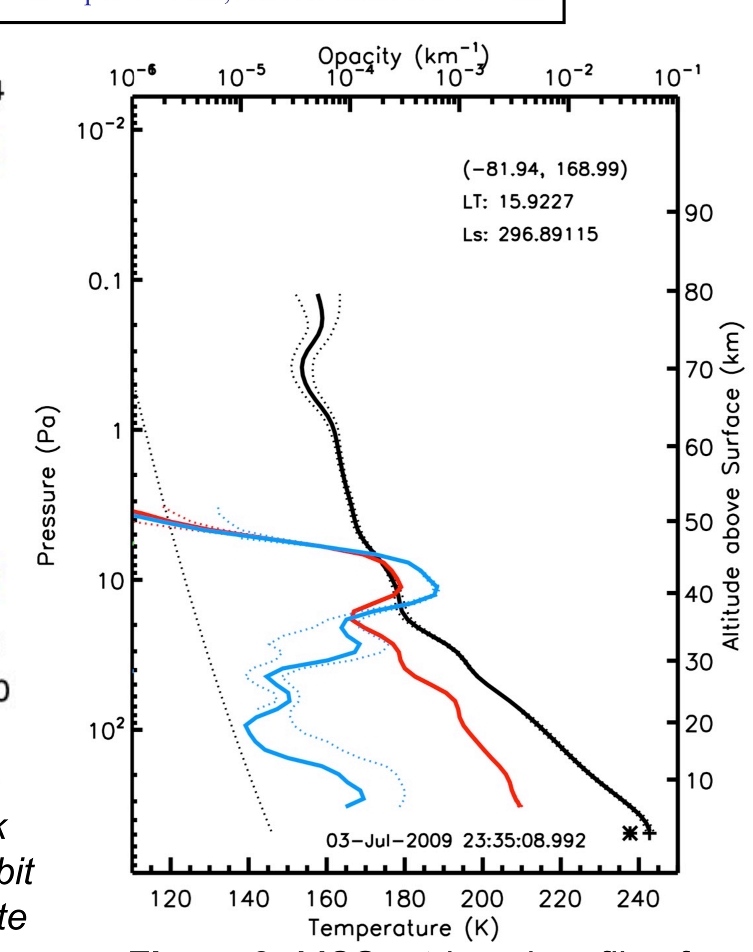



*Figure 2: MCS retrieved profile of temperature (black), dust (red), water ice (blue) and surface temperature (*).*

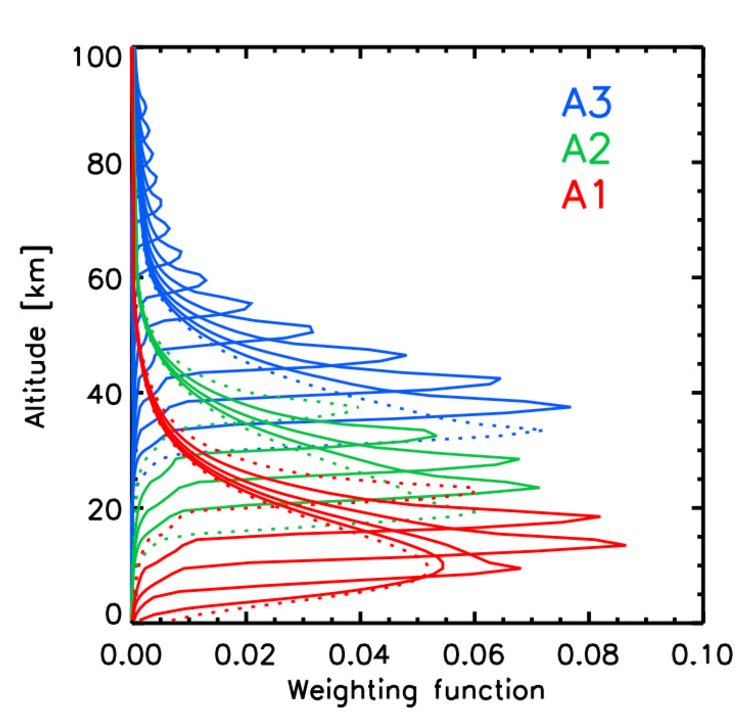



*Figure 4: Field of view averaged vertical weighting functions for the temperature retrieval (color indicates the specific channel; solid are used for the retrieval and dashed are adjacent weighting functions) [4].*

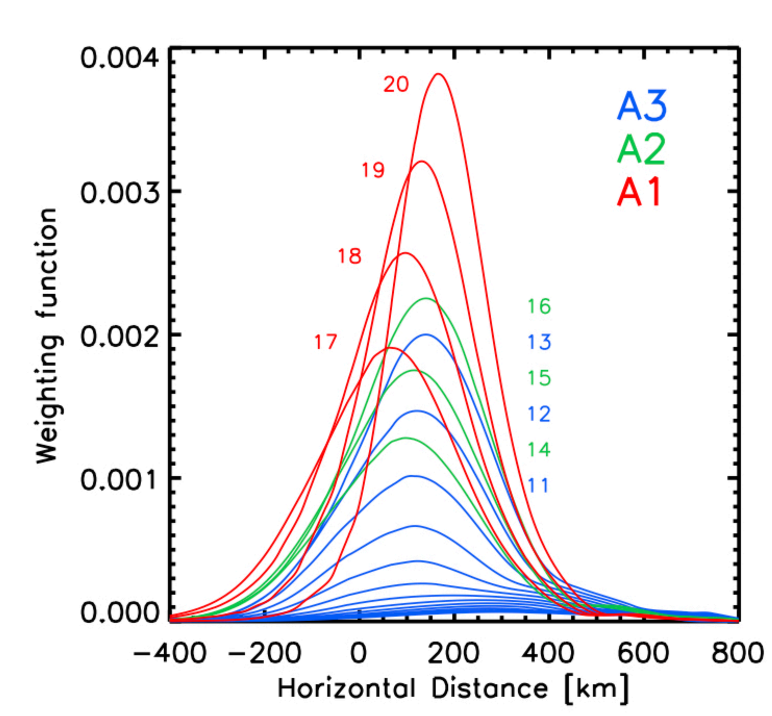



*Figure 5: Field of view averaged horizontal weighting functions for the temperature retrieval (color indicates the specific channel and number indicates the detector) [4].*


## MCS Retrievals:

The MCS retrieval algorithm [4, 5, 6] produces vertical profiles of temperature, dust and water ice extinction versus pressure (Figure 2). It also produces surface brightness temperatures. The retrievals are based on a modified Chahine method [7]. This is an iterative technique that simultaneously solves for all fields by minimizing the radiance residuals. The algorithm uses both limb observations and (where available) nearby on-planet or nadir observations. The on-planet observations are used for the surface temperature retrieval and to retrieve the temperature in the lower atmosphere when the limb is too opaque due to aerosols.

Aerosol radiative transfer is performed using both absorption and single scattering. The dust and water ice properties are determined with Mie calculations using a gamma distribution with an $r_{eff}$ = 1.06 µm for dust and an $r_{eff}$ = 1.4 µm for water ice.

Due to the limb viewing geometry, the MCS weighting functions have both a vertical and horizontal aspect (Figures 4 & 5). In the vertical, the location and shape of the weighting functions depends on the exact MCS pointing as well as the atmospheric structure. The horizontal weighting functions are extended in the direction of the instrument line of sight.

Retrieved profiles have been used for data assimilation by multiple groups [e.g. 9, 10, 11]. The assimilation work has produced a number of very exciting results.

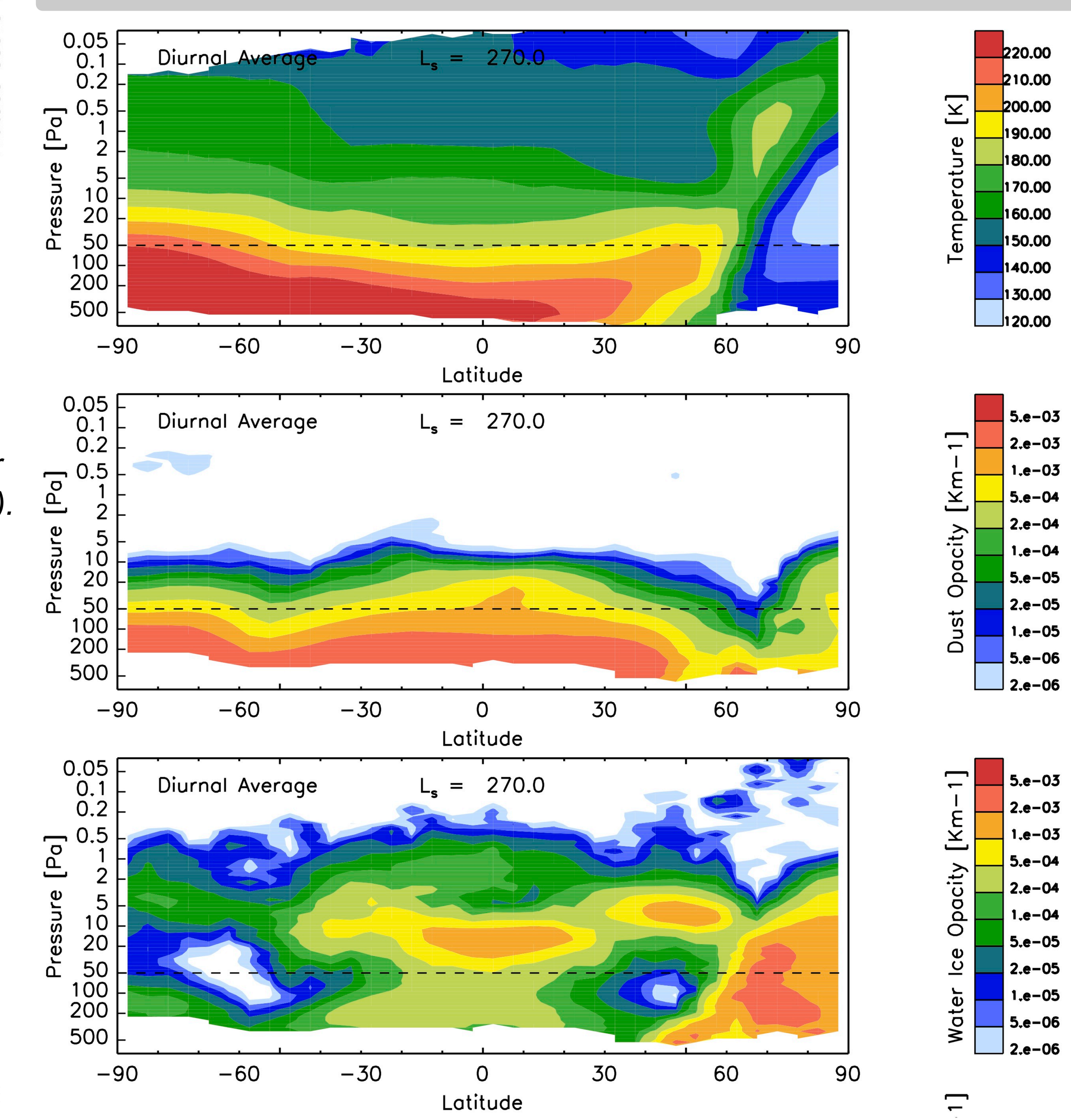



*Figure 6: MCS zonal mean cross-sections of temperature (top) dust (middle) and water ice (bottom). These are at the northern winter solstice for MY 33 (4° Ls bin). These are an average of the 03:00 and 15:00 data at this season. The B regional dust event [8] for the year is ongoing at this time.*


**References:**

[1] McCleese, *et al.* (2007) *JGR, 112*, E002790.
[2] Zurek and Smrekar (2007) *JGR, 112*, E05S01.
[3] Kleinböhl *et al.* (2013) *GRL 40*, 1952-1959.
[4] Kleinböhl *et al.* (2009) *JGR 114*, E10006.
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[8] Kass *et al.* (2016) *GRL 43*, 6111-6118.
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[10] Navarro *et al.* (2014) *GRL 41*, 6620-6626.
[11] Greybush *et al.* (2018) this workshop.


## MCS Dataset:

All MCS profiles are publicly archived on PDS:
http://atmos.nmsu.edu/data_and_services/atmospheres_data/MARS/aerosols.html


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