THE MARTIAN ATMOSPHERE DURING THE 2001 GLOBAL DUST STORM: OBSERVATIONS WITH SWAS AND SIMULATIONS WITH A GENERAL CIRCULATION MODEL

Takeshi Kuroda *(kuroda@mps.mpg.de)*, **Alexander S. Medvedev**, **Paul Hartogh**, *Max-Planck-Institute for Solar System Research, Katlenburg-Lindau, Germany*.

Introduction: The Earth-orbiting Submillimeter Wave Astronomy Satellite (SWAS) observed the global mean surface and atmosphere temperature on Mars as a function of the altitude [*Gurwell et al*., 2005]. Unlike for the infrared spectrometers, the temperature retrievals from submillimeter instruments can be performed in the presence of the atmospheric dust. During the 2001 global dust storm on Mars, SWAS measured the atmosphere and surface temperature for aerocentric longitudes from L_s=166˚ to 233˚, and observed a temperature inversion in the lower atmosphere.

We use a recently developed general circulation model of the Martian atmosphere (MAOAM-GCM, the detailed description is in *Hartogh et al*. [2005]) to simulate the temperature and other atmospheric fields under the conditions corresponding to those during the SWAS measurements. The model takes into account the radiative effects of the atmospheric dust. The radiation scheme and parameters of dust employed here are essentially the same as in CCSR/NIES Martian AGCM [*Kuroda et al*., 2005].

Results: The dust distribution is introduced after the TES3 dust scenario in *Kuroda et al*. [2005], as shown in Figure 1. During the SWAS observations, the local time at the center of the visible Martian disk varied significantly from early afternoons at the start of the measurement sessions to mid-mornings at the end of these sessions. The sub-Earth latitude of the observation also varied around the Martian equator, although only slightly. Using the accurate ephemeris to obtain the sub-Earth local time and latitude for any particular date, we reconstructed the appearance of the planet's disk out of the model output. Then, "disk average" temperatures were calculated from the GCM results employing the weighting function for the "visible" grid points based on the corresponding viewing geometry. Thus constructed temperatures allow for a direct comparison with the SWAS measurements. For simplicity, they are referred to as "global means" in this paper.

Figure 2 compares the simulated global "visible" (weighted grid points based on the corresponding viewing geometry) surface temperature between L_s=165˚ and L_s=235˚ with the SWAS and MGS-TES measurements. Since the data from MGS-TES exist for local times 2:00 and 14:00 only, they cannot be directly compared with the SWAS. Instead we made

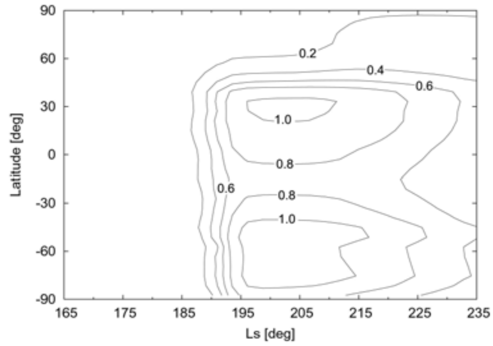


Figure 1: The time series of the zonal mean dust opacity at 9 µm employed in the simulations.

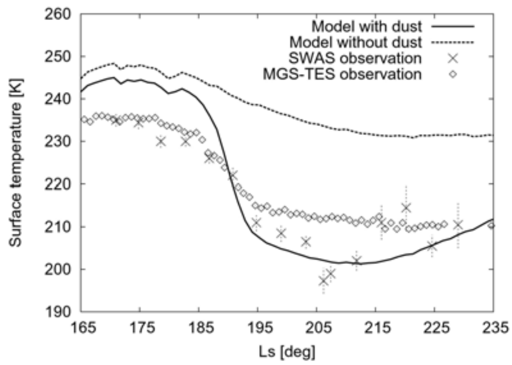


Figure 2: Global mean surface temperature simulated with the Martian GCM and measured from SWAS and MGS-TES. The solid line represents the temperature for the run with dust radiation included; the dashed line is for the run without the dust. The crosses and dotted error bars show the observational results by SWAS. The diamonds present the MGS-TES observation.

an assumption that diurnal variations of the Martian surface temperature follow the time dependence reproduced by the model. Thus, the corresponding plot in this figure is actually composed of the MGS-TES data at the two local times interpolated according to the assumed diurnal time dependence, and followed by averaging over the visible disk in the manner similar to the one described for the model output. Figure 2 shows an overall consistency in the time series. The temperature drops with the onset of the dust storm in both the measurements and simulations, although the drop is more gradual in the observations than in the model. To emphasize the role of the dust in the radiative energy transfer, we included the surface temperature simulated with the dust radiation scheme turned off. As seen in the figure, the global-mean surface temperature is up to 30-40 K colder in the run when the dust radiative effects are included. Pure seasonal change in the surface temperature accounts for about 10 K during this time of the Martian year, as the run without the dust shows.

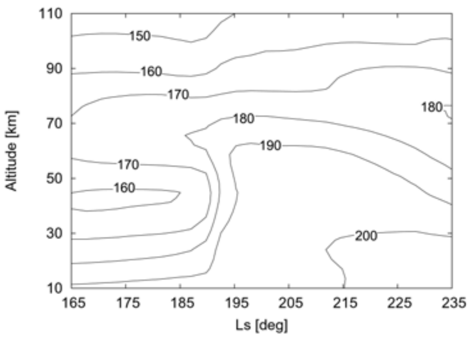
Figure 3 presents the vertical distributions of the simulated global-mean atmospheric temperature between L_s=165° and L_s=235°, and the comparison with the SWAS measurements at 0.05 hPa (~49 km). The temperature at 0.5 hPa (~25 km) is roughly consistent with the SWAS measurements (see Figure 3 in *Gurwell et al*. [2005]) before the onset of the dust storm, and rises in both the observations and simulations. However, in the model, the temperature increase owing to the global dust storm is 20-30 K lower than in the measurements. The model result in Figure 3(b) was smoothed over 8.5 degrees of L_s to match the SWAS data which were reportedly averaged over the same time interval. At 0.05 hPa the temperature time series is almost consistent with the observations during the global storm, although is ~10 K colder before the global dust storm (see Fig. 3(b)). At 0.005 hPa (~73 km), the model does not produce the temperature increase with the onset of the storm. This is consistent with the SWAS measurements, although the simulated temperature is generally ~10 K higher.

Discussion: The model reproduces a moderate atmospheric temperature inversion below 30 km around L_s=215°, as was measured by SWAS (*Gurwell*, personal communication). The simulated time series of the surface and 0.05 hPa atmospheric temperature are consistent with the observations. These observed features cannot be reproduced in the control run with the dust radiation scheme turned off. At 0.005 hPa, the temperature changes little during the global dust storm. This agrees well with observations. At 0.5 hPa, the simulated temperatures rises with the onset of the storm, but remain lower than in the observations.

There are several possible reasons which may explain these inconsistencies. First, the lack of measurements of the dust parameters results in the uncertainty in prescribing the dust in the model. There is a wide range of the observed aerosol particle distributions [*Tomasko et al*., 1999]. The size has a profound effect on the radiative transfer, and the corresponding heating/ cooling rates. Besides, there are no measurements concerning the vertical dust distribution. Therefore, the dust parameters prescribed in Martian GCMs still represent a very crude approximation, and should be treated cautiously. Further observations are required.

Second, possible improvements in model results can be expected if the radiative transfer in the 15 μm

(a)



(b)

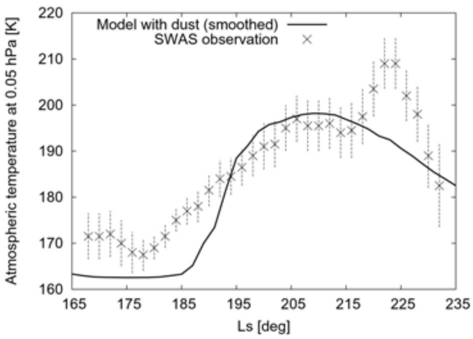


Figure 3: (a) Vertical distribution of the global-mean atmospheric temperature simulated in the Martian GCM with the dust radiation effects included. (b) The time series of the global mean atmospheric temperature at 0.05 hPa from the model (the solid line), and from the SWAS observations (crosses and dotted error bars).

CO_2 band due to the CO_2 and the dust is considered interactively, unlike in all Martian GCMs we are aware of.. Third, at low altitudes submillimeter nadir observations suffer from decreasing contrast to the surface and become more sensitive to baseline ripples, resulting in increased temperature retrieval errors.

References: Gurwell M. A. et al., *Icarus 175*, 23-31, 2005; Hartogh P. et al., *J. Geophys. Res. 110, E11008,* 10.1029/2005JE002498, 2005; Kuroda T. et al., *J. Meteorol. Soc. Japan 83*, 1-19, 2005; Tomasko M. G. et al., *J. Geophys. Res. 104*, 8987-9007, 1999.