REDERIVATION OF THE MGS RADIO OCCULTATION MEASUREMENTS IN THE MARTIAN SOUTH POLAR WINTER REGIONS USING MRO-MCS TEMPERATURE CLIMATOLOGY.

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Introduction

Radio occultation (RO) measurements can be used to obtain vertical profiles of temperature and pressure in a planetary atmosphere assuming that its atmospheric composition and a temperature at the uppermost altitude of the measurements are known. In the present study, we consider the change of the atmospheric composition in the Martian polar regions in polar night, where supersaturation and condensation of CO_2 frequently occur [*Kieffer et al.*, 1977]. We utilize the zonal-mean temperature climatology obtained by the Mars Climate Sounder (MCS) onboard Mars Reconnaissance Orbiter (MRO) in order to update the vertical profiles of temperature and pressure obtained from Mars Global Surveyor (MGS) RO measurements.

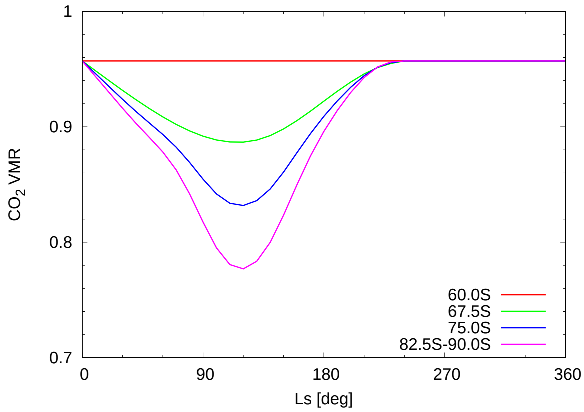

Figure 1: Time series of CO_2 VMR estimated from the GRS Ar measurements for the south polar region of Mars.

Data and Method

The MGS radio occultation data set [*Tyler et al.*, 2001], which can be obtained from the NASA Planetary Data System (PDS), includes more than 20,000 profiles during four Martian years from Mars Year (MY) 24 to 27. The data includes altitude, temperature, pressure and air number density. We took into account the measurement uncertainty of temperature which was provided in the original PDS data set, and added the uncertainty of temperature at each level when comparing with the saturation temperature [*Hu et al.*, 2012, *Noguchi et al.*, 2017] to exclude the wrong detection of supersaturation.

We focused on the southern polar night regions (60°S–90°S), where the decrease of CO_2 is large due to the condensation of CO_2 onto the polar cap. We followed the method proposed by *Noguchi et al.* [2014] to estimate the change of CO_2 volume mixing ratio (VMR) in the polar nights. We utilized the Ar measurement by the Gamma Ray Spectrometer (GRS) onboard Mars Odyssey [*Sprague et al.*, 2012] at two latitude bands (60°S–75°S and 75°S–90°S) and regarded the first band as the representation of 67.5°S, and the second as 82.5°S. Then, we interpolated the Ar VMR between 67.5°S and 82.5°S. As for the region north of 67.5°S, we extrapolated Ar VMR assuming that Ar VMR was constant (1.6%) at 60°S through a Martian year. Between 82.5°S and 90°S, we assume the constant VMR same as the VMR of 82.5°S for each Ls. Finally, we converted the Ar VMR into CO_2 VMR as follows:

$$\chi_{CO_2} = 1 - \chi_{Ar}(1 + f), \quad (1)$$

where f is the ratio of the standard VMR of N_2 to the standard VMR of Ar (=2.7%/1.6%) [*Withers*, 2010]. Figure 1 shows the time series of CO_2 VMR estimated from the GRS Ar measurement mentioned above. The minima of CO_2 VMR occurred around Ls=120° and the lowest value was approximately 78% at 82.5°S.

In the original MGS RO data set, temperature at the uppermost altitude of the measurements, T^u, was fixed to several typical values around the altitude of 40 km. In the present study, we used a temperature climatology based on MRO-MCS observations [*Kleinböhl et al.*, 2017] for T^u. The problem is that there is no overlapping period between the MGS and MRO observations. Thus, we have to apply data from different MYs of MRO-MCS to MGS-RO. The winter season in the southern hemisphere ranges in Ls=0°–180°, which is less influenced by dust and less interannually variable than the dusty season (Ls=180°–360°) [*Kass et al.*, 2016]. Therefore, we simply averaged the temperature profiles obtained by MCS in MY29–33 to make a zonal climatology of temperature. We gridded the zonal averages in five degrees of Ls and latitude bins.

Hereafter, we label the T^u of the original MGS-

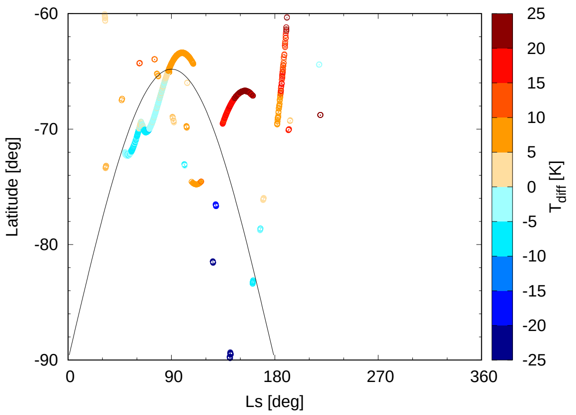

Figure 2: The difference of T^u_{MCS} from T^u_{org}. The black curve indicates the border of polar night.

RO dataset as T^u_{org} and the T^u from the MRO-MCS temperature climatology as T^u_{MCS}. We also refer to the whole temperature profiles rederived with T^u_{org} and T^u_{MCS} as T_{org} and T_{MCS}, respectively. The difference of T^u_{MCS} from T^u_{org} is shown in Figure 2. The T^u_{MCS} tends to be larger than T^u_{org} outside the border of polar night and smaller inside the border of polar night. The difference reaches 25 K in both cases, which suggests a large influence of the detection of CO_2 supersaturation when using T^u_{org} for the derivation of RO temperature profiles.

Results

In the present study, we focus on the effect of the replacement of T^u; we make comparison between T_{org} and T_{MCS}. The samples of the RO temperature profiles rederived are shown in Figure 3. In Figure 3(a), supersaturation occurred in T_{MCS} at several levels around 100 Pa, where no supersaturation was seen in T_{org}. The difference between T^u_{MCS} and T^u_{org} was more than 20 K, and such an overestimation of T^u caused the underestimation of the occurrence of supersaturation. The other way around, the underestimation of T^u caused the overestimation of the occurrence of supersaturation as is shown in Figure 3(b).

Figure 4 shows the histograms of CO_2 supersaturation found in the rederived temperature profiles. In the case of T^u_{MCS} lower than T^u_{org} shown in Figure 4(a), the total number of CO_2 supersaturation detected in T_{MCS} increased by 14% from T_{org}. Conversely, the total number of CO_2 supersaturation in T_{MCS} decreased by 19% when T^u_{MCS} higher than T^u_{org} shown in Figure 4(b). As expected from the results in Figure 3, the overestimation and underestimation of T^u result in the underestimation and overestimation of CO_2 supersaturation, respectively.

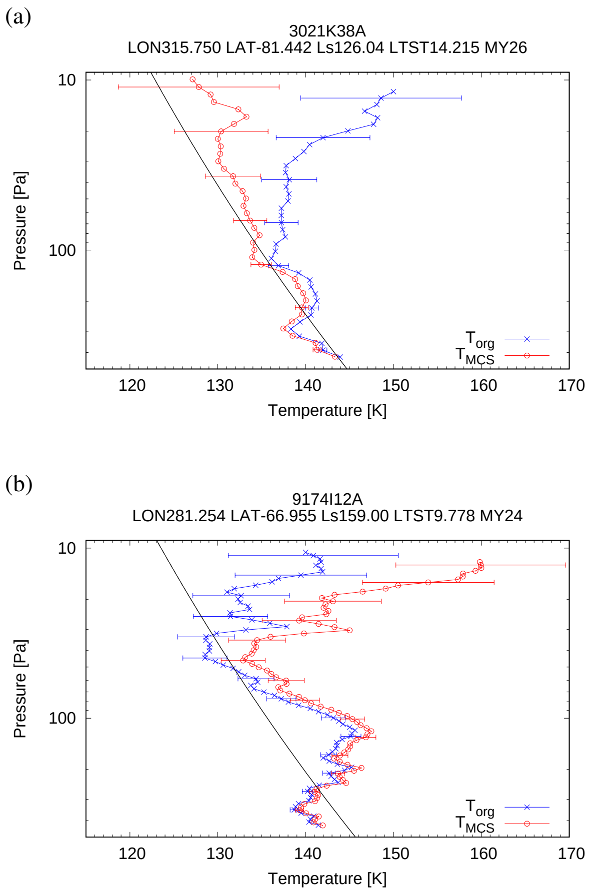

Figure 3: Samples of temperature profiles (T_{org} in blue and T_{MCS} in red) rederived by using MGS radio occultation data for the cases of (a) T^u_{MCS} lower than T^u_{org} and (b) T^u_{MCS} higher than T^u_{org}. The error bars for temperature are plotted by six points. The black curve indicates CO_2 saturation curve for CO_2 VMR = 90.8%.

Conclusion

The present study updated the MGS RO temperature profiles by considering the change of CO_2 VMR in the Martian southern polar nights and utilizing the MRO-MCS temperature climatology as T^u, which was fixed to several typical values in the original MGS RO data set. The replacement of T^u resulted in 14% increase of the total number in the detections of CO_2 supersaturation when T^u_{MCS} lower than T^u_{org}, and 19% decrease when T^u_{MCS} higher than T^u_{org}. This indicates that the assumption of T^u is important for the estimation of CO_2 supersaturation and would also affect the discussion of CO_2 condensation over the polar cap on Mars.

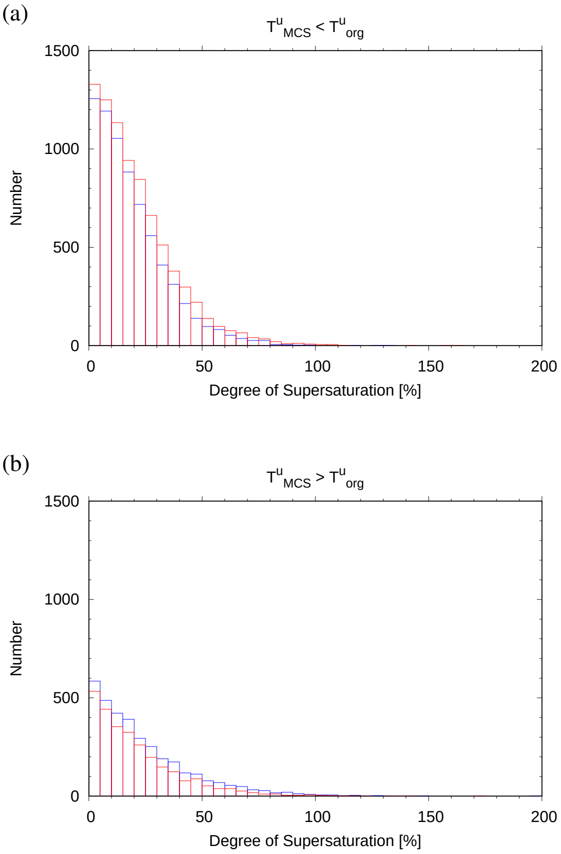

Figure 4: Histograms of CO_2 supersaturation for the cases of (a) T^u_{MCS} lower than T^u_{org} and (b) T^u_{MCS} higher than T^u_{org}. The bar graphs in blue and red indicate T_{org} and T_{MCS}, respectively.

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