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Retrieval of vertical CO_2 concentration in the Martian polar nights using MGS radio occultation data

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Abstract

This study aims at obtaining the information on the vertical profiles of carbon dioxide (CO_2) concentration in the Martian polar night region by radio occultation measurements, assuming that temperature in the region is close to CO_2 saturation temperature. We show the sensitivity of the proposed method to a boundary condition and the samples of the rederivations of both temperature and CO_2 concentration.

1. Introduction

Carbon dioxide (CO_2) is dominant in the Martian atmosphere. The supersaturation and/or condensation of CO_2 occur in the polar night regions on Mars since the air temperature frequently falls below the condensation temperature of CO_2 in those regions [1].

"Traditional" (or standard) radio occultation (RO) measurements derive temperature-pressure profiles of planetary atmospheres assuming composition concentration (volume mixing ratio, VMR). However, the raw data of RO also include the information of VMR in addition to the information of temperature. Assuming that air temperature in the Martian polar night region is close to CO_2 saturation temperature, we proposed the method to obtain the information on the VMR from radio occultation measurements.

2. Data

We used the Mars Global Surveyor (MGS) RO data [2], which is suitable for the studies of atmospheric thermal structures including CO_2 saturation. In the MGS RO measurements, more than 20,000 profiles of temperature and pressure on Mars during 1998-2007 (Mars Year, MY 24-28) are available. The MGS RO data includes altitude, temperature, pressure and air number density, and are provided at the website of the Planetary Data System (PDS), NASA. We focused on the northern polar nights regions (60°N-70°N), where the MGS RO data includes a sufficient number of profiles of temperature and pressure.

3. Method

RO normally derives a temperature profile of a planet assuming the initial temperature T_{init} at the highest level of the profile, and its atmospheric compositions (VMR of constituents, i.e., CO_2, Ar, and N_2 in the Martian atmosphere). Instead, this study simultaneously rederives the profiles of both temperature and VMR 1) by fixing T_{init} to a given value (as with the normal retrieval), 2) assuming that all the values of temperature at other levels are as close to saturation temperature T_{sat} as possible, and 3) assuming that the values of CO_2 VMR are monotonically increasing with altitude. Under those assumptions, rederived temperature becomes T_{sat} at the lowest level of the profile. Figure 1 shows the schematics of the calculations mentioned above.

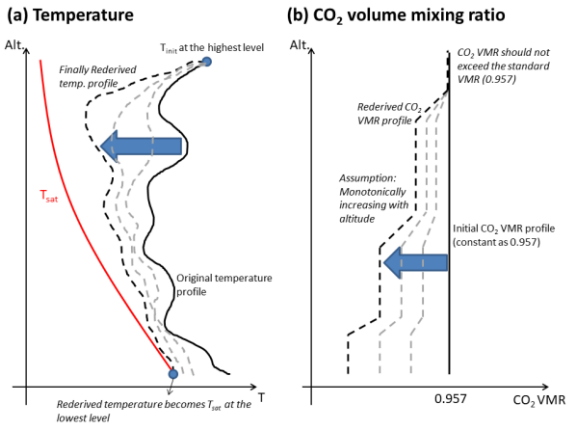

Figure 1: Schematics of iterative calculations to rederive (a) temperature and (b) CO_2 VMR.

4. Results

4.1 Sensitivity to T_{init}

In the rederivation, the arbitrary boundary condition, i.e., T_{init}, is the largest error factor. Therefore, we checked the sensitivity of the rederivation to T_{init}. Figure 2 shows the examples of the rederivation of temperature and CO_2 VMR when various values of T_{init} (110K-150K) were given. While temperature converged with altitudes decreasing regardless of T_{init}, CO_2 VMR largely depended on T_{init}. We also checked the sensitivity of the rederivation to the values of the initial CO_2 VMR, but it did not affect the convergence.

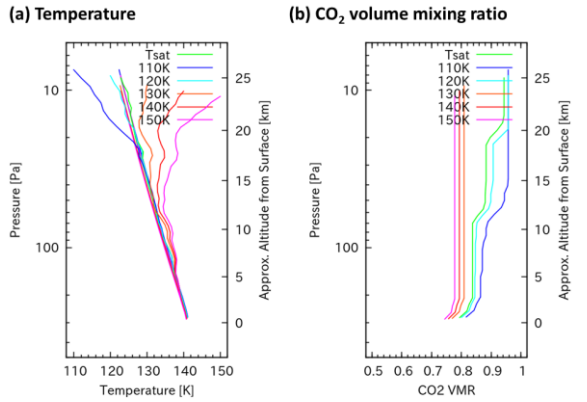

Figure 2: Samples of rederivations of (a) temperature and (b) CO_2 VMR for various T_{init} (110-150K).

4.2 Examples of Rederived Temperature and CO_2 VMR

The sensitivity study indicates that we need a reliable T_{init} for the rederivation. Here we focus on an original MGS-RO profile (#3051Q22A), which was obtained at the southern high-latitude (89°S) in midwinter (Ls=141°). The temperature values at the same latitude and in the same season in the Mars Climate Database (MCD) [3] are saturated at all the levels of the profile. Therefore, we adopted T_{sat} as T_{init} for the rederivation. Temperature in the original profile (the black curve in Figure 3(a)), which assumed T_{init} is 150K, is constantly deviated from the saturation temperature curve (in light green) in the lower altitudes. When we replaced the T_{init} value by T_{sat}, the temperature rederived became close to T_{sat} at almost all the levels. The CO_2 VMR rederived ranged from 70-90% with several step-like structures.

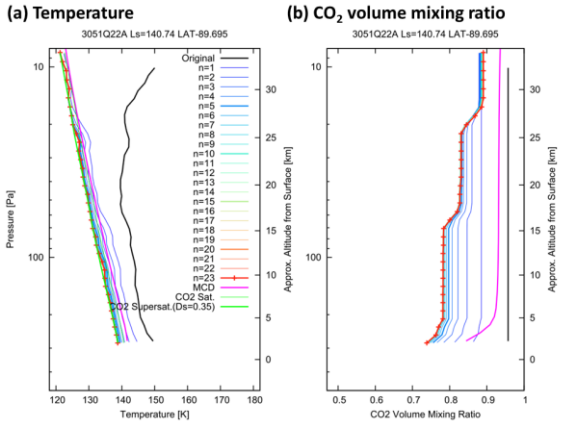

Figure 3: Samples of rederivations of (a) temperature and (b) CO_2 VMR for T_{init} equal to T_{sat}.

5. Concluding Remarks

Using RO measurements, we proposed a method to retrieve the vertical profiles of CO_2 VMR in the Martian polar nights assuming that CO_2 is saturated and temperature is close to T_{sat}. The method proposed is sensitive to a boundary condition of the temperature at the top level of the profile. For future work, the data from other measurements, e.g., MRO-MCS, will be examined to determine T_{init}.

Acknowledgements

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