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Atmospheric CO_2 supersaturation in the Martian polar nights: Role of large-scale atmospheric waves

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Abstract

This study aims at investigating the role of large-scale atmospheric waves (stationary waves and transient waves) on CO_2 supersaturation at northern winter high latitudes on Mars. A distinct longitudinal dependence of CO_2 supersaturation was observed at high altitude levels (around 100 Pa), where a wavenumber 2 stationary wave lowered the background temperature. However, the stationary wave alone was not sufficient to cause CO_2 supersaturation. We found that additional temperature disturbances caused by transient waves, namely, superposition of both waves, had a significant role in CO_2 supersaturation.

1. Introduction

In the Martian atmosphere, the main component is carbon dioxide (CO_2). Since the air temperature often falls below the condensation temperature of CO_2 in the polar night regions on Mars, it is supposed that the supersaturation and/or condensation of CO_2 occur in the atmosphere [1].

Previous studies showed that CO_2 supersaturation is caused by small-scale atmospheric waves (e.g., gravity waves and mountain waves) and large-scale atmospheric waves such as transient waves (baroclinic waves) and stationary waves. The present study investigates the effects of transient waves and stationary waves on CO_2 supersaturation in the Martian atmosphere by using the Mars Global Surveyor (MGS) Radio occultation (RO) data [2], which are suitable for the studies of atmospheric thermal structures including CO_2 supersaturation. We show the spatio-temporal distribution of the occurrence of CO_2 supersaturation, focusing on the northern polar nights regions (60-70N), where enough profiles of temperature and pressure of the MGS RO data are available. We also compare the MGS RO results with numerical simulation results.

2. Data

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, NASA. For comparison, we utilized simulation results from the numerical models, Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions (DRAMATIC) [3].

3. Results

At high altitudes (around 100Pa), CO_2 supersaturation appears at longitudes 90-180E and 270-360E, and no saturation can be seen in other longitude domains. The longitudinal sections where CO_2 supersaturation occurs overlap with zonal temperature minima with wave number 2 (s=2). The results from the numerical model, DRAMATIC, are consistent with the observations and suggest more frequent occurrence of CO_2 supersaturation even above 100 Pa, where much smaller number of CO_2 supersaturation events were observed by the MGS RO measurements.

At lower altitudes (around 610 Pa), CO_2 supersaturation occurs at almost all the longitude sections, although the effect of the stationary wave still remains. Past studies showed that transient waves with s=1,2 and 3 frequently appear in the mid-to high latitudes during autumn and winter [4,5]. We conducted a wavenumber analysis [5] to extract the fluctuation components of temperature caused by stationary waves and transient waves. Figure 1 shows an example of all the fluctuation components extracted by the wavenumber analysis and CO_2 supersaturation events observed by MGS RO on the pressure level of 610 Pa in MY 27. We can see that many CO_2 supersaturation events occur in negative phases of temperature. This suggests a strong influence of stationary and transient waves on CO_2 supersaturation.

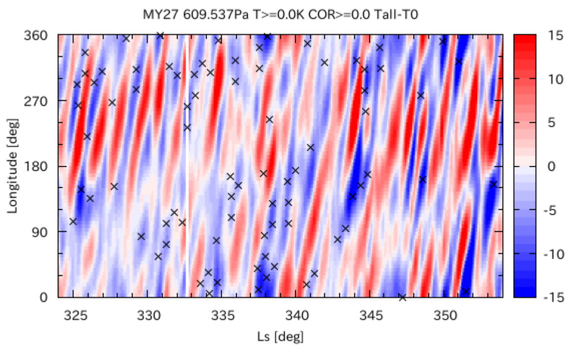

Figure 1: MGS RO temperature fluctuation components extracted by a wavenumber analysis (color shaded regions) and CO_2 supersaturation events (crosses) on the pressure level of 610 Pa in MY27.

4. Summary and Conclusions

We found the relationship between large-scale atmospheric waves including stationary and transient waves and the occurrence of CO_2 supersaturation in the northern hemisphere winter on Mars. The s=2 stationary wave played a significant role in lowering the background temperature and it was close to the CO_2 saturation temperature at around 100 Pa, where strong longitudinal dependence of CO_2 supersaturation was observed, but the stationary wave alone was not sufficient to cause CO_2 supersaturation. In addition to stationary waves, transient waves were also important and the superposition of both waves had a significant role in causing CO_2 supersaturation.

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