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Influence of atmospheric dynamics on the CO_2 ice cloud formation on Mars studied with a general circulation model

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Abstract

Although CO_2 ice clouds on Mars have been observed in the low- and mid-latitude mesosphere, they form in the winter polar regions and create the seasonal polar caps upon sedimentation. We have implemented a CO_2 ice cloud formation scheme into our Mars General Circulation Model (MGCM) to investigate the cloud formations and its relation with the atmospheric dynamical processes.

1. Introduction

CO_2 atmosphere on Mars condenses when temperature drops below saturation temperature, and CO_2 ice clouds can likely form at lower altitudes in winter polar regions, and in the mesosphere (above ~60 km) of low- and midlatitudes. Recently SPICAM, OMEGA, HRSC on Mars Express and THEMIS on Mars Odyssey have observed the mesospheric CO_2 ice clouds.

SPICAM UV stellar occultation measurements detected the 'detached layers' with particle sizes of ~100 nm in subtropics around 100 km as well as the cold temperature, which indicates a supersaturation of CO_2 [1]. OMEGA and HRSC observed the equatorial CO_2 ice clouds with particle sizes of 1-2 μm at 60-85 km altitude in visible and near infrared wavelengths [2,3]. The equatorial clouds are mainly seen during two periods before and after the aphelion, L_s=330-60° and 90-135°. In addition, THEMIS onboard Mars Odyssey observed also the clouds in northern midlatitudes during autumn and winter [4].

In the winter polar regions, formations of CO_2 ice particles with radius larger than ~10 μm have been estimated from low brightness temperature measurements by Mariner 9 IRIS and Viking IRTM [5]. Obviously, the formation of CO_2 ice clouds must be related to the temperature disturbances associated with the atmospheric dynamics, but the investigation of particular mechanisms have never been attempted before. We implemented a CO_2 cloud formation scheme into our MGCM to investigate the interactions between atmospheric dynamics and CO_2 cloud formation using numerical simulations.

2. Model

The model employed here is the DRAMATIC MGCM [6]. The horizontal resolution is set at about 5.6°×5.6° (~333 km at equator), the vertical grid consists of 49 σ-levels with the top of the model domain at about 100 km. The cloud formation scheme takes into account the formation temperatures below the CO_2 condensation threshold, processes of gravitational sedimentation, and deposition of CO_2 ice on the surface. The finite velocity of the sedimentation depends on the particle size of the clouds, assuming 50 μm at 0 km and 1 μm at ~78 km altitudes, which is consistent with the observational estimations [2,5].

3. Results

Figure 1 presents the simulated seasonal and latitudinal changes of zonal-mean daily-averaged CO_2 ice cloud mixing ratio at ~1 Pa (~64 km). It shows that the equatorial CO_2 ice clouds appear around the northern spring equinox and summer solstice, consistently with the HRSC observations [3]. The clouds also form in northern midlatitudes during the autumn and winter, which is consistent with the THEMIS observations [4].

Figure 2 shows a longitude-time cross-section of temperature and CO_2 ice cloud mixing ratio at the northern high-latitude (75° N) around the winter solstice. There is a strong correlation between the

CO_2 ice cloud distributions and temperature disturbances, which are evidently driven by the dominant at this season component of eastward-propagating baroclinic waves with the zonal wavenumber 1 and ~6 sols period [7].

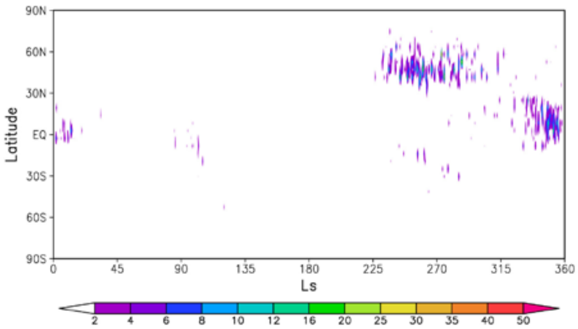

Figure 1: Time-latitude cross-section of the simulated zonal-mean daily-averaged CO_2 ice cloud mixing ratio [ppm of mass] at 1 Pa (~64 km).

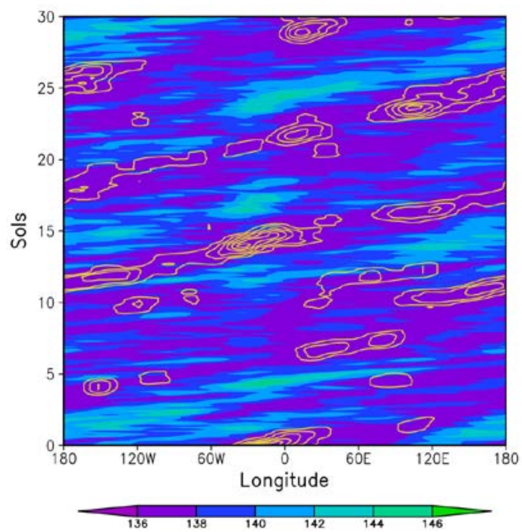

Figure 2: Longitude-time cross-section of the atmospheric temperature [K] (3-hours averaged, shades) and CO_2 ice cloud mixing ratio [ppm of mass] (1-sol averaged, yellow contours with interval of 2000) at 100 Pa (~20 km), ~75° N during L_s=260°-280° (for 30 sols).

4. Summary

Our MGCM well reproduces the observed seasonal and latitudinal dependences of the mesospheric CO_2 ice cloud formation. Simulations indicate a strong dependence of the cloud formations in northern polar winters with the dynamical processes in the lower atmosphere. Detailed analyses of the influence of baroclinic planetary wave on the cloud formation will be presented.

Acknowledgements

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