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STABILITY AND SCATTERING GREENHOUSE EFFECT OF CO2 ICE CLOUD UNDER MARTIAN PALEOENVIRONMENT

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Geomorphological evidence suggests that Martian climate was warm enough for liquid water to be stable about 3.8 Gyr ago. However, the solar luminosity at that time may be too weak to allow the existence of liquid water even if several bars of CO2 existed in the atmosphere, because the temperature lapse rate is decreased by the CO2 condensation at the upper region of the atmosphere. Recently, it is widely accepted that the radiative effect of CO2 ice clouds may resolve this enigma. This theory suggests that CO2 ice clouds have a strong warming effect because the backward scattering of infrared radiation by the clouds would be more effective than that of the solar radiation.

However, studies on the scattering greenhouse effect of CO2 ice cloud so far have several problems. The effects of the radiative absorption by the clouds remain poorly investigated, even though the scattering effects of the cloud layer are well studied. In this study, therefore, we construct a one-dimensional atmospheric radiation model to investigate the stability and greenhouse effect of CO2 ice clouds on early Mars. We particularly pay attention to the effect of radiative absorption by the cloud.

Our numerical results suggest that the cloud particles are condensable in the cloud layer even though they receive the radiative warming. The column density of the cloud layer can be estimated on the basis of the mass balance between the CO2 condensation and the particle loss due to gravitational settling. In addition, we can also calculate the cloud particle radius from the condensation mass flux and residence time, assumed for the particle number density. Our estimates yield that the cloud particle radius is about 10 micron and the column density is about 1 kg per square meter for the cloud number density same as that of the terrestrial cirrus cloud.

Cloud layers most adequate for the greenhouse effect have particle radius of 10-20 micron, because backward scattering of infrared radiation is most effective at these particle size. However, the cloud layers with these particle sizes can also cause anti-greenhouse effect when the column density is larger than about 1 kg per square meter. This is because the effect of infrared absorption lowers the infrared backward scattering. Our estimate of the particle radius satisfies a necessary condition for the greenhouse effect, but that of the column density suggests that the cloud might have anti-greenhouse effect. However, the column density may not be so large enough to cause an anti-greenhouse effect, since our estimate of the column density corresponds to the highest one by neglecting the effect of the surface infrared radiation.