P065-004 Room: 301B Time: May 26 16:05-16:13

MARTIAN CLIMATE TRANSITION BY CO_2 EXCHANGE BETWEEN THE ATMOSPHERE AND ICE CAP

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A significant process in forming the Martian surface environment is the condensation of CO2, the main component of the atmosphere. In this study, we investigate the climate transition by the atmosphere-ice cap CO2 exchange.

Mars is a cold planet at present. However, several lines of evidence suggest that climate warming and cooling have repeated during its history. In order to study the stability and evolution of Martian climate, we constructed a 2-dimensional (horizontal-vertical) energy balance climate model. The long-term CO2 mass exchange process between the atmosphere and CO2 ice caps is investigated with particular attention to the effect of planetary ice distribution on the climate stability. Based on the analysis of the climate stability, we made numerical simulations of the climate transition between warm and cold climate taking into account the evolution of CO2 ice cap topography (areal extent and altitude).

Our model calculation suggests that high atmospheric pressure presumed for past Mars would be unstabilized if H2O ice was widely prevailed. As a result, cold climate state might have been achieved by the condensation of atmospheric CO2 onto ice caps. We call this process ``collapse condensation''. On the other hand, the low atmospheric pressure, which is buffered by CO2 ice cap near the present pressure, would be unstabilized if the CO2 ice albedo decreases. This might have led the climate into a warm state with high atmospheric pressure owing to complete evaporation of CO2 ice cap. We call this process ``runaway evaporation''.

The time scale for the completion of collapse condensation and runaway evaporation is about 10^3 year, which is geologically very short. The pressure drop in the collapse condensation is larger for the larger H2O ice coverage and lower solar luminosity. The pressure would decrease from 10^5 Pa to 10^3 Pa due to collapse condensation at 3.8 Gyr ago. Areal extent of CO2 ice cap formed by the collapse condensation would be larger (toward the latitude of 70-80 degree) than the present one (about 85 degree). On the other hand, runaway evaporation could occur if the albedo of CO2 ice cap decreases enough.

Through albedo feedback mechanisms of H2O and CO2 ices in the atmosphere-ice cap system, Mars might have experienced warm and cold climates episodically in its history. The glaciated terrains observed in the middle latitude might be a signature of the past extension in H2O ice coverage. Polar layer deposits around the present ice cap might be traces of the past CO2 ice cap formed by the collapse condensation.