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Simulation of the early Martian climate using a general circulation model, DRAMATIC MGCM: Impacts of thermal inertia

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Abstract

We use a Mars General Circulation Model (MGCM) named DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) to reveal the nature of early Martian climate, "warm and wet" or "cold and icy". With high thermal inertia assuming the wet soil, the surface temperature greatly increased in comparison with the dry soil simulations. Under the assumption of ancient ocean which covers up to one third of Martian surface, the surface temperature could be maintained above 273 K throughout the year in low-mid latitudes of northern hemisphere in that case.

1. Introduction

Mars receives only 43% of the solar flux of Earth. And the solar intensity before ~3.8Ga is thought to be ~75% of today. However, there have been found many fluid traces and aqueous minerals such as phyllosilicate, sulfate, and chloride on the Martian surface paradoxically. Such evidences should indicate that the convincing action and effects of liquid water on the ancient Martian surface. Solutions to this paradox can be classified into two scenarios, "warm and wet" [1,2] and "cold and icy" [3,4]. The former scenario assumes the long-term warm and wet environments allowing the existence of permanent liquid water. The latter one assumes that the planet was mainly frozen and seasonal or impulsive melting of snow. Ice deposits due to volcanoes and meteorites would provide massive liquid water for forming fluid morphology.

2. Methods

The DRAMATIC MGCM is based on the dynamical core of CCSR/NIES/FRCGC MIROC model [5], and the implementations of physical processes for the current Mars environment have been done by [6,7]. In this study, to simulate the early Martian climate, we assume a pure CO_2 atmosphere with pressure of 2 bars, and solar flux is set to be 75% of the present-day value along with the standard stellar evolution model. Also, to provide the cooling effects in high-pressure conditions accurately, we have implemented the radiative effects of CO_2 gas assuming the sub-Lorentzian profile [8] for the far-line absorption and collision-induced absorption [9].

At first, for simplification, we compared the simulation results with globally uniform thermal inertia of between 250 and 3,000 (J $s^{-1/2}$ m^{-2} K^{-1}, hereafter the unit is omitted). Larger value supposes the wet soils, which is expected to prevent the dissipation of ground heat and strengthen the greenhouse effect. Second, we implemented the virtual ocean and lakes with the sea level of -2.54 km altitude (Figure 1) covering about one-third of the Martian surface. Thermal inertia and albedo of ocean and lakes were set to 2,000 and 0.07, respectively, where the surface temperature went above 273 K. In the locations where the surface temperature was below 273K, those parameters were set to 2800 and 0.5, respectively, assuming the icy ocean. Albedo in other areas was set to 0.22 assuming rocky surface.

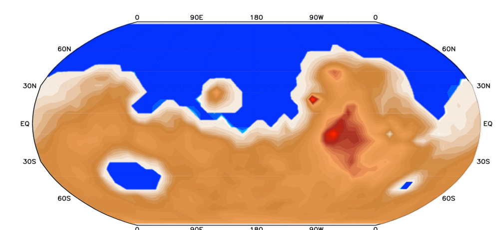

Figure 1: Martian topography with ocean and lakes with the sea level of -2.54 km altitude.

3. Results

In the "wet soil" simulation with globally-constant thermal inertia of 3,000, surface temperature increased up to ~260 K, which was higher than that with globally-constant thermal inertia of 250 (~240 K). In addition, annual mean surface temperature in equators and Hellas-basin went above 273 K (283 K on the equator and 279 K in Hellas-basin) (Figure 2). In this case, the temperature on the equator was kept to be above 273 K for a whole year. In the simulation putting virtual ocean and lakes with wet soil condition, the surface temperature went about 273 K, throughout the year in low- and mid- latitudes of northern hemisphere and half of the year in Hellas-basin. The results suggest that the surface conditions should be the key of the existence of liquid water in early Mars. The surface conditions with high thermal inertia could produce the high surface temperature enough to make liquid water even with the pure CO_2 atmosphere and solar insolation of only 75% of today.

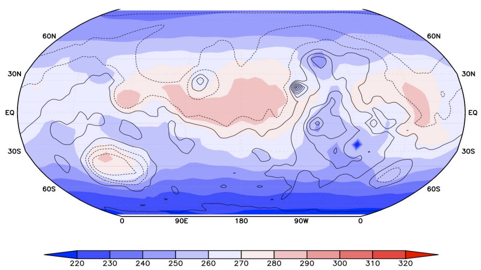

Figure 2: Annual mean temperature in thermal inertia of 3,000 (J $s^{-1/2}$ m^{-2} K^{-1}) at surface pressure of 2 bars.

4. Summary and Conclusions

Our simulation study showed that the early Martian climate under the "wet soil" condition could keep warm and wet conditions with radiative effects of CO_2 gas and clouds only, without considering other greenhouse gases such as SO_2 and H_2. Our results indicated a new direction in the research of early Martian climate, showing that the high thermal inertia would likely make warmer environment (allowing the existence of liquid water seasonally and spatially) than the studies before.

References

[1] J. B. Pollack, J. F. Kasting, S. M. Richardson, and K. Poliakoff: The Case for a Wet, Warm Climate on Early Mars, Icarus 71, 203-224, 1987.

[2] F. Forget, R. Wordsworth, E.Millour, J. B. Madeleine, L. Kerber, J. Leconte, and E. Marcq, R. M. Haberle: 3D modeling of the early martian climate under denser CO_2 atmosphere: Temperature and CO_2 ice clouds, Icarus 222, 81-99, 2013.

[3] S. W. Squyres, and J. F. Kasting: Early Mars: How Warm and How Wet?, Science 265,744-749, 1994.

[4] R. Wordsworth, F. Forget, E. Millour, and B. Charnay: Global modelling of the early martian climate under a denser CO_2 atmosphere: Water cycle and ice evolution, Icarus 222, 1-19, 2013.

[5] K-1 Model Developers: K-1 coupled GCM (MIROC) description, K-1 Tech. Rep., 1, Univ. of Tokyo, Tokyo, 1–34, 2004.

[6] T. Kuroda, N. Hashimoto, D. Sakai, and M. Takahashi: Simulation of the Martian atmosphere using a CCSR/NIES AGCM, J. Meteor. Soc. Japan 83, 1–19, 2005.

[7] T. Kuroda, A. S. Medvedev, Y.Kasaba, and P. Hartogh: Carbon dioxide ice clouds, snowfalls, and baroclinic waves in the northern winter polar atmosphere of Mars , Geophys. Res. Lett. 40, 1484-1488, 2013.

[8] M. Fukabori, T. Nakazawa, and M.Tanaka: Absorption properties of infrared active gases at high pressures – I. CO_2, J. Quant. Spectro. Rad. Trans. 36, 265-270, 1986.

[9] M. Gruszka, and A. Borysow: Roto-transitional collision-induced absorption of CO_2 for the atmosphere of Venus at frequencies from 0 to 2500 cm^{-1}, at temperatures from 200 to 800K, Icarus 129, 172-177, 1997.