古海洋・厚いCO2大気環境のもとでの火星古気候シミュレーション－水環境の気候に及ぼす影響

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Global climate simulation of early Mars with a paleo-ocean and a dense CO2 atmosphere: Impact of aquatic environment to climate

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There are many fluvial traces such as valley networks and outflow channels which are supposed to be made before ~3.8 billion years ago on the Martian surface. If those traces were made by the flow of liquid H_2O, the environment of the ancient Mars should be suitable for huge amount of liquid water. There have been several studies using 3-dimensional Mars Global Climate Models (MGCMs) to reproduce such environment of early Mars, assuming the solar insolation of ~75% of today and denser CO_2 atmosphere. However, previous studies have not reproduced the surface temperature above 273K even under the surface pressure up to ~7 bars, regardless of the existence of saturated H_2O vapor [*Forget et al*., 2013; *Wordsworth et al*., 2013].

In this study, we use a MGCM named DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) to reveal the nature of early Martian climate, focusing on the sensitivity of surface parameters. In addition to the physical processes for Martian paleo-climate similar to *Forget et al*. [2013], we have implemented the virtual ocean and lakes in the northern lowlands and wet soil in the southern highlands, making high thermal inertia of between 1,000 and 3,000(J $s^{-1/2}$ m^{-2} K^{-1}) which have never been implemented in the preceding studies. Also we have implemented a water cycle scheme assuming the phase changes among ice, liquid and vapor, including the frost of ocean below the melting point. The obliquity in the simulations is set to be the same as today's Mars (25.19 degrees),and the orbit is assumed to be circular with the radius of 1.523 AU. Furthermore, Rayleigh-friction coefficients are set to be the valid values, which reproduce wind field of today's Mars.

We performed the simulation with the averaged surface pressure (hereafter p_s) of 0.1-2.0 bars, for two cases (1) with ocean/lakes and wet soil (hereafter 'wet surface') and (2) without them (hereafter 'dry surface', assuming the dry soil which is the same as today's Mars globally). As a result, we produced higher surface temperature in 'wet surface' at all pressures, dT ~+30 K at p_s = 2.0 bars, in comparison with 'dry surface'. In the 'wet surface' simulation, the annual mean surface temperature was ~230 K at p_s = 1.0 bar and ~260 K at p_s = 2.0 bars. Although there were little precipitation and the paleo-ocean quickly froze in p_s below 1.0 bar, the paleo-ocean was maintained throughout the year in low-to-mid latitudes area in p_s above 1.0 bar with the precipitation of 1,000-3,000 mm in one Martian year (about 1.88 Terrestrial year) was shown alongside the shoreline, e.g. in the north-east of Hellas basin and at the foot of tall mountains such as Mt. Elysium, where large fluvial traces of outflow channels have been observed. Furthermore, the distribution of the amount of flowing water of the river, which is calculated by a 3-layers tank model [*Ishihara and Kobatake*,1979] and developed river flow model considering the river velocity calculated by *Manning* formula and confluence of several rivers, was also in a good consistency with the existence of fluvial traces of outflow channels on Martian surface.