火星古気候の大気・水圏結合モデリング：Valley network 再現に向けて

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Modeling of the coupled atmosphere-hydrosphere of the Martian paleoclimate: Towards the reproduction of valley networks

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Though the current Mars is a dry planet, the early Mars during the Noachian and Hesperian boundary (3.85-3.6 Ga) is thought to have been a water-rich planet like the present Earth. The isotopic ratios detected from Martian meteorites showed the evidence of surface pressure of higher than 0.5 bars in ~4.1 Ga [Kurokawa et al., 2018] and surface water abundance of ~550 m global equivalent layer around that time [Kurokawa et al., 2016], which should indicate that the surface liquid water made the observed fluvial traces. Also, the topographic evidences of the existence of long-term fluvial system in that time, called as valley networks (VNs), have been observed to represent the past water distributions on Martian surface.

Due to the weak solar luminosity (~75% of the current value) of early Mars, 3-dimensional numerical studies using Mars global climate models (MGCMs) had shown that the reproduction of surface temperature of above 273K (melting point of water) would be difficult with only the radiative effects of thick (up to 7 bars) CO_2 atmosphere, water vapor and clouds [Forget et al., 2013; Wordsworth et al., 2013]. To solve this contradiction, preceding studies have shown that adding other molecules such as SO_2 [Mischna et al., 2013] or H_2 [Ramirez et al., 2014; Ramirez, 2017] into the radiative schemes would make sense, but no study has performed with 3-dimension including the spatial changes of surface parameters such as liquid water surface (ocean/lake).

We present the results of a newly-developed 3-dimensional Paleo MGCM (PMGCM) assuming the $CO_2/H_2O/H_2$ atmosphere under the, with surface pressures between 0.3 and 7 bar. The PMGCM also has a hydrologic cycle module, which includes ocean thermodynamics, water vapor advection/convection/condensation/precipitation processes, and surface fluvial activities (e.g. fluvial and sediment transport) with high resolution.

For atmosphere including 3% H_2, the PMGCM simulation with a surface pressure exceeding 1.5 bar indicated that the early Martian surface environment would have been ’cool’ (surface temperatures exceeding 273 K during summer to allow seasonal melting of snow-ice deposits, and low enough during winter to produce considerable snow precipitation and accumulation), and ’wet’ (characterized by precipitation and seasonal melting of snow/ice), with enough fluvial sediment transport in the low to middle latitudes to reconcile Martian VNs within a relatively short time (less than tens of million years).

However, the simulated distributions of VNs had several discrepancies from the observations. One possible reason is the existence of Tharsis bulge. In the early Martian history, the formation time of Tharsis (the largest volcanic plateau in the Solar system) is under debate, and the presence or absence of Tharsis would be an important parameter in the discussion of the global water circulation in early Mars. Then we also performed the PMGCM simulation with surface topography before the Tharsis load. Our preliminary results with a 1.5 bar CO_2 atmosphere including 3% H_2 showed the reproduction of the clement surface environment and matured surface runoff systems consistent with observed VN systems without Tharsis bulge, while not consistent with Tharsis.

In addition, the sensitivity of different cumulus convection schemes on the simulated precipitation would affect the reproduction of VNs. We are comparing the results between the Relaxed Arakawa-Schubert scheme [Moorthi and Suarez,1991], which is often used in a terrestrial GCM, and the Kain-Fritsch scheme [Kain and Fritsch,1993], which calculates cloud structures in more detail. In the simulation under the terrestrial conditions, we could obtain similar results in both schemes, although there were slight differences in cloud amounts and precipitation. In the presentation we report the results in the early Mars conditions and evaluate the quantitative differences in both schemes.