Sensitivity of the difference of cumulus convection schemes to the precipitation distributions simulated in a Paleo Mars GCM

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Current Mars has a lot of fluvial traces, which are supposed to have been made during the late Noachian and early Hesperian boundary (3.8-3.6 Ga). If these traces are created by the fluvial activity, the climate of early Mars should be 'warm and wet' enough for the long-term existence of liquid water on its surface. However, solar luminosity at that time would be weaker by 20-30 % of today's value, which would make such the 'warm and wet' climate difficult ('Faint Young Sun paradox'). Possible occasions to overcome this contradiction are the collisions of meteorites or the eruption of Tharsis which might make a temporary heating, and/or the emission of H_2 and/or CH_4 which possibly make a long term greenhouse effect by enhancing the infrared absorption.

We have newly developed a 3-dimensional Paleo Mars Global Climate Model (PMGCM) with ancient ocean on its surface below a sea level of -2.54 km, including the absorptions of CO_2 / H_2O /H_2 (0-20%) gases, CO_2 / H_2O ice clouds, thermodynamics of land / ocean, and hydrological processes [*Kamada et al.,* 2020]. This model reproduced a clement surface environment enough for liquid water on surface and could create most of fluvial channels by hydrological processes. However, the fluvial channels reproduced in our model were partly not consistent with observations on current Mars [*Hynek,* 2010].

Here we focused on the sensitivity of cumulus convection schemes to explain this inconsistency. This process could be crucial for resolving atmospheric instability and affect the distribution and the amount of precipitations on early Mars. Therefore, we have introduced two cumulus convection schemes and compared the results produced by each other. One is the Relaxed Arakawa-Schubert scheme (RAS) [*Moorthi and Suarez,* 1991] which is often used in terrestrial GCMs. RAS creates several cumulus in one grid and considers detrainment only top at the cloud top. The other is the Kain-Fritsch scheme (KF) [*Kain and Fritsch,* 1993], which creates a cumulus in one grid and considers detrainment at all height. Those two schemes use different convection triggers, which can affect the precipitation and cloud distribution on PMGCM.

At first, we did the tests of those two schemes under the present terrestrial condition (1bar, N_2 / O_2 atmosphere, 1370 W m^{-2}). In the T21L20 resolution the results of surface temperature and precipitation were almost similar in the two schemes, but the vertical distribution of cloud amount in sigma=0.8 with KF was 1.5 times thicker than RAS. That is because the characteristics of detrainment for each scheme are different, and due to the difference of convection trigger, the precipitation distribution did not match exactly between two schemes.

As the next step, we implemented those two schemes into the PMGCM for the conditions of surface pressures between 0.5-2.0 bars and H_2 mixing ratios of 0, 3, 6%. In the all conditions, the PMGCM results of surface temperature and precipitation were similar for the two schemes. However, the tendency of cloud amount and precipitation distribution was different, and in certain conditions, KF's precipitation in the low latitudes was larger than RAS's.

Under the conditions in which KF had higher precipitation in low latitude than RAS (1.0bar and 6% H_2; 2.0bar and 3% H_2), the timescale of VN formation with KF would be 1.2 to 2.0 times faster than with RAS, because KF's detrainment in all altitudes resulted in more horizontal water vapor transport from the ocean than RAS. With KF, the change of precipitation area to higher latitudes, as seen in the higher temperature condition of *Kamada et al.,* [2020], tended to be smaller than with RAS because KF produced more humid atmosphere. It was difficult to generate new VNs which was not reproduced in *Kamada et al.,* [2020] with KF, i.e. the qualitative distributions of VN formations unchanged between KF and RAS in our PMGCM.

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