R009-28
Zoom meeting D ：11/2 AM2 (10:45-12:30)
11:00-11:15

River simulations on early Mars in the Noachian and the Hesperian periods using the global river model, CRIS

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The present Mars is cold and arid environment with little stable water on surface. However, the planetary environment on early Mars would have been quite different from that on the current Mars. Many observations have shown geological evidences for the past Martian environment, which should have been warm and wet enough to allow large-scale surface runoff activities. These geological evidences are called as “valley networks (VNs)", which are originated in the boundary between the Late Noachian and Early Hesperian (3.85-3.6 Ga). River might have been an important player for global water and material cycles in the early Mars as well as the present Earth.
We have newly developed a global-scale distributed river model for pan-planets named CRIS (Catchment-based RIver Simulator), which calculates the processes of 1) soil infiltration, 2) river transport, and 3) sediment transport. In the process 1), the storage height and surface, intermediate, and basal runoff in each soil layer are calculated using the model outputs of a paleo-Mars global climate model (PMGCM) [Kamada et al., 2020]. In the process 2), the river discharge and channel parameters are calculated from the runoff volume inputted from 1), assuming the flow down along given channel networks to the ocean and inland lakes. In the process 3), the sediment production and discharges of suspended and traction load are calculated using the river discharge and the channel parameters inputted from 2). The PMGCM assumed a CO2/H2O/H2 atmosphere under the ‘Faint Young Sun' condition (with a solar luminosity of ~75% of the current value) and the pre-True Polar Wander topography [Bouley et al., 2016] assuming the surface condition before late Tharsis formation, for surface pressures of between 0.5 and 2 bar, H2 concentration of between 1 and 6%, obliquity of between 20o and 60o. The horizontal resolution of CRIS is set to 1.125 degrees (~67 km grid interval at the equator), and that of the PMGCM is set to 5.625 degrees (~333 km).
The formation of V-shaped water channels (i.e., VNs) requires a large volume of liquid water combined with stable and long-term fluvial activity, which means that global mean surface temperature above the melting point and enough precipitation should be needed for the early Martian environment. When we assumed an H2-rich (more than 3%) atmosphere, the mean surface temperature rapidly approached and exceeded the melting point as the amount of background CO2 atmosphere increased. Also, the annual precipitation basically increased with surface pressures. Although precipitation on Early Mars is an order of magnitude less than that on Earth, it is enough for intense surface runoff to carve the VNs. Additionally, CRIS predicted that 1) for the obliquity of 20o, significant fluvial and sediment discharges are distributed around Tharsis regions and southern polar regions, although relatively fragile river channels are calculated in VNs regions; 2) for the obliquity of 40o, intense Martian river channels are mainly distributed in equator, seashore, lakeshore regions and Arabia Terra where intense precipitations are observed; and 3) for the obliquity of 60o, there are almost no significant fluvial features in southern low to middle latitudes because annual mean surface temperatures in these regions are less than the melting point of water.
CRIS revealed that warm and wet early Mars with obliquity of 40o would be more plausible to reproduce widespread precipitation-fed river channels across low to middle latitudes. However, even if we consider that Martian VNs are mainly created by rivers, it is not consistent with observations in some areas, such as the Arabia Terra. Recently, Davis et al. [2016] found extensive networks of sinuous ridges in Arabia Terra, which might be interpreted as inverted fluvial channels that formed in the Noachian before being buried. If so, it would be a strong evidence that Martian VNs were made by the ancient river activity.