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Four climate regimes on a land planet with wet surface: Effects of obliquity change and implications for ancient Mars

Yutaka Abe[1]; Goro Komatsu[2]

[1] Earth Planetary Sci., Univ. Tokyo; [2] IRSPS

Series of numerical experiments are performed using a general circulation model to gain insights on the hydrologic cycle on ancient Mars. Since the state of the ancient Mars atmosphere is not well constrained, we did not try to simulate an ancient Mars climate under warm and wet condition. In stead, we used an idealized model and tried to extract general features of the hydrologic cycle by modeling an ideal land planet that has no ocean on its surface. We ran GCM climate simulations of a planet with a wet surface and a wide range of the spin axis (obliquity) to investigate the influence of obliquity on climatic regimes that may have prevailed in particular during the Noachian period of Mars.

We have found that the planet could have four distinctive climatic regimes: 'warm-upright', 'warm-oblique', 'frozen-upright' and 'frozen-oblique' depending on the inclination of the obliquity and average surface temperature. In our simulations, the surface temperature was varied by changing the solar constant. If the surface temperature exceeds the freezing point in summer at least at the sub solar point, the precipitation concentrates in the polar regions when obliquity is small (less than about 30 degrees) 'Warm-Upright regime' but it concentrates in the equatorial region when obliquity is large (larger than about 30 degrees) 'Warm-Oblique regime'. If the temperature is always below the freezing point everywhere on the planet, precipitation is extremely low and surface is practically frozen 'Frozen regime'. The frozen regime is also divided into 'Frozen-Upright' and 'Frozen-Oblique' regimes depending on obliquity. Our experiments clearly indicate that obliquity and wet surface are very important factors for atmospheric transport of water to low latitude areas. And this trend would not change even if a larger set of other factors such as topography, greenhouse gasses, presence of oceans and lakes were included in the model. This could have profound implications for geomorphological processes on the planet. The period of active hydrologic cycle suggested from the geomorphology on Mars seems to be consistent with that at the 'warm-oblique' regime, which appears at warm (above-freezing) environment with high obliquity (higher than about 30 degrees) condition. In particular, some newly studied ice-related landforms in the equatorial region may require a wet surface and high obliquity conditions. Another finding of our simulation is that high temperature is possible at high latitudes with high obliquity. This may explain melting of once more extensive polar caps.