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The Role of Ocean on Planetary Climate: An Implication for Ancient-Mars

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Many fluvial features on Mars indicate past active hydrologic cycle. Many of networks were formed in Noachian (4.5-3.7Ga). Valley networks require supply of water to their source areas irrespective of their formation mechanism; either ground water sapping or precipitation runoff. Since the most efficient way of water supply is precipitation, the understanding of precipitation distribution is important for the interpretation of valley networks formation. Valley networks are located in the whole Mars. Therefore, it is supposed that all areas had precipitation for certain length of time.

Low latitude areas have water supply under limited conditions. When it is warm (above the freezing) and high obliquity (more than 30), low latitude areas have precipitation. When it is cold and wet, the planet completely freezes and all areas have no precipitation. Unless 'land planet' has high obliquity, low latitude areas are inevitably dried because atmosphere transport water to high latitude areas. (Abe and Numaguchi, 2001)

On the other hand, it is suggested that the northern plains of Mars might have oceans (Baker et al., 1991). If the ocean extends to the low latitude areas, it returns water to the low latitude areas and keeps there wet. In this study, we simulate hydrologic cycle on an idealized planet with an ocean. We clarify the general role of ocean on precipitation pattern on the planet. Especially, we focus on the condition for the precipitation in low latitude areas and occurrence of completely frozen state.

We consider a circular ocean centered at the North Pole. We change the latitude of the ocean edge from 0N to 60N to clarify the effect of ocean size. Then, we examined the effect of the ground ability to keep water. Finally, we examined the response of planatary climate on the solar flux. We changed the solar flux to mimic the variation of the greenhouse effect on ancient Mars, because we do not know the composition and pressure of ancient martian atmosphere.

An idealized planet model is made based on the CCSR/NIES AGCM5.4g, which has been developed for the research of the Earth climate by the Center for Climate System Research, University of Tokyo and National Institute for Environmental Research. We use an Earth-GCM as it is well tested for simulation of an Earth-like wet planet. We remove topographies and vegetation from an Earth-sized planet on a circular orbit at 1 AU with 1 bar air atmosphere and 23.5 obliquity.

The low latitude areas have precipitation when an ocean extends to the lower latitude than 30N. It is inferred that the precipitation pattern is controlled by relative position of the ocean edge and the extent of the Hadley-cell. If the Hadley-cell extends beyond the southern edge of the ocean, the equator-ward wind of the Hadley circulation transports water to the low latitude lands.

The criterion for the transition to the frozen regime depends on the ocean size. Transition occurs at high solar flux when the size of the ocean is large. When the ocean occupies the entire northern hemisphere, the planet enters the frozen regime when the surface of the ocean freezes. However, when the ocean edge is at 30N, the planet dose not necessarily frozen, even if the ocean is completely frozen. The planet with oceans freezes at the 70% of the present solar constant.

The first condition for the water supply to valley networks in low latitude is strong greenhouse effect to prevent the complete-freezing. The planet with an earth-like atmosphere freezes at 70-80% of the present Earth's solar constant. On the other hand, the solar constant on an ancient Mars is about 30% of the present Earth. The greenhouse effect on ancient Mars must be at least 2.3-2.7 times stronger than that of the present Earth in order to escape from a completely frozen state. The second condition is that the ocean extends to lower than the Hadley-cell (30N) while the obliquity is 23.5.