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Climate evolution of extrasolar terrestrial planets with water and carbonate-silicate geochemical cycle

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The surface environment of a habitable planet has been constrained in terms of orbital semi-major axis and an effective solar flux, focusing on the existence of liquid water, that is, the habitable zone (HZ) around main sequence stars (e.g., Kasting et al., 1993). It has been also pointed out that the carbonate-silicate geochemical cycle would be essential for maintaining the climate of a habitable planet (e.g., Tajika, 2003). However, the whole picture of evolution of climate of planets with carbonate-silicate geochemical cycle has not been known.

In this study, we investigate the climate evolution of an Earth-like planet (actually, the Earth itself) around a G-type star (= Sun). Steady states of climate of Earth-like planets are estimated systematically with a simple climate model coupled with a carbonate-silicate geochemical cycle model. We classified climates of Earth-like planets within the HZ into three modes, in terms of stabilizing mechanism. Then, the climate evolution is estimated based on the steady state solutions of the climate with models of the stellar evolution and the thermal evolution of planetary interiors. The results indicate that, on an Earth-like planet (the size of the Earth) orbiting around a G-Type star, climate depends on the thermal history of the planet in the early stages of its lifetime, and then depends on the stellar evolution. The climate evolutions are also estimated for the different mass both for stars and planets.

Keywords: Extrasolar planetary system, Habitable zone, Habitable planet, Carbonate-silicate geochemical cycle, EBM