# Dependence of Enviroment Stabilization on Parameters by Carbon Cycle

# Syugo Watanabe[1]; Yutaka Abe[2]

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

Habitable conditions are important environmental indicators of an extrasolar planet. One important habitability condition is the stability of liquid water for geological timescale. Tajika and Matsui(1990)(1) show that carbon cycle stabilize the surface temperature against the increase of solar radiation accompanied with the Sun's evolution. Kasting et al.(1993)(2) obtain the range of orbital radii for the continuously habitable planets considering both the carbon cycle and the runaway greenhouse effect.

The atmospheric temperature depends on the incident energy flux and the greenhouse effect in the atmosphere. The amount of carbon dioxide, which is an important greenhouse gas in the atmosphere, controlled by the balance between fluxes of degassing and fixation as carbonates. Hence, a large degassing flux results in a strong greenhouse effect, and a warm environment. Since the solar flux increases with the Sun's evolution, the degassing rate of CO2 required for keeping the surface temperature decreases with time.  On the other hand, owing to planetary cooling, the degassing rate decreases with time.  Thus, rapid cooling of a planet result in the decreses of the greenhouse effect below the critical value that is required for keeping the warm environment surface . Thus, the stability of warm environment depends on the thermal evolution of the planetary interia, which is dependent on the planetary size and the material properties. However, these depnedence is not well discussed yet.

Here, we investigate the planetary size dependence of the stability of liquid water over geological time scale by examining the length of the period while the surface temperature is kept above freezing. In the following,  we define the 'lifetime' of a habitable planet as the period while the surface temperature is kept above a certain reference temperature. For simplicity, we assume that the atmospheric and the surface temperatures are the same. We consider the reference surface temperature at 15C which is annually and globally averaged temperature on the present Earth. We Use simple expressions of the thermal evolution and degassing rate, the greenhouse warming, and the carbonate formation rate. We improve the Stagnant Lid Model by Breuer and Spohn(2003)(3) for the thermal evolution. We investigate the dependance of the lifetime on the planetary radius and the planetary properties (density, viscosity, heat capacity and so on) using a Monte-Carlo method.

The lifetime is shown to be strongly dependent on the planetary radius, the core radius/planetary radius ratio, the continental area and degassing efficiency, the mantle viscosity and the incident energy flux. The lifetime is very short, if the chosen parameter values includes one inadequate value. On the other hand, the lifetime is only weakly dependent on the potential crust thickness, density, heat capacity and so on. Qualitative depnedence and realize importance of each parameter is clarified in our study. However, we should discuss model dependence and convection mode dependence stil more.

(1)Tajika, E. and Matsui, T.(1990):The evolution of the terrestrial environments. In 'Origin of the Earth'(Newsoms, M. E. and Jones. H. eds.), Oxford Univ.

Press, pp.347-370

(2)Kasting, J. F., Whitmire, D. P., Reynolds, R. T.(1993):Habitable Zones around Main Sequence Stars, Icarus, 101, 108-128, 1993

(3)Breuer, D. and Spohn, T.(2003):Early plate tectonics versus single-plate tectonics on Mars:Evidence from magnetic field history and crust evolution,

Journal of Geophys. Res. 108, 5072, 2003