[JJ] Evening Poster | P (Space and Planetary Sciences) | P-AE Astronomy & Extrasolar Bodies

[P-AE20]Exoplanet

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Exoplanetary science, which began with the discovery of a hot Jupiter in 1995, has reached a major turning point by the discovery of countless super-Earths by the Kepler mission. More recently, planets that are similar in size to the Earth and also receive similar amounts of stellar radiation (namely, located in the so-called habitable zone) have been discovered around nearby stars such as Proxima Centauri and TRAPPIST-1. As a result, not only theoretical, but also observational studies on the atmospheres and surface environments of Earth-like exoplanets have been started. Moreover, the number of planets discovered around early-type and late-type stars has become large enough that the occurrence rate and orbital distribution of planets around a wide variety of host stars have become clear. Thus, new observational insights, which become the basis of pan-planet formation theory, are now gathering. While exoplanets have been mainly targeted for astronomy until recently, it can be said that earth planetary science is finally becoming a research field to make a central contribution. In this session, we aim to share cutting-edge research results in exoplanetary science which is in such a transition period.

[PAE20-P08]Planetary climate on terrestrial exoplanets with excess water within the habitable zone

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Conventional theories regarding planetary habitability assumed an Earth-like planet where the amount of ocean water was small enough that land and ocean coexist on the planetary surface. However many recent theories of planet formation predict terrestrial exoplanets in the habitable zone could have much more water than the Earth. Such terrestrial planets are covered entirely with oceans, which are called ocean planets. Ocean planets with much water in the habitable zone are predicted to have extremely hot climate due to strong greenhouse effect of CO_2, because H_2O high-pressure (HP) ice prevents the chemical weathering on the seafloor. However, recent numerical experiments of thermal convection of the HP ice suggested that heat flux from oceanic crust result in melting the HP ice. Although previous studies assumed the horizontally uniform and small heat flux from oceanic crust, plate tectonics produces a large variation of the heat flux, which would lead to melt more larger portion of the HP ice than that in previous studies. Furthermore, melting the HP ice raises the temperature on the interface of rock/water regardless of the surface temperature in contrast to that obtained by the adiabatic condition. Such high temperature enhances seafloor weathering because of temperature dependence of chemical weathering. Consequently, ocean planets would have cold climate due to large removal flux of atmospheric CO_2, if the HP ice was massively melting.

In this study, we consider an Earth-sized ocean planets with plate tectonics and explore the possibility that the high heat flux at the mid-ocean ridge leads to melting the HP ice and thus making seafloor weathering efficiently works. To that end, we develop integrated climate model for ocean planets that includes melting of HP ice, seafloor weathering, and the carbon cycle. As a result, we have found that the high-pressure ice is entirely molten when the high-pressure ice is thin (e.g., <130 Earth's ocean masses for the current mean heat flow in the Earth's mantle) and then the weathering occurs in the seafloor. We have also found that the planetary climate for large ocean masses (e.g., >60 Earth's ocean masses for Earth-like degassing flux) lapses into two extreme climates; quite hot ones with a CO_2 rich atmosphere, in which the surface temperature is larger than 350 K, or cold ones with a CO_2 poor atmosphere, even a snowball state. The abrupt transitions from warm to extreme climates are triggered by two runaway processes; CO_2 accumulation induced by the upper limit to the seafloor weathering flux and CO_2 clearing induced by melting of the high-pressure ice. This result suggests a low probability of exoplanets with clement climates, like the present Earth, and necessity that we consider water amounts and their thermo-chemical structure to discuss planetary climate, even if the planet in the habitable zone.