A numerical experiment of aquaplanet climates with a coupled atmosphere-ocean-sea ice model

*Yuta Kawai[1,2], Yoshiyuki O. Takahashi[1], Masaki Ishiwatari[5], Seiya Nishizawa[2], Shin-ichi Takehiro[4], Kensuke Nakajima[3], Hirofumi Tomita[2], Yoshi-Yuki Hayashi[1]

1.Kobe Univ., 2.RIKEN AICS., 3.Kyusyu Univ., 4.Kyoto Univ., 5.Hokkaido Univ.

To explore the diversity of climates on exoplanets, some planetary atmospheric scientists have been conducting numerical experiments of exoplanet climates. Our research group also has been performing numerical study of climates on a planet globally covered ocean (aquaplanet) to understand the role of atmospheric and oceanic circulation on determining planetary climates. For example, Ishiwatari et al. (2007) discussed the diversity of climates and multiple equilibrium states with three-dimensional atmospheric general circulation model. But, at that time, ocean dynamics is not considered entirely, because they used greatly simplified ocean. Actually, if there is ocean on a planet, oceanic heat transport also has an important role on determining and maintaining planetary climates. In fact, the heat transport carried by the ocean is an important component of Earth’s heat budget (Trenberth and Caron 2001). Recently, Rose et al. (2009) discovered the presence of a new stable climate state in one-dimensional meridional energy balance with the oceanic heat transport effect. The recent improvements of computational performance have been able to explore aquaplanet climates with a coupled atmosphere-ocean-sea ice model. Smith et al. (2006) is pioneer work in aquaplanet experiments with coupled models. After their studies, with couple models some researchers have been investigating the dependence of some planetary parameters, such as solar constant, rotation period and rotation angle (e.g., Ferreira et al., 2011).
To explore aquaplanet climates considered both atmospheric and oceanic circulation, our research group is now developing atmospheric general circulation model, oceanic general circulation model, and thermodynamic sea ice mode, and coupling these models. The ocean model calculates the large-scale distributions of current velocity, temperature and salinity explicitly, while the effects of some sub-grid scale processes, such as small-scale eddies and convection, are parameterized. The thermodynamic sea ice model calculates the thickness and temperature of sea ice. These models are coupled with atmospheric model, DCPAM, with a coupler library (Arakawa et al., 2011). For simulations of high resolution and parameter studies to span a wide range of climatic regimes, this couple model is a parallel program, which can run in some parallel computational environments. Furthermore, in order to accelerate temporal integration of ocean model, we adopt the following temporal integration method. First, the coupled model is run over few years. Next using atmospheric forcing from the coupled run, ocean-sea ice model alone is integrated over few hundred years. This cycle is repeated until the coupled system reaches quasi-equilibrium state.
To check behavior of our coupled model, we are now conducting numerical experiments of an aquaplanet climate in which present Earth’s parameters are given. Initially, atmosphere and ocean are isothermal (280 K) at rest. The couple system is driven by annual and diurnal mean incoming solar flux. Using above temporal integration method, we can currently perform about 20-30 cycles of integration (equivalent to about 4000 years integration for the ocean). After this long time integration, we have obtained global patterns of atmospheric and oceanic circulations similar to the result of previous studies (e.g., Marshall et al., 2007). But the thickness of sea ice and thus ocean salinity continue to increase. One of the reasons is probably that meridional transport of sea ice is not considered. We are also checking heat and water budgets. Therefore, an immediate task is to obtain equilibrium state in our coupled model. In the near feature, using the coupled model, we will examine solar constant dependence of aquaplanet climates, and consider the role of

the atmospheric and oceanic circulation on the climates.

Keywords: aquaplanet , coupled atmosphere-ocean-sea ice model

