On the mechanism of vegetation feedback to the Arctic warming amplification

*Masakazu Yoshimori[1,2], Ryouta O'ishi[3,4], Ayako Abe-Ouchi[3]

1.Faculty of Environmental Earth Science, Hokkaido University, 2.Arctic Research Center, Hokkaido University, 3.Atmosphere and Ocean Research Institute, The University of Tokyo, 4.National Institute of Polar Research

It is well known that the Arctic climate is sensitive to the external radiative forcing and its response is generally larger than the rest of the world. Observations show that the Arctic is indeed warming at about twice the speed of the global average, and climate model simulations also projects that the Arctic warming amplification continues to the future. Various physical processes have been listed as important contributors to the amplification, but the feedback effect of vegetation distribution change in response to the climate change is not always taken into account. Here, we extend the study of O’ishi and Abe-Ouchi (2009) in which the vegetation change is internally predicted in a coupled climate-dynamic vegetation model. In the current study, a calibration for the model’s systematic bias against present-day observations is added. This is important as the present-day vegetation distribution impacts on how the vegetation changes under the perturbed climate, and that the vegetation responds to the temperature itself and not to the temperature anomaly. Detailed energy transport and energy balance analysis are conducted for the doubled and quadrupled CO_2 equilibrium experiments.
In the experiment of atmospheric CO_2 increase, much of the current tundra area is replaced by the boreal forest, and the temperate forest expands as the boreal forest migrates to the north. Arctic land surface warms the most in spring due to albedo increase through vegetation-type changes and earlier snow melting. The effect of vegetation feedback is, however, not confined to the land warming. The large warming occurs in the Arctic Ocean in winter. Part of the excessive energy over land is cancelled by the increased evaporative cooling and part of it is transported to the Arctic Ocean in spring. This transport is accomplished by the mean meridional circulation (polar cell) in the atmosphere. This increased heat transport induces sea ice albedo feedback in summer and large heat release from the ocean in winter, causing the Arctic warming amplification.

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