The role of interactions between ocean circulation and ocean carbon cycle —A case study of Nagoya simple model

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Thermohaline circulation and ocean carbon cycle interact each other. On one hand, Manabe and Stouffer (2003) have shown that abrupt changes of the atmospheric CO2 concentration influence the strength and pattern of thermohaline circulation. On the other hand, biological-pump controls the atmospheric CO2 concentration. In addition, efficiency of the pump may be affected by the strength and flow pattern of the thermohaline circulation.

To treat this interaction mechanism in a consistent manner, we construct a simple coupled model, which includes two-dimensional ocean circulation and ocean carbon cycle. We use the two-dimensional ocean model of Stocker and Wright (1991), and a simplified biological-pump of Yamanaka and Tajika (1996). We also include the CO2 exchange between the ocean and atmosphere. We model the CO2-dependent sea-surface temperature, which mimic the radiative forcing of the atmospheric CO2.

When the CO2 dependence is weak, steady-state solutions are obtained. When the CO2 dependence is strong (e.g. doubling of the atmospheric CO2 concentration increases the sea surface temperature by 5 degC), the flow is oscillating; stagnant deep-ocean forms most of the time, and abrupt mixing occurs for a short time. The time scale of the oscillation is about a half of that of the vertical thermal diffusion. The atmospheric CO2 concentration is high (e.g. 400 ppm) during the stagnant regime, whereas the CO2 concentration is low (e.g. 300 ppm) during the circulation regime.

We have shown that the interaction of the thermohaline circulation and biological-pump controls the atmospheric CO2 concentration. The interaction has of importance for long time-scale climate changes.