Long-term Global Warming Projections of GHG Stabilization Scenarios – What is the Dangerous Anthropogenic Interference with Climate System? –

Background

The ultimate goal of UNFCCC Article 2 is to achieve stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent "Dangerous Anthropogenic Interference" (DAI) with climate system. Such a level should be achieved to allow ecosystem to adapt naturally to climate change and to satisfy other conditions. Recently, EU countries have proposed to stabilize global temperature increase within 2˚C for the Post Kyoto Protocol. However, there is not sufficient information of feasible stabilization levels of GHG concentrations in the atmosphere described in Article 2.

Objectives

To have good scientific information regarding the ultimate goal of UNFCCC, we conduct long-term global warming projections of GHG stabilization scenarios. We analyze large amounts of output data and have information about climate changes and environmental impacts under the stabilization scenarios to make clear the question, "What is DAI?"

Principal Results

1. GHG stabilization scenarios and climate model

We applied two stabilization scenarios based on IPCC A1B and B1 scenarios for projections from year 1870 to 2450. In both scenarios, the concentrations of GHGs, such as CO_2, CH_4, N_2O etc., beyond year 2100 were held fixed to the level of year 2100 (Fig.1). In addition, CRIEPI proposed an idealized overshoot scenario where the concentrations of GHGs reduced from the A1B stabilized level to B1 stabilized level between year 2150 and 2250 followed by 200 years integration with that constant B1 level of concentrations to investigate how the climate system would respond to such a large change in the concentrations If all the countries in the world could achieve zero emissions beyond year 2150, the concentrations of CO_2 would decrease due to absorption of CO_2 by the terrestrial ecosystem and the ocean. Through the international research consortium with the National Center for Atmospheric Research (NCAR) and others, we conducted long-term global warming projection for the scenarios using the world fastest class supercomputer, the Earth Simulator with the atmosphere ocean coupled model (CCSM3) having resolutions of about 150 km in the atmosphere and 100 km in the ocean.

2. Climate changes and impacts

(1) In A1B scenario, the permafrost deceases rapidly in the regions with high latitudes (Fig.2). Projected thawing of the permafrost both in Eastern Siberia and Alaska compares well with observation in the 20th century.

(2) In general, "Thermohaline Circulation" (THC) in the oceans transports solar energy from the tropical regions to the regions with high latitudes (Fig.3). A part of THC near Greenland is called the Atlantic "Meridional Overturning Circulation" (MOC). Although the MOC decreases both in A1B and B1 scenarios, the MOC keeps almost constant after stabilization of GHGs and recovers under the overshoot scenario (Fig.4). Temperatures over the North Atlantic Ocean and Europe are projected to warm despite such decrease of the MOC. It is likely that DAI such as occurrence of the ice age will not happen.

(3) The sea ice in the Arctic shrinks rapidly under two scenarios. In the latter part of 21st century for A1B scenario, the sea ice is projected to disappear in September (Fig.5) and it suggests serious impact on the arctic ecosystem. Sea level rise due to thermal expansion of seawater continues for almost a millennium even after stabilization of GHGs. Under the overshoot scenario, climate changes almost recover to B1 level except for a significant hysteresis effect shown in the sea level change (Fig.6).

3. Implication for the ultimate goal of UNFCCC

The projected results suggest that the GHG stabilization level at year 2100 under A1B scenario will not meet the goal of UNFCCC due to the possibility of DAI such as disappearance of the sea ice in the Arctic. The stabilization level under the B1 is one of the candidate target levels. However, the feedback of ecosystem to climate changes has not been scientifically clarified yet.

Future Developments

We will conduct projections to make clear the feedback between ecosystem and climate changes using a new Earth System Model including carbon cycle model component through international collaboration with NCAR in USA.

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References

K. Maruyama et al., 2005, "FY2005 research report on the development of high-resolution atmosphere-ocean coupled model", V990601 (in Japanese)

K. Maruyama et al., 2004, "FY2004 research report on the development of high-resolution atmosphere-ocean coupled model", V990401 (in Japanese)

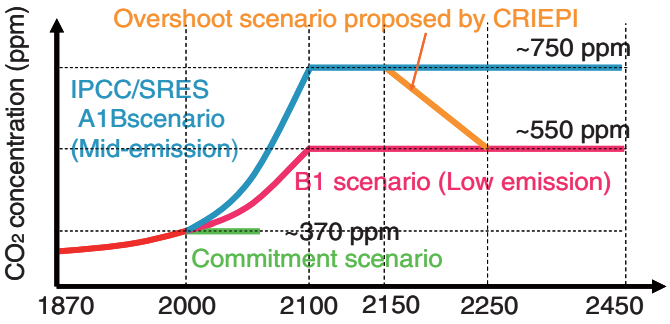

Fig.1 Emission scenarios

We conducted three member-ensemble projections with different initial conditions in year 1870 for each scenario.

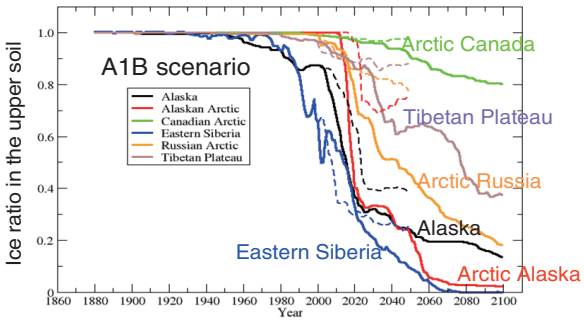

Fig.2 Thawing of permafrost in regions with high latitudes in A1B scenario

The ice in the upper soil both in Eastern Siberia and Alaska is projected to start to thaw before year 2000.

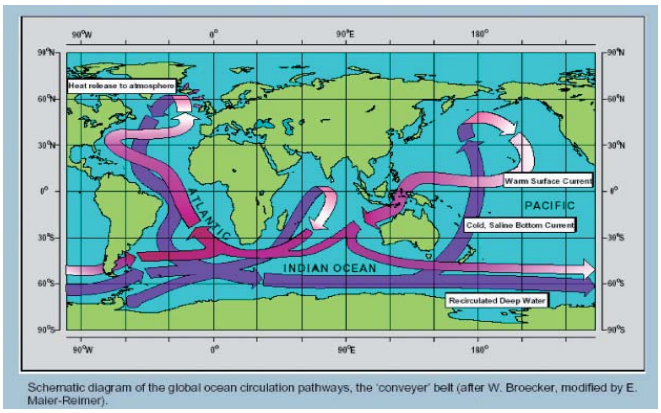

Fig.3 Schematic graph of Thermohaline Circulation (THC) and MOC

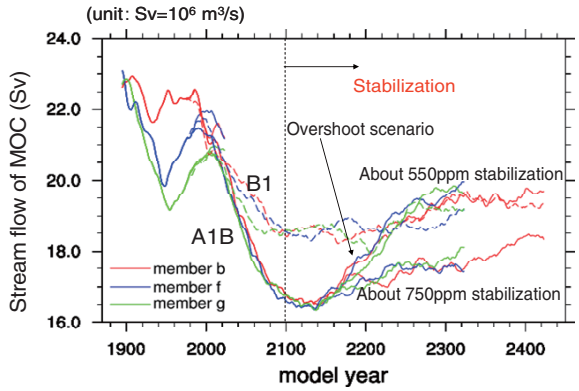

Fig.4 Changes of the MOC

After stabilization of GHGs, the MOC keeps almost constant and recovers under the overshoot scenario.

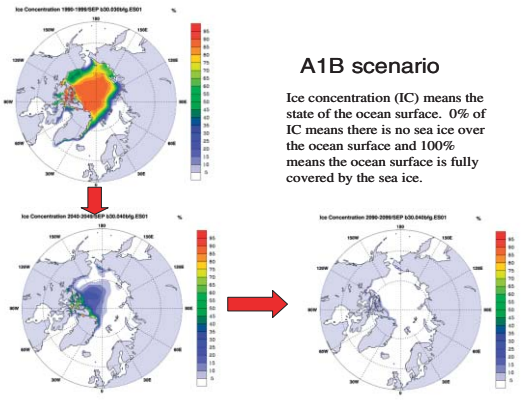

Fig.5 Decrease of the sea ice in the Arctic

In the latter part of 21st century, the sea ice disappears in September.

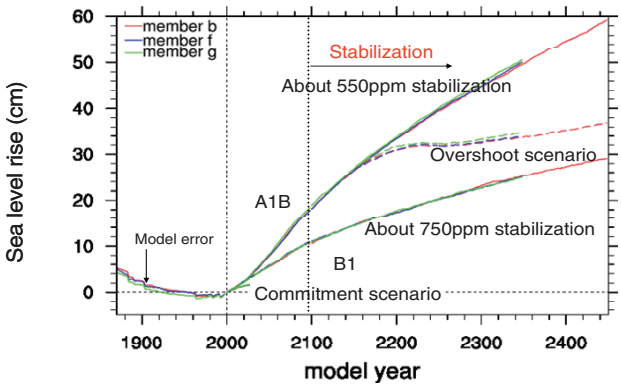

Fig.6 Sea level rise due to thermal expansion of seawater

Sea level rise continues for almost a millennium even after stabilization of GHGs.