Multi-century Global Warming Projections under CO_2 Stabilization and Overshoot Scenarios
– Estimation of Stabilization Effects of Greenhouse Gases –

Background

The Kyoto Protocol's entry into force in February 2005 will trigger further discussion and negotiation on the reduction of green house gases (GHGs) putting, for example, participation of developing countries in perspective. However, the effects of GHGs stabilization in atmosphere have almost never been estimated on the scientific basis.

Objectives

The ultimate goal of the United Nations Framework Convention of Climate Change (UNFCCC) is to stabilize atmospheric concentration of GHGs to prevent dangerous anthropogenic interference with climate system. To find a pathway to this goal, future climate changes are projected using a coupled climate system model based on several kinds of GHGs stabilization scenarios, thereby, the effects of GHGs stabilization are investigated.

Principal Results

1. Model and GHGs concentration scenarios

The National Center for Atmospheric Research Community Climate System Model (CCSM3) was used for the global warming projection experiments. The CCSM3 is the state-of-the-art coupled climate model consisting of atmosphere, land, sea ice and ocean components. Its spatial resolution is about 150 km in the atmosphere and 100 km in the ocean. The GHGs stabilization experiments were conducted using two stabilization scenarios based on IPCC SRES (Special Report on Emission Scenarios) A1B and B1 scenarios. In both cases, GHGs concentrations beyond year 2100 were held fixed to the level of year 2100. Hereafter, the stabilization scenarios based on SRES A1B and B1 scenarios are respectively called "A1B+750 ppm" and "B1+550 ppm" scenarios. In addition to these stabilization scenarios, an overshoot scenario is proposed, where the GHGs concentration once overshoots to higher SRES A1B level, then, decreases to lower B1 level. The dependency of climate system on GHG concentration pathways can be investigated through this overshoot experiment. As described in the IPCC synthesis report in 2001, it takes at least several hundreds years for the climate system to be stabilized. Therefore, we have conducted very long term experiments up till year 2450. All the numerical experiments were carried out using the Earth Simulator, one of the fastest supercomputers in the world.

2. Results and implications to world energy policy

(1) A three-member ensemble experiment was conducted on each GHGs concentration scenario. Thus, the representation of present climate was much improved (see Fig.1).

(2) The future climate changes due to global warming beyond 21st century were predicted using the state-of-the-art climate system model (for example, see Figs.2 and 3). The stabilization of GHGs concentration works as a brake to weakening of meridional overturning circulation, thus, catastrophes such as a severe cooling event due to the shutdown of deep ocean circulation are likely avoidable. However, the sea level keeps increasing due to thermal expansion for very long time throughout the projection experiments up till year 2450.

(3) GHGs stabilization level under the "A1B+750 ppm" stabilization scenario should not meet the goal of UNFCCC. This is because it may result in dangerous anthropogenic interference such as disappearance of sea ice (see Fig.3). However, an overshoot pathway is expected to be useful for risk management to cope with delay in the emission reduction of carbon dioxide.

(4) The GHGs stabilization level under the "B1+550 ppm" scenario is one of the candidate target levels. However, the response of ecosystem to climate changes has not been scientifically clarified yet. Therefore, it is necessary to further study such uncertainties to establish scientific criteria for appropriate stabilization levels.

Future Developments

To develop higher resolution atmosphere-ocean coupled climate model to improve reliability of climate change projections on regional scale.

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Reference

K. Maruyama et al., 2005, "FY2004 research report on the development of high-resolution atmosphere-ocean coupled model", V990501 (in Japanese)
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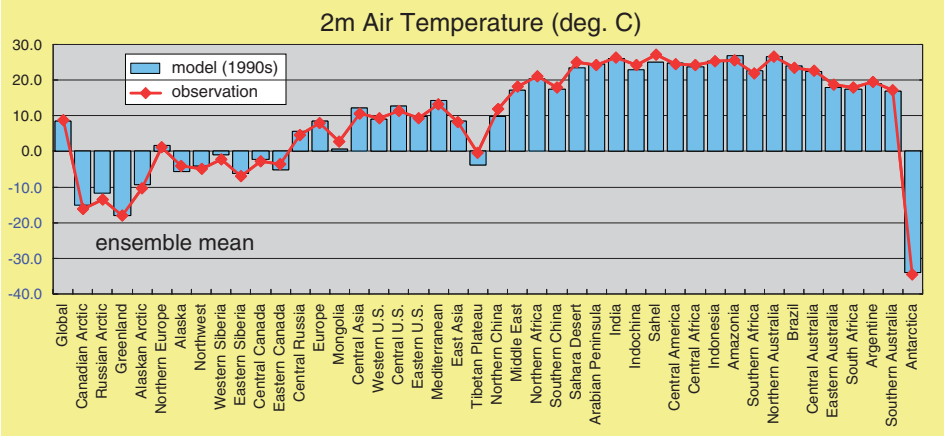

Fig.1 Comparison of surface air temperature simulated by CCSM3 model with observations The model results employ ensemble means for 1990-1999 period.

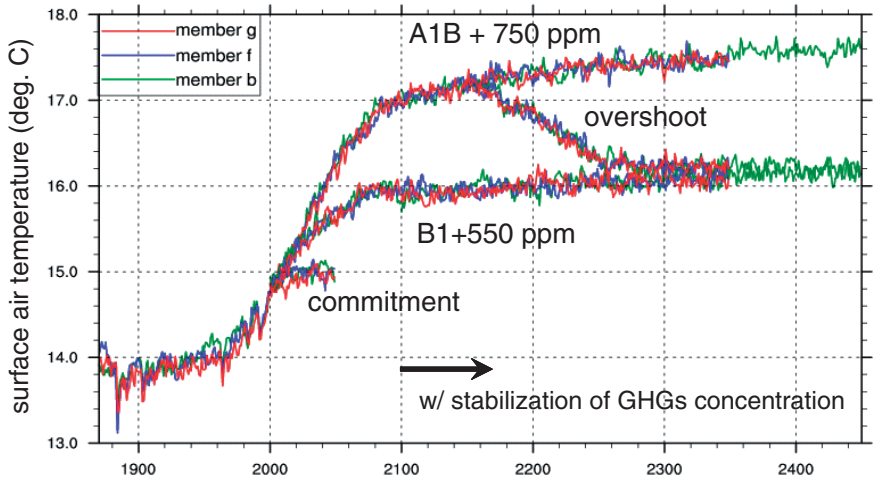

Fig.2 Projected results of global mean annual surface temperature for all the scenarios

Temperature and precipitation increases during 21st century are respectively about 2.5 degree C and 6% under the A1B scenario: about 1.5 degree C and 3.9% under the B1 scenario. Under the "A1B+750 ppm" scenario, the surface air temperaturekeeps increasing even after the stabilization of GHG concentration.

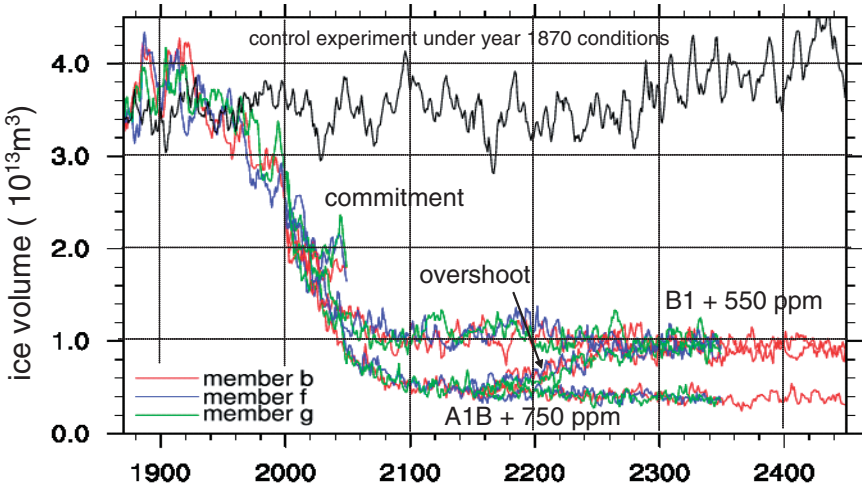

Fig.3 Decrease in sea ice volume in Northern hemisphere

Throughout 21st century, the sea ice volume decreases by about 80% and 65% under A1B and B1 scenarios, respectively. Under the "A1B+750 ppm" scenario, the ice volume keeps decreasing and it may disappear at all.