Development of Atmosphere-Ocean Coupled Model for Global Warming Projection

Background

For the stabilization of greenhouse gases (GHGs) concentration at a level that would prevent dangerous interference with climate system, a discussion on the emission reduction beyond Kyoto Protocol will begin in 2005 at the Conference of Parties. To strengthen scientific contributions to this problem, the ministry of education, culture, sports, science and technology has launched the project for sustainable coexistence of human, nature and the earth. Within this framework, CRIEPI has been developing a moderately high-resolution coupled climate model suitable for the world fastest supercomputer, the Earth Simulator (ES), jointly with National Center for Atmospheric Research (NCAR).

Objectives

To develop a moderately high-resolution atmosphere-ocean coupled climate model for global warming projections to contribute to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).

Principal Results

1. Development of atmosphere-ocean coupled model

The CCSM-3 coupled model consists of atmosphere, land, sea ice and ocean components. The spatial resolution of atmosphere and land components is T42 (~300km) or T85 (~150km), and the ocean and sea ice components have nominal one degree resolution. CRIEPI and NCAR jointly have ported this software to the ES and carried out considerable software optimizations, e.g., employment of new algorithms/methods for vectorization and fast communication, to bring out the outstanding hardware performance of the ES. As a result, a 100-year coupled model simulation can be completed within a week using the ES. A control experiment under the present-day climate conditions was conducted, thus, stability and performance of the model was confirmed (Fig. 1).

2. Global warming projection experiments under simple CO2 concentration scenarios

A 200-year global warming projection experiment was conducted under a simple CO_2 increase scenario with a constant increase rate of 1%/year. The CO_2 stabilization experiments were also carried out where the CO_2 concentration was held fixed after the CO_2 concentration had reached the double and quadruple of its initial value (Fig. 2). The global annual mean surface temperature change at the doubled CO_2 concentration is 1.39 and 1.43 degree respectively using T42 and T85 atmosphere components (Fig. 3). The model experiments imply that the sea ice may disappear in Arctic region in a part of summer season due to the global warming about 100 years after the CO_2 increase begins (Fig. 4).

Future Developments

To more directly contribute to the IPCC AR4, long-term ensemble projection experiments will be carried out based on more realistic GHGs emission scenarios recommended by IPCC Working Group I.

Main Researchers:

Yoshikatsu Yoshida, Ph.D, Research Scientist, Atmospheric Environment Sector, Environmental Science Research Laboratory
Hideyuki Kitabata, Ph.D, Visiting Scientist, Atmospheric Environment Sector, Environmental Science Research Laboratory
Koki Maruyama, Ph.D, Senior Scientist, Geospheric and Hydrospheric Environment Sector, Environmental Science Research Laboratory

Reference

Maruyama et al.: FY2003 research report on the development of high-resolution atmosphere-ocean coupled model. V990401 (June 2004), in Japanese.

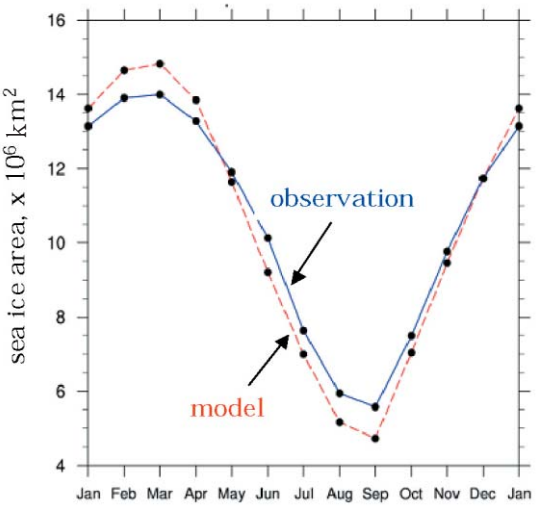

Fig.1 Comparison of sea ice area.

Sea ice area in northern hemisphere in present day control experiment. Model result is in good agreement with observation.

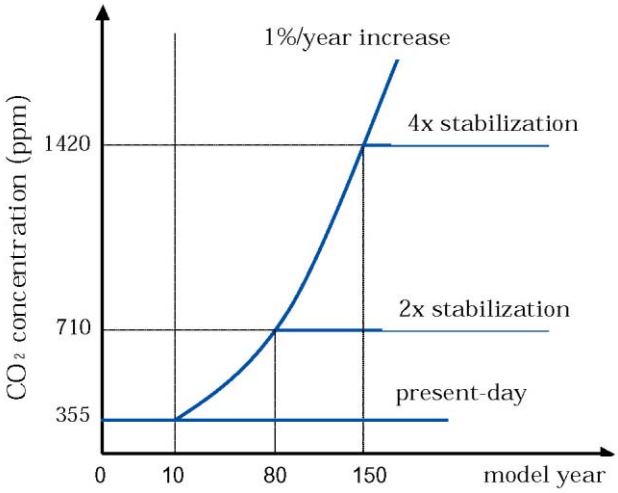

Fig.2 A simple CO_2 concentration scenario.

Experiments were carried out under the present day condition, 1% per year increase case, double and quadruple stabilization cases.

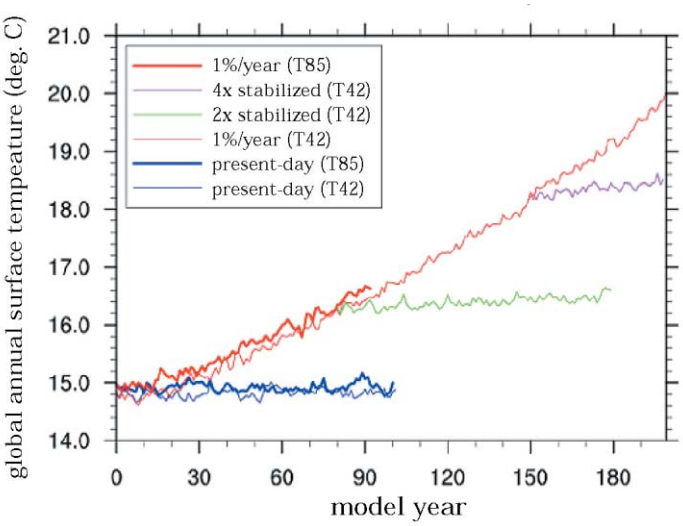

Fig.3 Predicted global surface temperature.

Global warming projection experiments were carried out using both T42 and T85 atmosphere components. The global annual mean surface temperature rise at the doubled CO_2 is 1.39 and 1.43 degree respectively using T42 and T85 models.The stabilization experiments will be continued toinvestigate the relationship between deep seacirculation and CO_2 stabilization levels.

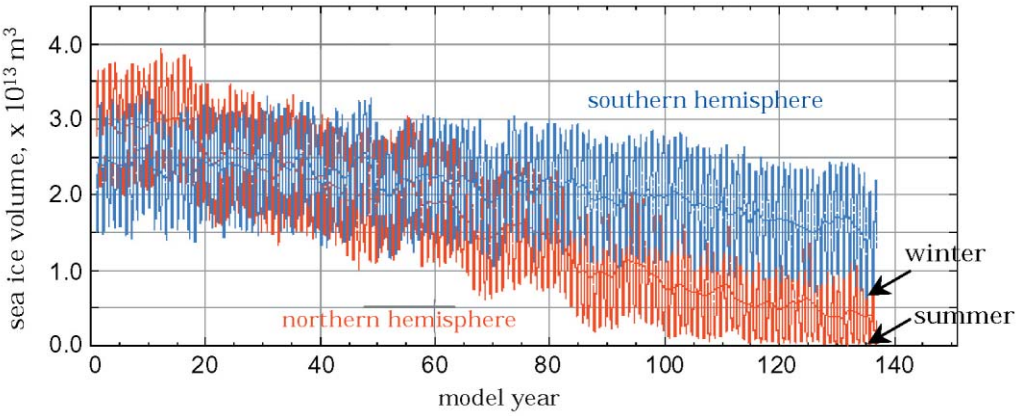

Fig.4 Sea ice volume in northern and southern hemispheres.

Results from 1% per year increase experiment using T42 model. Significant reduction of sea ice volume is predicted in the northern hemisphere where most of sea ice may disappear in a part of summer season about 100-year after CO_2 concentration rise begins.