IR-3 Study on Integration of Climate Model and Impact/Mitigation Measure Evaluation Model for Synthetic Analysis of Global Warming (Abstract of the Final Report)

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1. Introduction

To clarify responses of climate against various scenarios of emission of greenhouse gases and aerosols controlled by reduction of their anthropogenic emissions, with use of numerical climate models, may contribute to the IPCC (Intergovernmental Panel on Climate Change). On the other hand, climate models so far have coarse horizontal resolutions of a few hundreds km owing to limited computer resources and poor understanding of the climate system, and have not been able to predict surface air temperature, precipitation, etc., on regional scales, which is required to evaluate impacts of climate change on nature and society. It is required to develop regional climate models or other schemes to provide regional scale climate scenarios for the impact evaluations in a quantitative manner.

2. Research Objective

The ultimate objectives of the project are to develop a comprehensive model by integrating a socio-economic model of emission and impact evaluation models into a three-dimensional global climate model, and to obtain basic information on impact of emissions of greenhouse gases and aerosols on agriculture production, water resources, etc., through regional climate changes. Concretely, to integrate the socio-economic model into the climate model, both being developed separately from this research project, we develop the interface between emission scenarios and climate model, and the interface between climate models and impact evaluation models. We thus develop a comprehensive model treating emission, climate, and impact. We next apply the model to the past 100 years of the 20th century to simulate the past climate and its impacts for validating the model, and to clarify the mechanism of the variations of the past climate.

3. Methods and Results

As a global climate model, we use the CCSR/NIES coupled atmosphere-ocean general circulation model (AOGCM), which is developed through joint research of NIES (National Institute for Environmental Studies) with CCSR (Center for Climate System Research, University of Tokyo) and is developed separately from this research project. A regional climate model is classified as an interface between a global climate model and an impact evaluation model.

The project consists of the following three sub-themes. Some of the details of the results are described in the papers[1-9].

1) Study on the interface between emission scenarios and a climate model

To evaluate climate change associated with anthropogenic greenhouse gases and aerosols with use of the three-dimensional AOGCM global climate model, we should know change in their atmospheric concentrations as a result of their emissions to the atmosphere. The objective of this research is to develop an interface between the emission scenarios and the climate model, that is, to make an interface to convert the country-base emission data, especially for the aerosols, into grid-pointed ones to be adapted for the grid spacing in the climate model. Because the emission data are, in general, provided for administrative districts such as countries and cities, and because the future emission scenarios are also provided for nearly the same categories as the emission data, we at first made an interface to make a country-base emission data. For sulfur dioxide (SO_2), which is a main source of sulfate aerosols in the atmosphere, we used country-base emission data of SO_2 constructed previously because they provide information about their historical emission, and also because the emission scenario has a category of SO_2. On the other hand, for the black carbon (BC) which is one of the major aerosols in the troposphere, we made a country-base emission data by using historical data of energy use, amount of agricultural production, fuel wood consumption, etc., because there is little information about the historical BC emission.

Next, we developed a scheme to make grid spacing of 0.5° in latitude and 0.5° in longitude with a weight of population distribution. The scheme was made to support historical changes in population distribution. In order to input the emission data into a climate model, we also developed a scheme of the grid conversion programming from the resolution of 0.5•in latitude and 0.5•in longitude to the resolution adopted in the climate model. The scheme is designed to conserve total global emission when the grid resolution is changed. We applied the scheme to the anthropogenic SO_2 and BC emission data in the past 150 years, and obtained reasonable results of global distribution of the emission.

Finally, these two schemes are applied to the IPCC SRES scenarios for the 21st century. When making future country-base emissions for the anthropogenic SO_2 and BC, we related each major emission source to a scenario category that seems to be most appropriate. Then, grid-pointed emission data was made by applying the developed scheme here with the present population distribution. We also obtained reasonable results of global distribution of the future emission.

2) Study on the interface between a climate model and an impact evaluation model

The objective of the research is to develop an interface between climate models and impact assessment models for an integrated assessment of climate change problem, and to estimate future climate change impacts in the Asian region more reliably than the existing studies. First of all, as a preparation for the development of interface, obstacles that hinder the integration of climate models and impact assessment models are identified, and solutions to overcome those obstacles are investigated. It is found that there are several gaps between what climate models can provide and what impact assessment models demand in respect of spatial and temporal resolutions, type of climate variables, and premised emission scenarios.

After recognizing those gaps we refined the existing global climate model (GCM) and regional climate model (RCM), and provided future climate projection to the impact assessment study. First, GCM, which has a role of supplying boundary conditions to RCM, was revised with the objective of better reproduction of observed historical climate data in the Asia region. Since stratiform precipitation in low-latitude region estimated by the existing model was lower than the observed data, model parameters in the physical process modules were tuned to increase precipitation from anvil clouds. As a further revision, a new land surface module (MATSIRO: Minimal Advanced Treatments of Surface Interaction and Runoff) was introduced to simulate surface hydrological process more realistically. As a result of the revisions of physical process modules, the ability of the model to reproduce spatial distribution of precipitation has improved. Next, the revisions of physical process modules were also applied to RCM in order to ensure consistency of model features between GCM and RCM. Finally, climate change experiments were executed and the revised RCM successfully provided future climate projection reproducing meso-scale phenomena like orographic rain which could not be reproduced by low-spatially-resolved GCM.

Further, as an approach to climate impact assessment research, a methodology to develop climate scenarios (input data for impact assessment model), which makes the best use of currently available climate model outputs, was investigated. Since the ability of currently available climate models (both RCM and GCM) to reproduce real climate with accuracy is not sufficient for directly providing input data to impact assessment models, new methodologies to remove biases of climate model outputs as well as to add spatial detail were needed for creating climate scenarios. Change of potential productivity of wheat and rice due to the climate change from 1980s to 2040s was estimated on the basis of climate projections of GCM and RCM. The maximum difference of wheat/rice productivity change (nation-mean of the Asian countries covered by the RCM experiment in this study) due to the choice of GCM or RCM output is about 25% in the specific case of climate model simulations executed in this study.

3) Study on synthetic evaluation experiments using an integrated model of global warming

We develop an integrated model of global warming to synthesize climate scenarios due to emission scenarios and impact scenarios due to the climate scenarios, and, in order to evaluate these scenarios with reduced uncertainty, we validate the model by applying the model to the situation in the past 100 years of the 20th century.

At first, we made numerical experiments using previous version of our three-dimensional AOGCM global climate model, which was developed separately from this research project, by giving emission of greenhouse gases and aerosols in the past 100 years with a simple and tentative interface, and compared the results with climate observations. The globally averaged surface air temperature calculated in the model well reproduced the slow cooling in the mid-century and the rapid warming in the recent decades. On the other hand, it did not reproduce the warming in the first half of the century. This may be because the given emission of carbon aerosols in the first half of the century is more than the real emission and the indirect effect of the excess aerosols may bring the associated cooling.

Next, we collected various external forcing dataset which is needed when we perform climate change simulation in the 20th century. Especially, we surveyed historical anthropogenic changes in the tropospheric and stratospheric ozone and natural variability such as solar flux variability and stratospheric aerosol change due to large volcanic eruptions, which have comparatively large influences on the climate. We also introduced them into a climate model as external boundary condition data.

Finally, we perform climate change simulation in the 20th century using newer version of our three-dimensional global climate model with the natural and anthropogenic dataset collected here. The global and annual mean surface air temperature change in the experiment with full forcing shows very good agreement with the observation. In the experiment with natural forcing only, the simulated temperature change shows good agreement with the observation in the early part of the 20th century, while it does not show warming in the latter half of the 20th century because cooling by increased aerosols in response to large volcanic eruptions is effective under the condition of no increase in concentrations of greenhouse gases. In the experiment with anthropogenic forcing only, there is no warming before 1950s, but after that, the simulated temperature shows warming due to an increase in the concentrations of greenhouse gases.

4. Concluding Remarks

IPCC consists of the following three Working Groups (WGs), WG I (The Scientific Basis), WG II (Impacts, Adaptation, and Vulnerability), and WG III (Mitigation), to provide synthetic scientific assessment for policymakers. This research project tries to integrate researches associated with WG II and WG III into climate models associated deeply with WG I. In the IPCC activity, cooperation among the three WGs carries out synthetic scenario analyses. WG III does research on change in storylines of the world development tendency and social elements to obtain associated change in emissions of greenhouse gases and aerosols (emission scenario), WG I does research on change in atmospheric concentration of greenhouse gases and aerosols due to the emission scenarios to obtain associated change in climate (climate scenario), and WG II does research on various natural and social impacts (impact scenario). The main purposes of IPCC include evaluation of effectiveness of policy and cost analyses on the basis of such comprehensive and consistent scenarios following the various storylines. A climate model thus is classified not only as a tool of detecting climate changes and clarifying their mechanism within WG I but also as a tool of playing a role in the scenario analyses attained by the cooperation among WG I, WG II, and WG III.

The present research subject was carried out in view of the concept on climate models stated above. It reproduced climate changes in the past 100 years using the integrated model of global warming to validate the model. We envisaged applying the model to future projections of climate change. The project required computer resources, and utilized the computer system of NIES including the supercomputer (NEC SX-4 and SX-6).

Part of the project aims at contributing to IPCC, especially IPCC AR4 (Fourth Assessment Report) scheduled in 2007, by applying the developed model. The database of emissions of several kinds of aerosols developed by the project was requested by a climate model research group at the Hadley Centre for Climate Prediction and Research of the Meteorological

Office of the United Kingdom, which was and is active in contributing to IPCC, and was provided to the group. It was also provided to other climate model research groups in Germany and USA. The works by the climate model groups including us will contribute IPCC AR4.

The project could not be realized without Dr. Tsuneyuki Morita who passed away in September 2003.

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