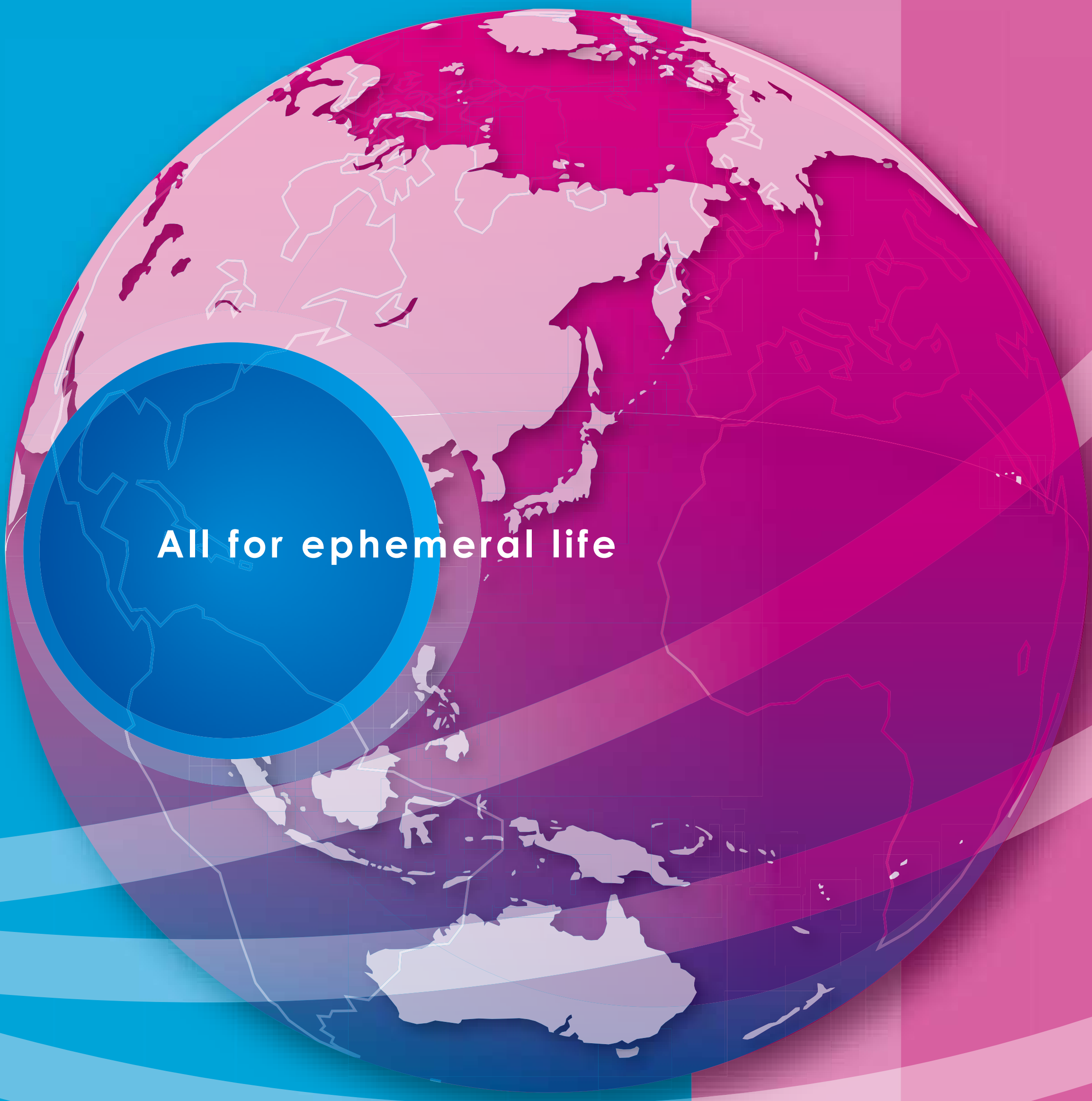
KAKUSHIN

Innovative Program of Climate Change Projection for the 21st Century



MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

KAKUSHIN

General Description

The **third phase** (FY2006 - 2010) of Japan's **Science and Technology Basic Plan** began in April 2006, with priorities focusing on the same four fields as the second phase. One of these priority fields is research on the **environment**, within which **climate change research** is one of the five focus areas.

As part of this national strategy, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has launched a **5-year (FY2007 - 2011)** initiative called the **Innovative Program of Climate Change Projection for the 21st Century (*KAKUSHIN Program*)**, using the Earth Simulator (ES) to address emerging research challenges, such as those derived from the outcomes of the **MEXT's *Kyosei Project* (FY2002 - 2006)**, that has made substantial contributions to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). The ***KAKUSHIN Program*** is expected to further contribute to the Fifth Assessment Report (AR5).

Considering the strong worldwide concerns regarding global warming, and particularly, its potential impact on natural disasters caused by increasingly severe extreme weather events, the KAKUSHIN Program is targeting three major themes:

- **(A) Advancing climate modeling and projection** for better simulation of physical and biogeochemical processes by sufficient reflection of feedbacks;
- **(B) Quantification and reduction of uncertainty** for more reliable projections of climate change using model comparisons and other methodologies;
- **(C) Application of regional projections to natural disasters** for better assessments of natural disasters caused by extreme events using sufficiently high-resolution regional projection.

Three teams participating in the KAKUSHIN Program are covering these three themes through the following respective foci. Each abridged study title is followed by the main research organization involved; see the following pages for study details.

1. **Long-Term Global Change Projection**: Frontier Research Center for Global Change (FRCGC/JAMSTEC);
2. **Near-Term Climate Prediction**: Center for Climate System Research (CCSR), the University of Tokyo;
3. **Extreme Event Projection**: Meteorological Research Institute (MRI).

In addition, two other teams are conducting process studies for theme (A):

Logo

The logo design features two planets: the current Earth colored in blue and the future Earth colored in red, with three rising curves representing the temperature tendencies suggested by several emission scenarios and symbolizing a major message of the IPCC.

We have accentuated the "I" in KAKUSHIN to emphasize "Innovation". Our overarching hope is that the achievements of this program will contribute to society.

Research Organization

Program Coordinators

Taroh Matsuno
Special Advisor
MEXT
Principal Scientist
FRCGC/JAMSTEC

Shuzo Nishioka
Special Advisor
MEXT

Secretariat

Director: Hiroki Kondo
Principal Scientist
FRCGC/JAMSTEC

Research Teams

Long-Term Global Change Projection

Long-term global environmental projection using an integrated earth system model

Representative: Tatsushi Tokioka
Director-General
FRCGC/JAMSTEC

- Long-term global environmental projection using an integrated earth system model
- Reduction in cloud uncertainty using a global cloud-resolving model
- Development of a global vegetation model

…

- Uncertainty estimation for long-term climate change projection using a hierarchy of models

…

- Evaluation of how natural disasters associated with climate change will affect the stability of major cereal crop production
- Long-term global assessment of coastal hazard risks in relation to sea-level rise and global warming

Near-Term Climate Prediction

Near-term climate prediction using a high-resolution coupled ocean-atmosphere general circulation model

Representative: Masahide Kimoto
Professor
Center for Climate System Research, the University of Tokyo

- Near-term climate prediction using a high-resolution coupled ocean-atmosphere general circulation model
- Improvement of future climate change projection by developing a high-performance ocean model

…

- Development of a technique to quantify the uncertainty in near-term climate prediction using ensemble data assimilation

…

- Estimation of changes in the risk of water-related disasters based on near-term climate prediction with uncertainty considerations

Extreme Event Projection

Projection of the change in future weather extremes using super-high-resolution atmospheric models

Representative: Akio Kitoh
Director
Climate Research Department, Meteorological Research Institute

- Projection of the change in future weather extremes using super-high-resolution atmospheric models

…

- Quantification and reduction of the uncertainty in climate change projection by super-high-resolution atmospheric models

…

- Integrated assessment of climate change impacts on watersheds in a disaster environment
- Assessment of the impact of climate change on flood disaster risk and its reduction measures over the globe and specific vulnerable areas

Cloud Modeling

Representative: Kazuhisa Tsuboki
Professor
Hydrospheric Atmospheric Research Center,
Nagoya University

- Sophistication of the cloud-resolving model and its coupling with global models

Subgrid-Scale Parameterization

Representative: Toshiyuki Hibiya
Professor
Department of Earth and Planetary Science,
Graduate School of Science, the University of Tokyo

- High-precision parameterization of marine microphysics using large eddy simulation

Shaping the globe with our descendants far into the future

Long-term global environmental projection using an integrated earth system model

The continuing anthropogenic emission of CO_2 will worsen global warming. Recent studies have warned that global warming and sea-level increases will continue for more than a century, even if the CO_2 concentration can be stabilized at a constant level during this century. Furthermore, achieving the stabilization of CO_2 may not be possible if we focus only on anthropogenic emissions because global warming affects various processes of the land (forests and soils) and ocean (nutrient and plankton) ecosystems and the absorption of atmospheric CO_2 by the sea surface. We will project global warming using an integrated earth system model and project long-term changes in the global environment under various CO_2 stabilization scenarios. We will also estimate the allowable CO_2 discharges under CO_2 stabilization scenarios based on the results of the global warming projection. Uncertainty estimation of the global warming projection and reduction of the uncertainty will be achieved via additional numerical experiments that incorporate statistical approaches. In addition, natural disaster impact assessment will be conducted based on the global warming projection.

Projection of long-term global change

The improvement of the integrated earth system model that was developed during the MEXT project Kyosei 2 is planned to allow for global warming projections up to the year 2300. The model consists of biogeochemistry components with coupled atmosphere-ocean-land carbon-cycle feedback and atmospheric chemistry -aerosol interaction at resolutions of 200 km for the atmosphere and 100 km for the ocean. Our focus is on the introduction of a dynamic vegetation model, the advancement of the carbon cycle model and aerosol transport model, and the improvement of physical processes such as an ice sheet. Using global warming experimental data, we will estimate the temperature rise, sea level rise, and allowable CO_2 concentration under various CO_2 stabilization scenarios.

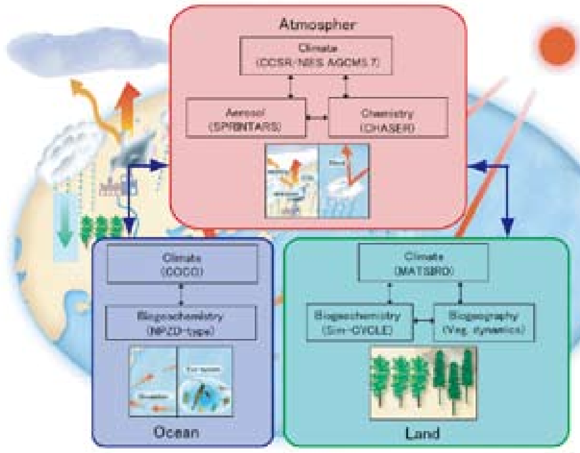


Fig. 1 Schematic representation of the integrated earth system model.

Reduction in cloud uncertainty using a global cloud-resolving model

To reduce the large uncertainty regarding cloud behavior in current climate models, we use a newly developed, innovative, high-resolution global atmospheric model with global cloud-resolving capabilities. With a horizontal mesh size of a few kilometers and direct resolving of deep clouds in the tropics, the model simultaneously calculates multi-scale disturbances from cloud- to planetary-scale circulations. This global cloud-resolving model is expected to provide a greater understanding of physical cloud-feedback mechanisms and contribute to more reliable projections of monsoon circulations and tropical cyclones.

Development of a global vegetation model

Climate conditions strongly affect the terrestrial ecosystem. The terrestrial ecosystem also affects the climate, particularly through changes in evapotranspiration, carbon cycling, and albedo. Thus, for the reliable projection of global climate changes, integrated terrestrial ecosystem models that include biogeochemical processes and vegetation dynamics are required. To fulfill this need, this research is developing a global vegetation model that simulates changes in ecosystem functions (e.g., carbon and water fluxes), as well as ecosystem structures (e.g., distribution and composition). This model links several modules that have different computational time steps. Some of the modules are functions of environmental factors, allowing the model to simulate ecosystem responses to environmental changes.

Uncertainty estimation for long-term climate change projection using a hierarchy of models

Global warming projection always involves uncertainties. The Fourth Assessment Report of the IPCC presents uncertainties as error bars for the warming projected by each of the future CO_2 concentration scenarios. However, various details such as the probability of future warming achieving the upper limit are not specified. For such a projection to be realized, numerous experiments with slightly different settings are required, necessitating high levels of computational power and statistical techniques to sort out the experimental results. An aim of the KAKUSHIN Program is to establish a probabilistic global warming projection by using both a general circulation model (GCM) and an earth system model with intermediate complexity (EMIC), combined with advanced statistical techniques.

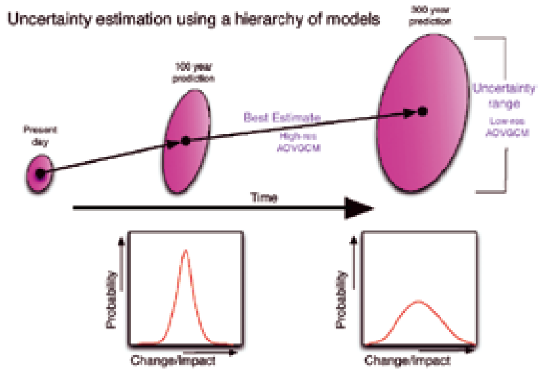


Fig. 2 Concept of the filtering techniques that can be used to sort out the experimental results.

Evaluation of how natural disasters associated with climate change will affect the stability of major cereal crop production

Major production areas for cereals, especially maize and soybean, are located in China, USA, and Brazil. There is a risk that natural disasters associated with climate change could occur simultaneously in these areas, resulting in massive damage to world cereal production. This research aims to evaluate the probability of such simultaneous disasters and the resulting instability of the world cereal supply.

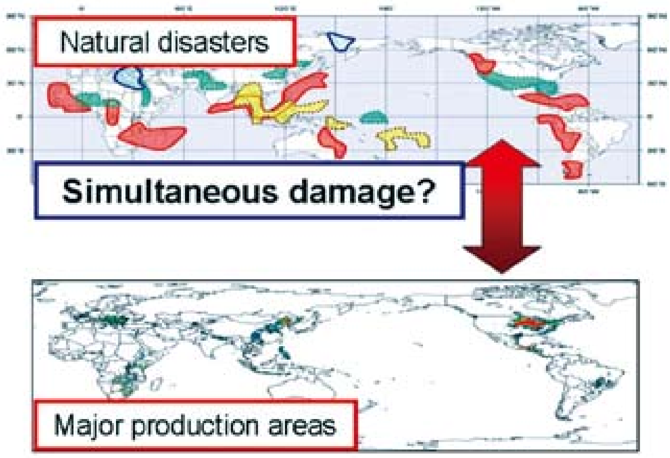


Fig. 3 Upper: Spatial distribution of weather anomaly associated with El Nino or La Nina event. Lower: Spatial distribution of land density for corn and soybean cultivation.

Long-term global assessment of coastal hazard risks in relation to sea-level rise and global warming

The target of this research is to predict inundation and flood risks caused by sea-level rise and storm surges induced by tropical cyclones that are enhanced by global warming. The assessment will cover all coastal areas of the world until 2300 and will be based on long-term simulations of sea-level rise and global warming by the earth simulator. Of particular focus are Asian mega-delta areas because of the compound risks of inundation and flooding, as well as land subsidence and saltwater intrusion. Coastal risks will be evaluated by considering the area, population, and properties (land uses) of the inundated and/or flooded areas. The prediction of these risks will help in the development of appropriate strategies and risk-management measures against sea-level rise and global warming.

Climate 2030

Near-term climate prediction using a high-resolution coupled ocean-atmosphere general circulation model

Future climate prediction up to the year 2030 is planned using a global climate model with 60-km atmospheric resolution coupled with a 20 x 30 km eddy-permitting ocean model. The research goal is to provide a basis for more quantitative assessment of regional climate change, including change in extreme weather events, so that more realistic strategies and risk-management options can be developed.

The model will be initialized using decades of observed climate data. Ensemble integrations into the future will provide measures of uncertainty. Whether such a prediction as an initial-value problem is feasible or not in the global warming projection is a great scientific challenge. The development and investigation of an initialization and ensemble prediction methodology are novel aspects of this research. The coupled model will take into account not only increases in greenhouse gases, but also increases in emissions of various aerosols of anthropogenic origin.

Model development

The physics and resolution of the Model for Interdisciplinary Research on Climate (MIROC) atmosphere-ocean coupled climate model will be upgraded for better representation of both global climate and regional extremes. The model has been developed cooperatively by the Center for Climate System Research (CCSR) of the University of Tokyo, the National Institute for Environmental Studies (NIES), and the Frontier Research Center for Global Change (FRCGC) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The model has provided projection data with high spatial resolution that have been used in the IPCC's Fourth Assessment Report. The new version of the model will include 60-km atmospheric resolution and a 20 x 30 km eddy-permitting ocean model, which will help to represent heavy rain disturbances and local ocean current systems. The parameterization of clouds, the boundary layer, aerosols, and sea ice physics will be upgraded for better reproducibility of past and present climate.

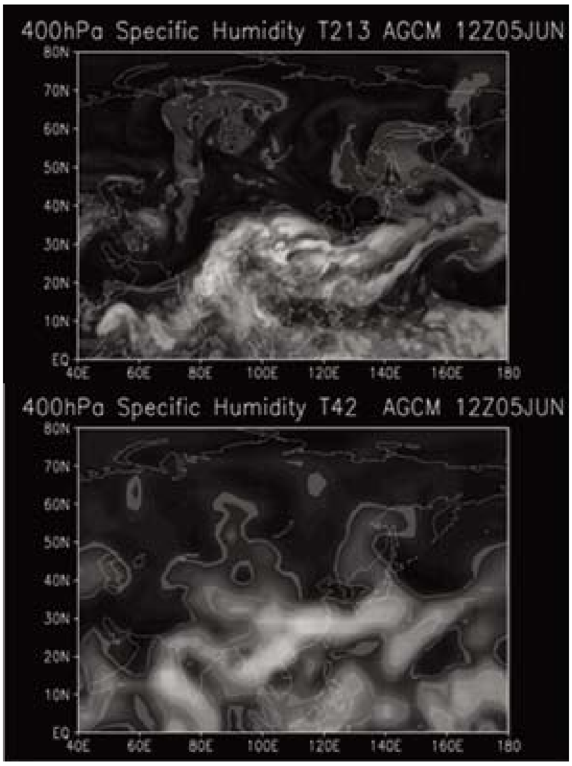


Fig. 1 Simulations of upper-air (7-km height) moisture content over the summertime Asian monsoon using a 60-km (upper) and 300-km (lower) mesh models.

Improvement of future climate change projection by developing a high-performance ocean model

This research aims to improve the future prediction ability of climate models by developing a sophisticated global ocean model. Particular emphasis will be placed on the area around Japan. Based on an already existing 20-km grid global ocean model that can represent small-scale ocean eddies, particularly high resolution will be achieved around Japan. For other regions, processes will be studied using regional fine-resolution models; the results should provide better climate reproducibility at 20-km resolution. Once developed, the previous ocean component of the model will be replaced, and research will verify the extent to which this high-performance ocean model improves the quality of future climate projection.

Development of a technique to quantify the uncertainty in near-term climate prediction using ensemble data assimilation

An ensemble data assimilation technique to quantify the uncertainty in the reproduction and prediction of long-term climate change using a dynamical model will be developed. The technique will be used to create optimal initial conditions for near-future climate prediction and to estimate the uncertainty involved in the reproduced and predicted climate states. The main focus will be on the accurate reproduction of ocean conditions. The developed technique will be applied to the final experiment of near-term climate prediction.

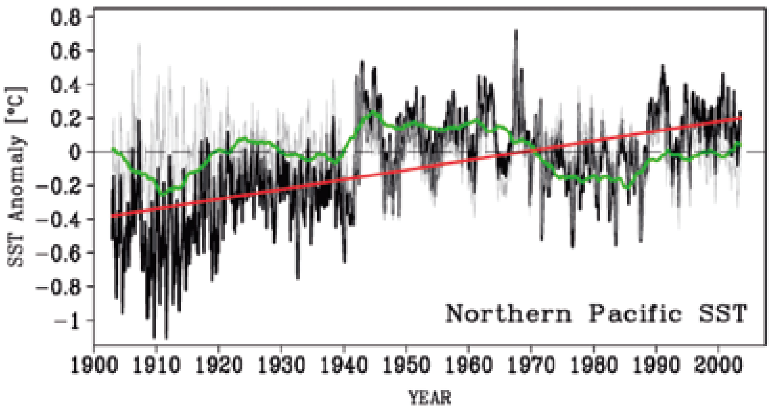


Fig. 2 A time series of observed sea surface temperature (SST; 20N — 60N, 140E — 120W; black) is decomposed into a global warming trend (red), a decadal component (green), and the rest (gray). The decadal component is comparably large to the trend, and therefore it is important how well the component is reproduced and predicted in the system developed.

Estimation of changes in the risk of water-related disasters based on near-term climate prediction with uncertainty considerations

A comprehensive hydrological cycle model will be developed. The outputs from the high-resolution climate model, which will be developed by the subgroup of the project described above, will be used as the inputs to the model. Hydrological quantities that are strongly related to water hazards, e.g., river discharge and soil moisture, will then be simulated using the hydrological cycle model. The simulation results will be compared with simulation results for the 20th century, and changes in the risk of water-related disasters will be estimated.

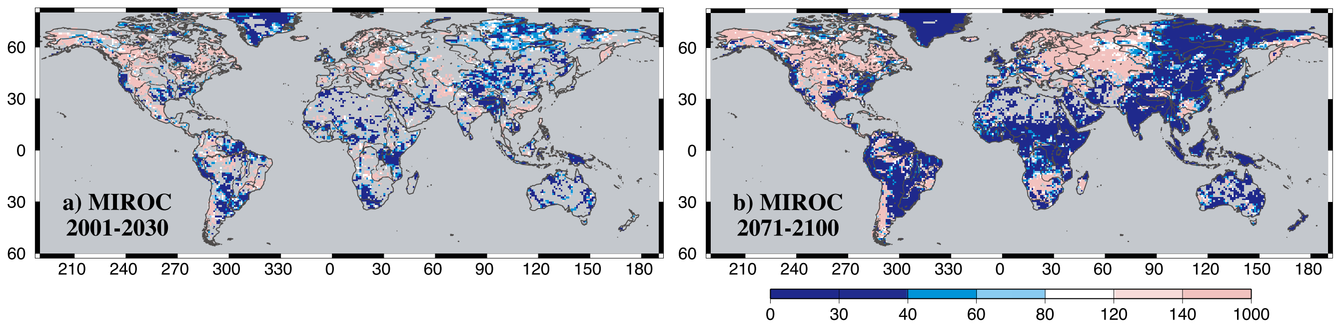


Fig. 3 Projected return period [year] of the 100-year floods in the present-day (1901-2000) simulation during a) 2001-2030 and b) 2071-2100 by MIROC.

Will tropical cyclones and heavy rainfall in the East Asian rainy season cause more natural disasters?

Projection of the change in future weather extremes using super-high-resolution atmospheric models

- What is our target and how do we accomplish it?

We will perform climate projections for the near future and for the end of the 21st century using atmospheric models of unprecedented super-high-resolution. The climate change studies will be based on a global 20-km mesh atmospheric general circulation model; emphasis will be placed on extreme events, including tropical cyclones and heavy precipitation during the East Asian summer monsoon season. The multi-model ensemble of sea surface temperatures (SSTs) projected by atmosphere-ocean general circulation models (AOGCMs) used in the IPCC Fourth Assessment Report (AR4) will be input to the global 20-km mesh atmospheric model to obtain the future climate projection (time-slice experiment). Furthermore, in a focus on local climate change over Japan, 5-km and 1-km mesh regional atmospheric models embedded in the global model will be used to investigate changes in heavy precipitation. Much literature has already been published to describe our super-high-resolution atmospheric model; these reports are cited in the IPCC's AR4. The uncertainty of the projected climate change will be evaluated and quantified using multiple sets of ensemble experiments to provide information on the reliability of the model outcomes. Using data computed from the model projections, environmental changes that may lead to disasters such as landslides, debris flows, floods, droughts, storm surges, and strong winds will be evaluated for Japan. The climate-change impacts on river planning in Japan will be also assessed. Moreover, flood risk assessment will be extended to a global scale for cooperation with international projects on disaster mitigation.

- Will tropical cyclones (TCs) intensify?

Figure 1 shows the global change in TC intensity as a function of surface maximum wind. The IPCC A1B scenario was assumed for the future climate simulation. The frequency of intense TCs will increase in a future warmer climate, suggesting that the risk of natural disasters will also increase.

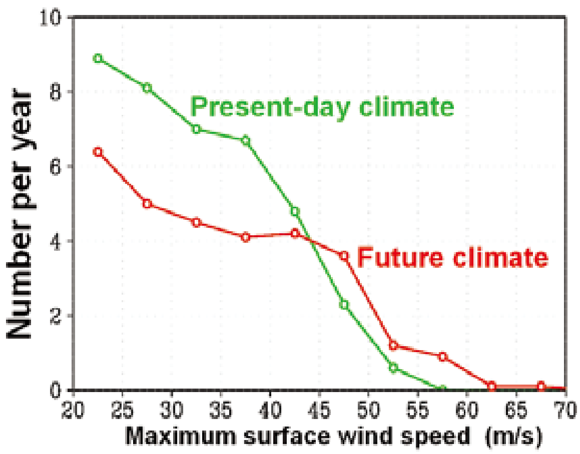


Fig. 1 Frequency distribution of surface maximum wind of TC for the present climate at the end of 20th century and future climate simulations at the end of 21st century.

- What changes will occur in rain bands (Baiu/Meiyu/Changma frontal precipitation systems) of the East Asian summer monsoon?

Changes in the precipitation characteristics of rain bands during the East Asian summer monsoon season have been investigated. This research suggests that total precipitation from June to July will increase over the Yangtze River valley, the East China Sea, and western Japan, but decrease over Korea, Taiwan, and northern Japan. Heavy precipitation will increase over the Yangtze River valley, the East China Sea, and western Japan, increasing the risk of natural disasters in these regions.

Quantification and reduction of the uncertainty in climate change projection by super-high-resolution atmospheric models

- Will the number of typhoons and hurricanes increase? Is the answer certain?

Figure 2 shows the projected change in the number of typhoons and hurricanes. Future simulations depend on the SST provided to the atmospheric model because the atmosphere is greatly affected by the SST underneath. There appears to be no consensus among researchers on projected changes in the number of typhoons and hurricanes. The quantification of future changes in the number of TCs is one of the challenges especially emphasized in the IPCC's AR4.

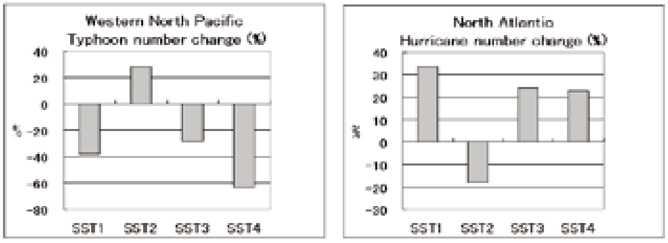


Fig. 2 Change in annual number of TCs at the end of 21st century relative to present climatology (%). Horizontal axis denotes experiment type in which the geographical distributions of SST are different. Left: Typhoon. Right: Hurricane.

Integrated assessment of climate change impacts on watersheds in a disaster environment

- How will floods in Japan change?

Figure 3 shows an example from a pilot study of possible changes in the number of floods requiring dam operation and emergency dam release. Precipitation and evapotranspiration data included in the Japanese Standard Climate Scenario ver. 2 (2004), provided by the Japan Meteorology Agency (JMA), were input to a high-resolution distributed hydrological model, which was used to assess the Yodo River basin in Japan. The number of severe floods is predicted to increase, suggesting an increased risk of flooding caused by heavy rainfalls.

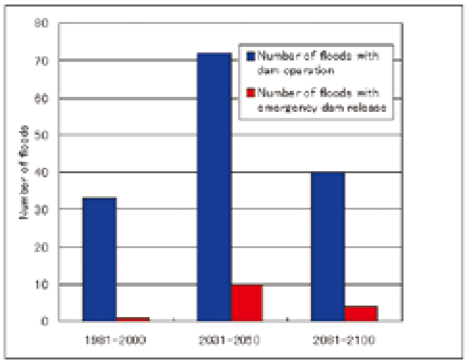


Fig. 3 Changes in the number of floods which cause dam operation and emergency dam release in a dam reservoir during 1981 to 2000, 2031 to 2050, and 2081 to 2100, respectively.

Assessment of the impact of climate change on flood disaster risk and its reduction measures over the globe and specific vulnerable areas

- How will the worldwide flood risk change in the future?

Although various flood risk maps are available, the data used to make these maps contain numerous uncertainties, including uncertainty regarding the magnitude of flood hazard. This research will clarify the current and future status of flood hazards quantitatively by combining advanced AGCM outputs, state-of-the-art hydrological models, and socioeconomic databases. The outputs will be used to produce a quantitative map of flood risk under conditions of climate change. To accomplish this goal, the available information must be examined. There are some of the technical issues to be solved such as differences in temporal and spatial scales between AGCM simulations and ground-based observations. Current AGCMs tend to produce weaker and longer-duration precipitation relative to observations. Considering the reproducibility of precipitation by AGCMs in the present climate, we will develop an engineering model for the future climate projection.

Cloud modeling and typhoon research

Sophistication of the cloud-resolving model and its coupling with global models

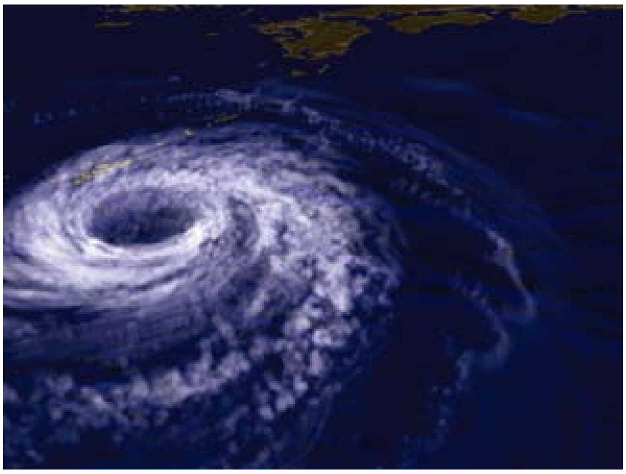


Fig. Three-dimensional cloud display of Typhoon 0418 simulated by the CReSS model with 1 km resolution.

Cloud physics is one of the key processes in modeling studies of climate change, especially for global warming. Improvement of cloud processes is necessary for accurate simulations by global models. Cloud processes are also core processes in simulations of high-impact weather systems such as heavy rainfalls and typhoons. The cloud modeling team will focus on addressing four objectives. First, the cloud microphysics of the "Cloud Resolving Storm Simulator (CReSS)" model will be improved. The dynamic part of the CReSS model will also be improved for accurate and high-speed calculation. Second, the cloud parameters of global models will be examined using the CReSS model. Satellite observations are used for verification of the cloud modeling. Third, the CReSS model will be coupled with global models interactively for accurate modeling of convective regions. In particular, convective clouds in the tropical region and typhoons will be studied using the models. Fourth, the CReSS model will be used for typhoon research. This aims to contribute to verifications of typhoon simulations made by global models, and to accurate and quantitative evaluations of typhoon impacts on human society under the present and warming climates.

Subgrid-Scale Parameterization

Ocean micro-scale processes control the Earth's climate

High-precision parameterization of marine microphysics using large eddy simulation

The aim of this research is to develop the parameterization of subgrid-scale oceanic processes using the results of a fully three-dimensional large eddy simulation. The advanced parameterization scheme will be incorporated into an ocean general circulation model or a coupled atmosphere-ocean general circulation model to project the interannual variability in ocean mixed layer processes and other processes. By resolving the uncertainties of conventional parameterization schemes, we can expect significant improvement in the ability to model future climate change.

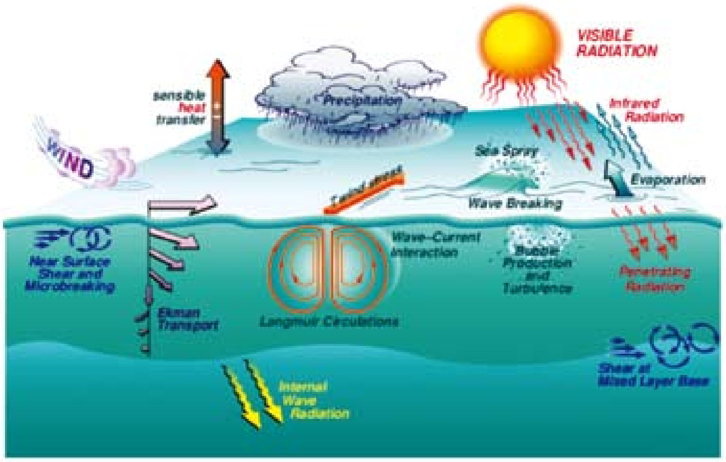


Fig. A schematic diagram of physical processes occurring near the air-sea interface [R. Weller, WHOI].

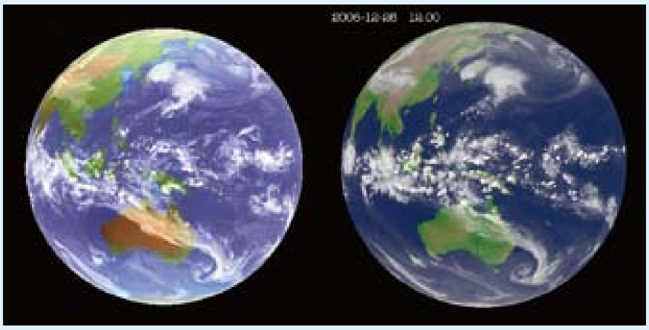
Emerging New Achievement of Tropical Cloud Simulation

Tropical clouds are one of the important elements in the global environmental system. They drive the global atmospheric circulation and affect the global climate condition. They form a multi-scale structure such as individual cumulus, cloud clusters, and monsoon circulations. Tropical cyclones, which cause serious disasters over the world, are generated from organized tropical cloud systems. Tropical clouds also directly affect weather in Japan by heavy rainfalls in the Baiu season.

The existing climate models cannot directly resolve tropical clouds, since their resolution is about 100km, much coarser than the scale of cumulus convection, 10km. Instead, a semi-empirical method called "cloud parameterization" is used in climate models to represent tropical clouds. However, it is known that the use of cloud parameterization is one of the major causes of the ambiguity of climate models. To overcome this difficulty, we have developed the **global cloud-resolving model**, called **NICAM**, which can be run with a mesh size about a few kilometers. This new model directly resolves tropical cloud systems without using cloud parameterizations.

NICAM enables us to represent tropical clouds almost comparable to the cloud image by the geo-stationary meteorological satellite. As shown by the figure, NICAM captures the multi-scale structure of tropical clouds associated with the Madden-Julian Oscillation, whose realistic simulation has been difficult by the present climate models. NICAM also reproduces the tropical cyclogenesis in the realistic timing and at the precise location in this case.

We expect that NICAM will contribute to more reliable predictions of future global warming. NICAM will clarify problems in current climate models and will help reductions of the uncertainties in simulations of tropical clouds. Especially, we hope that NICAM will promote studies of future changes in tropical cyclones.



Left : The satellite cloud image from Himawari-6 (MTSAT -1R). Source: Kochi Univ., Tokyo Univ., JMA.
Right : NICAM / global cloud-resolving model. Source: FRCGC/ JAMSTEC.

Updating the Earth Simulator System

Since the start of its operation in 2002, the Earth Simulator (ES), a super-computer system installed at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), had been No.1 in the ranking of "the TOP500 list (the list of the 500 most powerful supercomputer systems in the world)" for two and a half years. It still maintains practically the highest level performance among supercomputers in the world which are available for the research in earth science. The *Kyosei Project* was conducted under the MEXT strategy and funds from 2002 to 2006 making the best use of the ES. Outcomes from this project have substantially contributed to the IPCC Fourth Assessment Report.

Six years have passed since the launch of the ES' s mission. The system will be updated in March 2009 to improve the ES' s effective performance by more than 2 times and further advancement is expected for the research in earth science fields such as global warming projection.

The *Kakushin Program* has been utilizing the ES and will use the updated new system to further contribute to the IPCC for its Fifth Assessment Report.

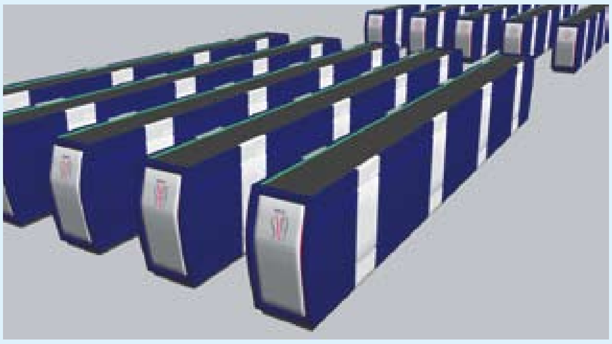


Image of the new system to start March 2009. Source: JAMSTEC.

Outline of the new system	
	Type: vector type processor architecture (shared memory multi-node) **Peak performance:** 131 teraflops (current system: 40 teraflops) **Application sustained performance:** twice of existing system (estimation) **Main memory capacity:** 20 terabytes (current system: 10 terabytes)

KAKUSHIN

Organization participating in the Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN Program)

Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT)
http://www.mext.go.jp/english/index.htm

Long-Term Global Change Projection

Frontier Research Center for Global Change (FRCGC/JAMSTEC), Japan
http://www.jamstec.go.jp/frcgc/eng/index.html
National Institute for Agro-Environmental Sciences
http://www.niaes.affrc.go.jp/index_e.html
Dept. of Urban and Civil Engineering, Ibaraki Univ., Japan
http://www.civil.ibaraki.ac.jp/

Near-Term Climate Prediction

Center for Climate System Research (CCSR), the Univ. of Tokyo, Japan
http://www.ccsr.u-tokyo.ac.jp/ehtml/etopindex.shtml
Institute of industrial Science, the Univ. of Tokyo, Japan
http://www.iis.u-tokyo.ac.jp/index_e.html
FRCGC/JAMSTEC

Extreme Event Projection

Meteorological Research Institute (MRI), Japan
http://www.mri-jma.go.jp/Welcome.html
Disaster Prevention Research Institute (DPRI), Kyoto Univ., Japan
http://www.dpri.kyoto-u.ac.jp/web_e/index_e.html
The International Centre for Water Hazard and Risk Management (ICHARM/PWRI)
http://www.icharm.pwri.go.jp/index.html

Cloud Modeling

Hydrospheric Atmospheric Research Center (HyARC), Nagoya Univ., Japan
http://www.hyarc.nagoya-u.ac.jp/hyarc/index.html

Subgrid-Scale Parameterization

Dept. of Earth and Planetary Science, Graduate School of Science, the Univ. of Tokyo, Japan
http://www.eps.s.u-tokyo.ac.jp/index_en.html

Contact Point

Frontier Research Center for Global Change (FRCGC)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
Email: KAKUSHIN@jamstec.go.jp
URL: http://www.kakushin21.jp/eng/