

SOUSEI

Program for Risk Information on Climate Change



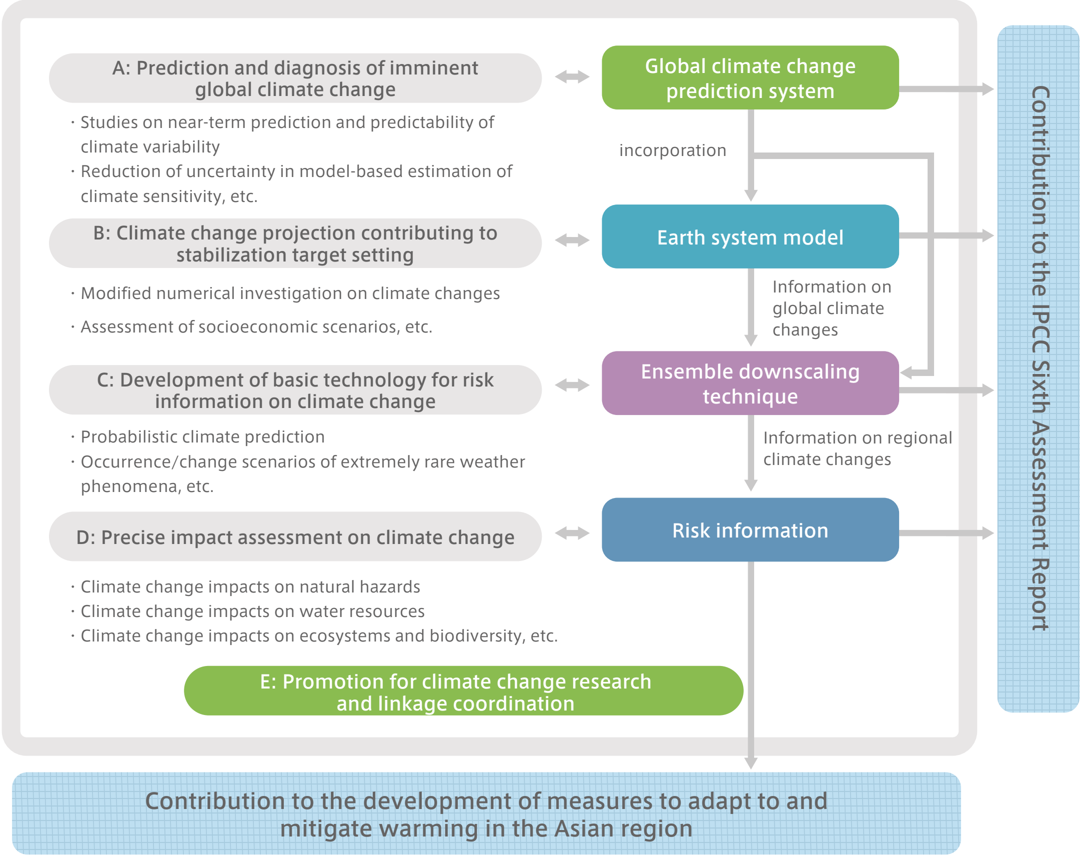

MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

Overview

A program is underway to prepare for the conceivable scenario and to enable risk evaluation at the world's highest level.

On the Japanese archipelago, which is mountainous and long north to south, there is significant variation among the regions in temperature, precipitation, wind, and clouds. Since the islands are surrounded by the ocean, they are often hit by typhoons during the summer and fall. Moreover, in recent years, extreme weather phenomena have become frequent occurrences, including concentrated heavy rainfall, unusually high temperatures near 40 degrees Celsius (104 degrees Fahrenheit), and tornadoes strong enough to destroy houses. These types of abnormal weather phenomena threaten our daily lives and are causing immense damage to society and the economy.

The Program for Risk Information on Climate Change (SOUSEI) carries on the work of the Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN) (FY2007-FY2011). The aim of the SOUSEI program is to evaluate the risk of disasters, damage, etc., that are expected to occur as a result of the above-mentioned extreme climate changes based on the assumption of certain scenarios and to generate information that aids risk management. This program began in FY2012 and has reached the halfway point of its five-year program term. By developing the highest level of research and development in the world, we are generating information that plays a role in climate change risk prediction not only in Japan but also in countries around the world including those in Southeast Asia.



SOUSEI

Message from Program Director

Reduction of the uncertainty of climate change prediction and usage of "risk information" in the real world

In March 2015, when the 3rd UN World Conference on Disaster Reduction was being held in Sendai, unprecedented damage in Vanuatu caused by cyclone was reported by the media. As symbolized by this disaster, extreme weather phenomena occur frequently these days. At the conference, the opinion that we "should integrate measures against global warming and disaster prevention measures" was stressed. We have now reached the point where it is necessary to take concrete measures against actual impact and damage, while regulations on the emissions of greenhouse gases, such as carbon dioxide, and international agreements on the reduction of greenhouse gas emissions are making little progress.

The major mission of the Program for Risk Information on Climate Change is to further boost the basic technology for climate change prediction, predict the probability of the occurrence of extreme weather phenomena including concentrated heavy rainfall, and conduct the risk assessment of the associated damage.

Themes constructed in a nested fashion

This research program is arranged with a multilayered structure. Theme A is the lowest-level layer. On top of that is Theme B, followed by Theme C and Theme D.

Theme A focuses on the development of the basic model which is the basis of this program. In this program's precursor, the Innovative Program of Climate Change Projection for the 21st Century, research on the basic model was driving the overall program, but in the current program, we aim to update the basic model itself and to add more advanced functions.

Theme B has a sibling relationship with Theme A. It adds elements such as the environmental biogeochemical cycles and biological activity to the basic model, develop a more detailed climate system model, and studies target levels for stabilization of the climate.

The aim of Theme C is to generate more detailed climate information that contributes to impact assessment research and to describe the "conceivable worst-case scenario" of extremely rare weather phenomena, including large typhoons comparable to Isewan Typhoon (Typhoon Vera), for use in impact studies. In response, Theme D aims to realize risk prediction and assessments in order to provide adaptation to natural disasters and measures to minimize the impact.

What are needed are scientific grounds and reliability

We are already at the point of no return with regard to global warming, but when it comes to "risks associated with global warming," its meaning and perceived seriousness vary greatly depending on one's generation and location. For instance, having experienced the tsunami and the nuclear accident following the Great East Japan Earthquake, we in Japan understand that even a disaster with the extremely small probability of "once in 1,000 years" causing exceedingly massive damage may actually occur. This experience suggests that we must take measures, assuming "unanticipated phenomena" more than ever before. As mentioned above, measures against global warming and disaster prevention measures need to be taken in an integrated manner. Similarly, the urgent issue of local regeneration also needs to be consistent with measures against global warming. Measures against global warming need to be integrated with measures against various issues in society today, instead of being implemented independently.

In order to take efficient, specific action under the current circumstances which include a declining birthrate, an aging society, and less-than-abundant funds, we must have reliable risk assessments based on scientific grounds. In this program, we intend to scientifically question and ascertain the matters which seem certain and the matters which are still not well understood. All participating researchers are pushing forward with research to provide reliable results that will serve as grounds for every person to think and make decisions. We would appreciate your continued support and guidance.

Program Director (PD) Akimasa Sumi (special advisor to MEXT)

President, National Institute for Environmental Studies (NIES)

Outline

PD supervises the program so that it is carried out efficiently and effectively, and he handles the overall coordination of the program. A PO (program officer) is assigned to each theme to assist the PD in managing the progress of research topics and adjusting research plans, etc.

PD (Program Director) Akimasa Sumi

Special Advisor to MEXT
President NIES

PO Mitsuo Uematsu

Special Advisor to MEXT
Professor/ Director
International Advanced Research
AORI

PO Fujio Kimura

Special Advisor to MEXT
Research Fellow
Center for Computational Sciences
University of Tsukuba

PO Hideo Harasawa

Special Advisor to MEXT
Vice President
NIES

Theme A: Atmosphere and Ocean Research Institute, the University of Tokyo (AORI)

Prediction and diagnosis of imminent global climate change

Representative: Masahide Kimoto
Vice Director/Professor, AORI, the University of Tokyo

The coming global warming is unavoidable, and all segments of society are seeking ways to adapt to it. In an effort toward providing climate change risk information and contributing to building a society highly adaptive to climate change, this theme develops a climate prediction system that enables verification using observation data on various timescales and provides climate projection information with high reliability. We aim to improve the reliability of projections of future climate changes through analyzing major contributing factors, verifying hindcasts, and assessing the impacts of anthropogenic factors associated with past climate changes involving severe weather and extreme events. In addition, we attempt to reduce the uncertainty in climate projection due to physical processes controlling climate sensitivity through verification using observation data, which is a yardstick of climate system responsiveness to external forcing such as that caused by changes in concentration of carbon dioxide.

【Research Topics】

Understanding mechanisms of climate variability and change

■ Studies on prediction and predictability of climate variability from interannual to decadal time scales (AORI)

■ Towards reducing uncertainty in model-based estimation of climate sensitivity (National Institute for Environmental Studies:NIES)

■ Reduction of uncertainty in climate models relevant to climate sensitivity (JAMSTEC)

Development of an integrated prediction system for global climate studies

■ Development of a seamless prediction system for seasonal-to-decadal time scales (Meteorological Research Institute JMA:MRI)

■ Development of data assimilation technology for optimizing initial and boundary conditions (JAMSTEC)

Theme B: Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Climate change projection contributing to stabilization target setting

Representative: Michio Kawamiya
Director, Project Team for Risk Information on Climate Change, JAMSTEC

Uncertainty in the projection of carbon dioxide concentration, together with uncertainty concerning climate sensitivity, is a major obstacle to predicting the future climate. In this research theme, we are developing an earth system model that handles the environmental biogeochemical cycles including the carbon cycle and the nitrogen cycle as well as changes in land use. These are critical for more accurately predicting changes in the balance of carbon dioxide and changes in ecosystems and agriculture, etc. When developing our research, we study, from a scientific standpoint, the socio-economic scenarios that form the preconditions on which the projection experiment is premised. In studying targets for carbon dioxide, it is important to understand phenomena that may occur in the future but must be avoided as well as the impact of methods we could use to avoid them. This is why we work to create new scientific knowledge concerning the impact and effects of violent changes (tipping elements) which may arise when the degree of anthropogenic environmental changes exceed a certain threshold as well as methods to lower the average temperature of the earth artificially so as to suppress the damage due to warming (geoengineering).

【Research Topics】

Long-term global climate change projection based on diverse scenarios

■ Development of an earth system model dealing with variations of greenhouse gases, land use change, etc. (JAMSTEC)

■ Information gathering and examination on socio-economic scenarios toward stabilization target setting (JAMSTEC)

■ Integrated assessment on climate projection experiments and socio-economic scenarios (Central Research Institute of Electric Power Industry:CRIEPI)

Obtaining scientific perceptions on large-scale variations and modifications of climate

■ Development of technologies for numerical investigations on tipping elements and irreversibility of environmental changes (ice sheet collapse, etc.) (JAMSTEC)

■ Development of technologies for numerical investigations on geoengineering (stratospheric aerosol injection, etc.) (JAMSTEC)

Theme C: University of Tsukuba

Development of basic technology for risk information on climate change

Representative: Izuru Takayabu
Director, Atmospheric Environment and Meteorology Research Department, Meteorological Research Institute (MRI)

In recent years, climate change impact assessments and development of countermeasures have been undertaken around the world. However, there is currently no standard downscaled data that can simultaneously address various demands (from changes in the mean field to hazard analyses). In this research theme, we aim to produce probability data that enables hazard analyses related to both high-frequency phenomena and low-frequency phenomena (typhoons, heavy rainfall, etc.) in the region of Japan. For this purpose, we are further refining the existing super high-resolution atmospheric model and applying statistical methods on model results to generate data on the probability of climate change predictions in the Asian monsoon region, including Japan. We aim to prepare a standard dataset (climate scenarios) together with data concerning the uncertainty in basic variables in climate prediction, which can be used in different applications of prediction data.

【Research Topics】

Probabilistic climate prediction for risk assessment

■ Efficient approach for climate ensemble experiment (National Research Institute for Earth Science and Disaster Prevention:NIED)

■ Development of statistical methodology of ensemble data on climate change (The Institute of Statistical Mathematics:ISM)

■ Improvement in cost-efficiency of dynamical downscaling for ensemble data (AORI)

Producing a standard climate scenario by using super high resolution models

■ Development of quantification method for reliability and uncertainty of climate change information (University of Tsukuba)

■ Downscaling of the change in future weather extremes by using high-resolution models (MRI)

■ Development of a coupled ocean-atmosphere non-hydrostatic model for typhoon research (Hydrospheric Atmospheric Research Center, Nagoya University: HyARC)

Theme D: Disaster Prevention Research Institute, Kyoto University (DPRI-KU)

Precise impact assessments on climate change

Representative: Eiichi Nakakita
Vice Director/Professor, DPRI, Kyoto University

To generate information that contributes to climate change risk management, it is important to perform a more detailed assessment of the impact, together with specifying the risks and understanding the probabilities. In this research theme, we are performing a quantitative impact assessment from a variety of perspectives including natural hazards, water resources, and ecosystems and biodiversity, using climate change prediction information as well as prediction information produced in this program. We are also performing a variation estimate of the expected risk value, an estimate of the uncertainty of that estimate, and an impact assessment on the worst-case scenario of a natural hazard. Next, using these figures, we perform a variation estimate of the socio-economic risk and aim to compile the basic information for adaptation strategies. With regard to natural hazards, in conjunction with proposing various basic approaches to the adaptation strategies, we aim to study assessment methods for comprehensive disaster mitigation measures that can alleviate a disaster to some degree when external forces occur that exceed the existing facilities plan, as part of the worst-case scenario. We also aim to construct a methodology for the economic assessment.

【Research Topics】

Climate change impacts on natural hazards

■ Risk assessment of meteorological disasters under climate change (DPRI-KU)

■ Risk assessment of water-related disasters under climate change (Kyoto University Graduate School of Engineering)

■ Risk assessment of coastal disasters under climate change (DPRI-KU)

■ Measuring socio-economic impacts of climate change and effectiveness of adaptation strategies (DPRI-KU)

■ Development of risk assessment and adaptation strategies for water-related disaster in Asia (Public Works Research Institute:PWRI)

Climate change impacts on water resources

■ Assessment of socio-economic impacts on water resources and their uncertainties under changing climate (DPRI-KU)

■ Assessment of climate change impacts on the social-ecological systems of water resources and hydrological cycles (Institute of Industrial Science, University of Tokyo:IIS)

Climate change impacts on ecosystem and biodiversity

■ Assessment of climate impacts on ecosystem and biodiversity (Tohoku University)

■ Economic evaluation of ecosystem science (Tohoku University)

■ Eco-climate system in northeastern Eurasia and southeastern Asian tropics: Impacts of global climate change (Nagoya University)

■ Assessment of multiple effects of climate change on coastal marine ecosystem (Hokkaido University)

Theme E: JAMSTEC

Promotion for climate change research and linkage coordination

Representative: Michio Kawamiya
Director, Project Team for Risk Information on Climate Change, JAMSTEC

Promotion for effective researches on climate change

▪Support for program implementation and outreach

▪Support for forming common recognition on climate change risk information

▪Establishment of a system required for providing information and advice on climate change risk

Theme A: Prediction and diagnosis of imminent global climate change

Understanding the current climate changes and predicting the future – Provision of basic information for measures against climate changes

Representative: Masahide Kimoto
Vice Director/Professor, AORI, the University of Tokyo

To take measures against global warming which is progressing due to human carelessness, we need reliable prediction information on the types and probability of climate events that are expected to take place in the future. Under this theme, we are developing a system that can predict climate changes on various timescales, from El Niño over a half year to global warming over 10 years or 100 years, by making more sophisticated climate models which are tools to obtain prediction information and by incorporating atmosphere and ocean observation data into the models. Moreover, we are trying to understand the ongoing climate changes by conducting numerical experiments using this system.

Is this year's heat wave caused by global warming?

It is often said that disasters occur when least expected. Even though the frequency may be low, summers with heat waves and winters with heavy snow come inevitably as an indication of the natural climate changes of the earth, and we cannot attribute individual climate events to global warming alone. However, global warming is slowly progressing and changing the frequency of several abnormal or extreme weather phenomena, although it is a slight change. By conducting a large number of elaborate simulations, we can understand the mechanism of climate events and calculate the contribution of global warming. In Theme A, such research is called "event attribution." By promoting this research, we can widely convey to society the message: "The probability of a heat wave such as that, in 2013, it would have been much lower without global warming. In other words, global warming is increasing the risk of heat waves by x%." At the same time, the research can promote an understanding of the relationship between natural changes and global warming risk.

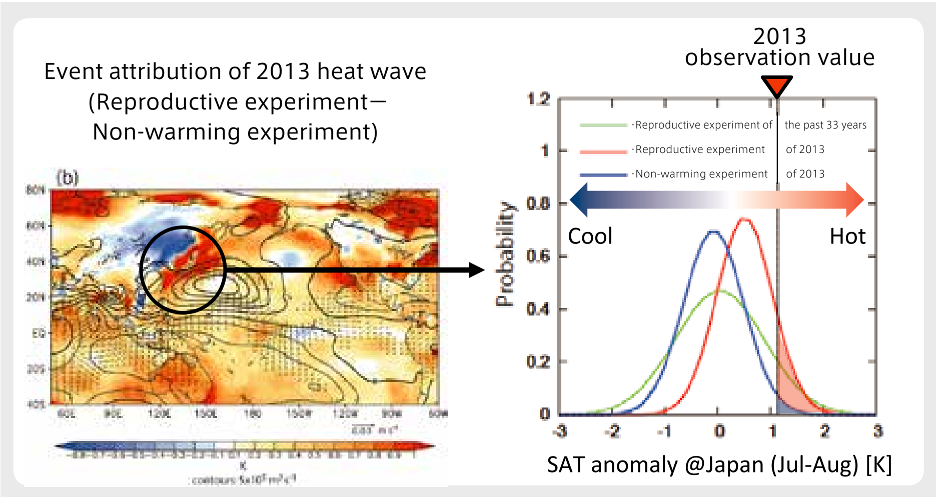


Fig. 1: Event attribution
We conducted a reproductive experiment of 100 members with different initial values, giving boundary values (sea surface temperature and sea ice) observed in a global atmosphere model, and an experiment in which warming elements were excluded from the boundary values. We assessed the contribution of warming to the occurrence probability of less frequent abnormal weather, etc., by comparing the probability density distribution (PDF) of meteorological elements obtained from these experiments. The figure on the left shows the differences in the surface air temperature (color), 850 hPa stream function (isogram), and 200 hPa divergent flow (arrow mark) obtained in the reproductive experiment on the heat wave in Japan in 2013 and the non-warming experiment. The figure on the right compares the surface air temperature PDF near Japan obtained in the reproductive experiment (red) and non-warming experiment (blue). Green shows a climatological PDF of the same variables obtained in a longer term reproductive experiment. The probability of a hot summer compared to that observed in 2013 (shown in the top part of the figure) is only 1.7% in the overall non-warming case. In the actual (warmed) conditions, however, the probability is estimated to be 12.4%, indicating that warming is increasing the risk of heat waves (Imada et al. 2014, Bulletin of the American Meteorological Society).

Has global warming stopped?

Not only individual climate events but also the relationship between global warming and climate trends in recent years observed in observation data often attracts the attention of society. The plateau in the elevation of the world's average temperature over 15 years after the record-setting El Niño in 1998 is known as the global warming "hiatus." It has become a major topic of social and scientific interest. In addition, frequent cold winters in recent years, despite global warming, are often reported by the media. Is global warming actually progressing?

The research on Theme A also tries to provide a scientific answer to this question. With regard to the hiatus, we found that the ocean interior temperature is rising steadily although the surface air temperature stays at the same level. It is believed that the temperature rise has temporarily halted primarily in the sea surface as a result of natural fluctuations of heat transportation inside the ocean. We also found that the impacts of global warming are increasing, rather than decreasing, as a result of an analysis during recent decades. Regarding cold winters, the research demonstrated that a decrease in sea ice in the Arctic Ocean due to global warming is causing a change in a pressure pattern that increases the intensity of the Siberian anticyclone. The research also indicated that it cannot be said that the Northern Hemisphere will experience more cold winters if global warming progresses because the Arctic oscillation, which is another natural fluctuation, makes a larger contribution after the progress of global warming.

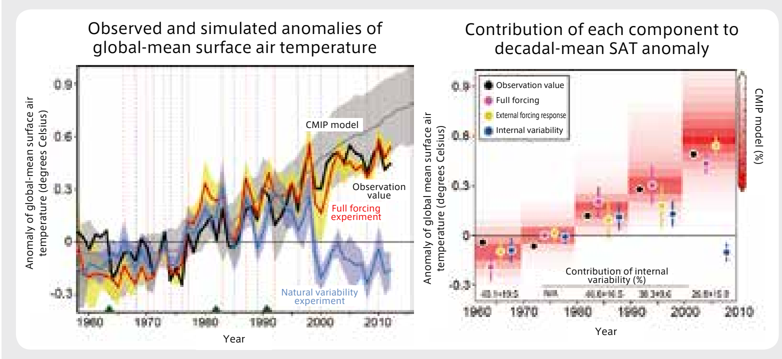


Fig. 2: Reproduction of the hiatus and attribution analysis
We successfully reproduced the hiatus in global temperature rise since 2000 in a simulation using a global climate model (left). Moreover, we found that natural climate fluctuations contribute to global temperature changes (right) to a non-negligible degree at 47%, 38%, and 27% in each decade from 1980 to 2010, respectively. Such contribution is decreasing as anthropogenic warming becomes prominent. It is suggested that contribution rates will further decrease if global warming progresses in the future (Watanabe et al. 2014, Nature Climate Change; Press release on September 1, 2014).

The new prediction system expands not only future information but also past information.

With regard to climate models, we are steadily preparing a new model to be used in the next phase of the Coupled Model Intercomparison Project. We decided to introduce a new method known as the Ensemble Kalman Filter (EnKF) to "data assimilation" to incorporate observation data. This method involves a larger amount of calculation than conventional methods, but it can incorporate atmospheric and oceanographic data simultaneously and makes it possible to handle variables which are technically difficult to incorporate, such as sea ice. In addition, the method increases the accuracy of variables which are different from the incorporated variables. By using this property, it is expected that pre-1950's climate conditions, for which upper-air observation data and ocean interior observation data are very scarce, can be reconstructed, using relatively abundant surface observation data. If "150 Year Climate Reanalysis" can be realized, abnormal weather samples and extreme climate samples will increase, and the understanding of multidecadal climate changes will improve. Furthermore, attribution and risk assessment of Muroto Typhoon (1934)-class climate events will become possible if combined with a downscale approach, etc. The coverage of a wider range of past phenomena directly leads to the improvement of the reliability of future predictions.

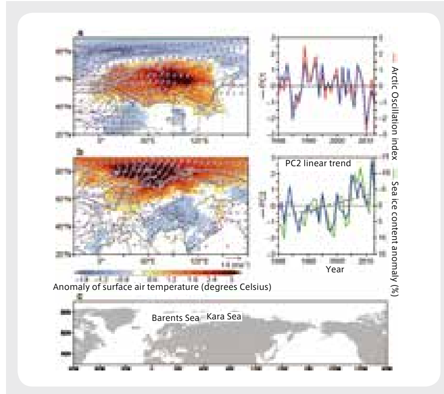


Fig. 3: Attribution analysis of frequent cold winters in mid-latitude regions of the Eurasian continent
A large ensemble simulation using an atmospheric model revealed that the cold winter probability in mid-latitude regions of the Eurasian continent has more than doubled due to the rapid decrease of sea ice in the Arctic Ocean in recent years. The analytical results of future prediction simulations using climate models around the world suggest that the increase in cold winters in recent years is a transitional phenomenon that temporarily occurs in the warming process. The figure shows space patterns obtained from a principal component analysis of observed surface air temperature anomaly in winter (left: surface air temperature anomaly (color), associated surface atmospheric pressure anomaly (isogram: 1 hPa interval), and surface wind (arrow mark) anomaly) and their time coefficients (right). The first principal component (panel a) represents the Arctic Oscillation and the second principal component (panel b) indicates a pattern linked to interannual changes in sea ice anomaly (time series in green), which is the average of the Barents Sea and the Kara Sea (Fig. (c)) (Mori et al. 2014, Nature Geoscience; Press release on October 27, 2014).

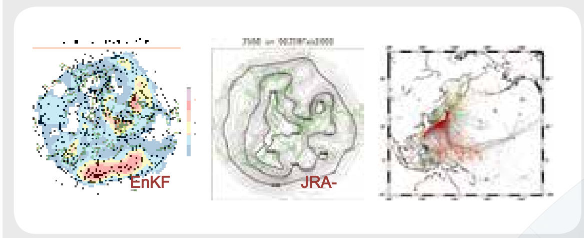


Fig. 4: Toward 150-year climate reanalysis
The figure shows a comparison between a 500 hPa (approx. 5 km) height field in the air reproduced only from surface atmospheric pressure data using a new data assimilation method (EnKF) (left) and the analytical value provided by the Japan Meteorological Agency (center). The shade in the left figure indicates a yardstick of errors based on the ensemble method. The figure on the right shows the distribution of upper ocean temperature data before World War II. The colored part shows data provided by Japanese institutions. We are also working to digitize climate observation data collected by the former Imperial Japanese Navy.

Related Organizations
JAMSTEC NIES

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Theme B: Climate change projection contributing to stabilization target setting

How will the global climate change if CO_2 emissions are reduced? We explore ways to control global warming.

Representative: Michio Kawamiya
Director, Project Team for Risk Information on Climate Change, JAMSTEC

How much impact will the reduction of anthropogenic CO_2 emissions have on the global climate? In handling such a question, we also need to take biological and chemical processes such as photosynthesis of plants into consideration. In this theme, we study global climate issues, using an "Earth system model" which is a climate model incorporating biogeochemical and chemical processes.

Impact of the uncertainty of the Earth system model on social and economic projections

The amount of carbon that human beings may emit in the future cannot be determined automatically even if we set a target for the degree of global warming control. The amount varies depending on the amount of carbon absorbed by land ecosystems and the ocean. To develop a global warming control scenario for the future, it is important to consider the impact of the uncertainty, which is caused by such models' differences in the responses of the Earth system components, on socioeconomic systems. This research emphasizes a combination of climate and economic models to study this point. Specifically, we have conducted the following studies.

First, as the preconditions of the research, we adopted the intermediate stabilization scenario(RCP4.5) which is the second lowest temperature rise among the four Representative Concentration Pathways* used in the IPCC's Fifth Assessment Report. In the scenario, we took note of the amount of carbon that can be emitted to realize annual target concentrations, analyzed the impact of the uncertainty of the "Earth system model," which is a climate model capable of considering the absorption of greenhouse gases, on society and the economy, using an "applied general equilibrium model" which is one of economic models, and we obtained the following results.

(1) When the world's total GDP without global warming countermeasures is set at 100, the world's total GDP in 2100 will be 95.8 if the amount of carbon that can be emitted is large, while the GDP will be 91.9 if the carbon amount is small. (The difference in the carbon amount is attributed to the uncertainty of Earth system responses.) GDP in the case of a small amount of emitted carbon is lower by 4.1% than GDP in the case of a large amount of carbon (Fig. 1).

(2) There will be a difference of three times in the carbon price (carbon tax), depending on the difference in Earth system responses, between the small and large emission reduction cases, even if the target CO_2 concentration is the same (Fig. 2). Thus, the difference in Earth system responses has a significant impact on emission reduction scenarios.

(3) The estimated total demand for primary energy in 2100 does not differ greatly between the smallest and the largest emission cases. However, the demand structure in two cases differs. In the largest emission case, the use of fossil fuels is relatively large. In particular, natural gas is expected to be used in the largest proportion. In the smallest emission case, on the other hand, the use of fossil fuels is relatively suppressed. Instead, the use of renewable energy will increase. In particular, the proportion of biomass is expected to be the largest.

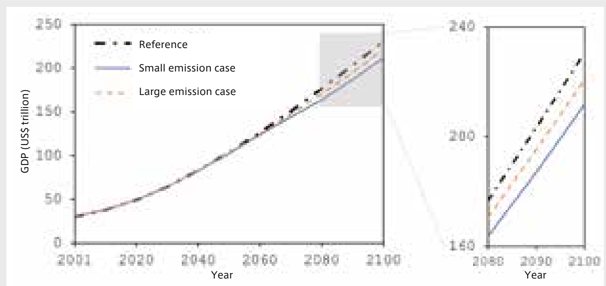


Fig. 1: GDP (global total)
The figure on the right is an enlarged 2080-2100 graph.
(Matsumoto et al. 2015, Computers & Operations Research)

These results suggest that the amount of carbon that can be emitted has more than a little impact on the economy but that the difference in the amount will not generate a significant difference in economic growth if a single carbon price is applied by such means as worldwide emission trading and if the reduction of emission is realized efficiently.

* Scenarios that present the future changes in the concentration of atmospheric greenhouse gases causing global warming, also known as RCPs.

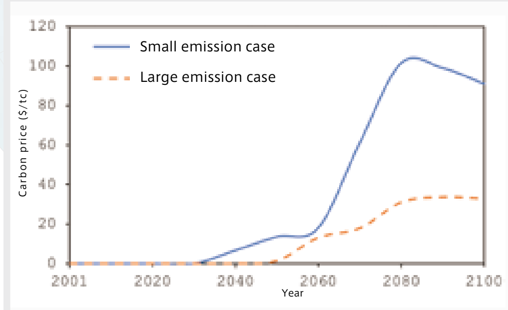


Fig. 2: Carbon price (Matsumoto et al. 2015, Computers & Operations Research)

Learning from the Earth and thinking over geoengineering approaches

Iron dissolved in the seawater is an essential nutrient for phytoplankton and is indispensable for photosynthesis. In other words, iron is an important element when we think of how much marine ecosystems absorb CO_2 and reduce global warming. Iron is supplied to the ocean from the atmosphere via aerosol.* Iron solubility, which indicates the degree of availability of total iron in aerosol for organisms, is observed in a wide range from 0.01% to 80%. Numerical models incorporating an iron cycle in the ocean assume that a certain proportion of soluble iron exists in soil-derived aerosol particles. This makes the calculation of the amount of CO_2 absorption by marine ecosystems highly uncertain.

The "global aerosol chemical transport model" developed in this research simulates from where aerosols are supplied and how aerosols circulate around the Earth. The model dynamically solves the aging process in which relatively insoluble iron in fine particles originating in forest fires and fossil fuel combustion, in addition to soil-derived aerosols, chemically reacts with inorganic/organic acidic substances and dissolves out. This is the first numerical model that is capable of reproducing a wide range of measurements (i.e., 1 to 2 orders of magnitude lower iron solubility in mineral dust aerosols than in combustion-influenced aerosols). Simulation results revealed that the high iron solubility observed in aerosols is related primarily to combustion-derived aerosols, suggesting the importance of fossil fuel combustion as the supply source of soluble iron.

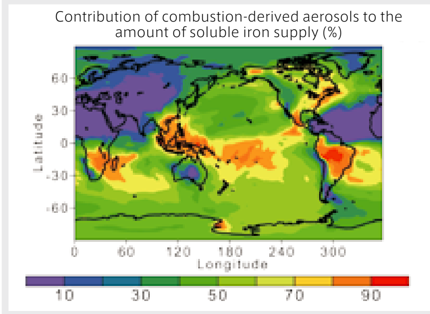
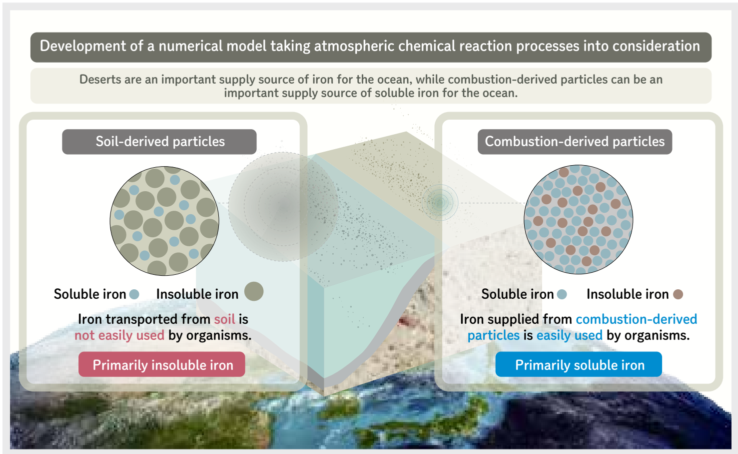


Fig. 3: Simulation result of a deposition of soluble iron using the IMPACT global aerosol chemical transport model (Ito 2015, Environmental Science & Technology Letters)



Spraying soluble iron in the ocean is proposed as a geoengineering method to promote the photosynthesis of phytoplankton and to remove CO_2 from the atmosphere. The results of this research suggest that soluble iron has already been dumped in the ocean through human activities, although it was not an intentional activity.

* Liquid or solid micro-particles floating in the air

Aims of Theme B "Climate change projection contributing to stabilization target setting"

To control global warming and to avoid violent environmental changes, it is necessary to develop well-established future scenarios for the reduction of CO_2 and other greenhouse gas emissions, taking socioeconomic aspects into consideration. To develop such scenarios, we must not only comprehend how CO_2 circulates in the global environment (carbon cycle) but also pay attention to the possibility of some irreversible, rapid changes, such as ice sheet collapse, if CO_2 emissions are not regulated. We should also understand whether or not the artificial control of climates, including iron spray in the ocean, is effective, along with the side effects of such control, in order to avoid rapid changes. In this theme, we will contribute to the development of ways to control global warming through efforts to resolve these complex issues.

Related Organizations
- The Univ. of Shiga Pref.
- CRIEPI

Describe the "possible future scenarios" by analyzing extreme weather events like typhoons in the past 50 years and global warming simulations for the coming 100 years!

Representative: Izuru Takayabu Director, Atmospheric Environment and Meteorology Research Department, Meteorological Research Institute (MRI)

The aim of this research theme is to describe "possible future scenarios" which include probability information on climate change and weather phenomena in areas surrounding Japan by developing methods for statistical analysis and assessment. There are two types of basic information to be used for considering risks associated with global warming: one is probability information for the likely scenarios, while the other is scenarios of the strongest possible class of weather phenomena. The former is necessary for disaster prevention, the latter for disaster mitigation.

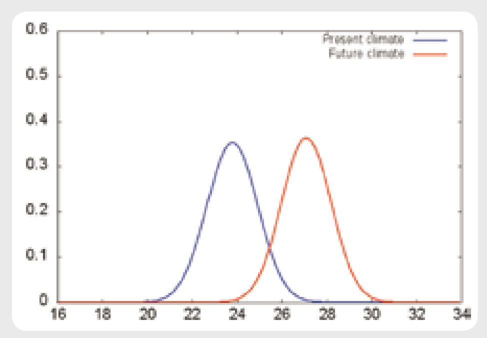


Fig. 1: Present (1969-1998, blue) and future (2069-2098, red) probability distribution of monthly mean surface air temperature in Tokyo in July.

How warm will Tokyo be at the end of the 21st century?

In this research, we developed a method to estimate climate change probability information and applied the method to the monthly mean temperature of Tokyo. Figure 1 shows how warm Tokyo will be at the end of this century. We used 21 model simulations based on the SRES A1B* greenhouse gas emission scenario. The figure indicates an increasing trend in the temperature and its uncertainty.

Figure 2 shows the results obtained from a high-resolution model applied in this program. We extracted four representative patterns in sea surface temperature rise predicted by 28 global models based on the RCP8.5 scenario** and performed dynamical downscaling simulation by using each extracted pattern. The dynamical downscaling was accomplished by driving a 5-km grid regional climate model using the boundary coming from a 20-km equivalent grid global atmospheric model. The variations in temperature and precipitation are shown in each area, and the temperature rise is larger in northern Japan. It is considered that the temperature rise reflects a reduction of the drift ice area in the Okhotsk Sea set as a boundary condition. The uncertainty of the precipitation changes is very large, thus the trends are not significant.

* A scenario of future greenhouse gas emissions assuming significant technological innovation for oil, natural gas, and new energy.

** One of the future climate change scenarios that predict changes in greenhouse gas concentrations. Among the four patterns of the RCP8.5, 6.0, 4.5, and 2.6 scenarios, the RCP8.5 scenario shows the most remarkable progress of global warming.

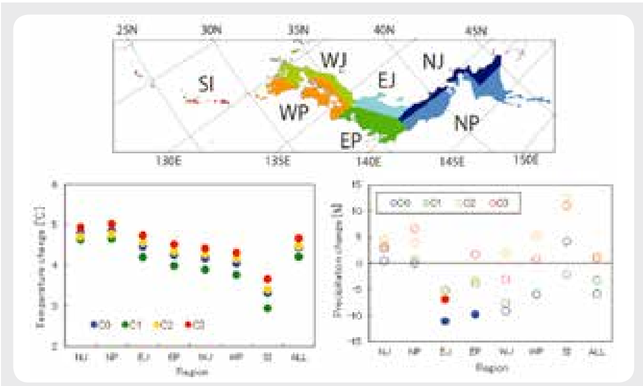


Fig. 2: The top portion shows segmented regions for future change comparison. The bottom-left portion shows the area-specific changes in annual mean temperature (Future-Present), and the bottom-right portion shows projected future changes in annual precipitation (change rate). C0, C1, C2, and C3 are indicating ensemble members. Future changes are statistically significant in all areas and members. The painted dots show statistically significant changes (significance level: 5%).

Does global warming induce extreme weather events?

It is pointed out that extreme weather events increase with global warming. Figure 3 shows the result that comes from simulations in the water-resource management model following the atmospheric state until 2100 (projected by five global climate models based on RCP8.5). It shows the years in which the number of drought days assessed by the model is expected to increase to an unprecedented level and never decrease to the previous level. According to the analysis, such years are approaching in Chile and the western part of North America. These results were obtained in collaboration with Theme D.

Next, how will the precipitation in monsoon regions change with global warming? Figure 4 shows projected future precipitation in each monsoon region evaluated in 24 ensemble experiments (SRES A1B scenario) using a global atmospheric model with 60-km equivalent resolution. Precipitation tends to increase on the whole. In East Asia including Japan in particular, an increase in rainy season precipitation is indicated at a high probability.

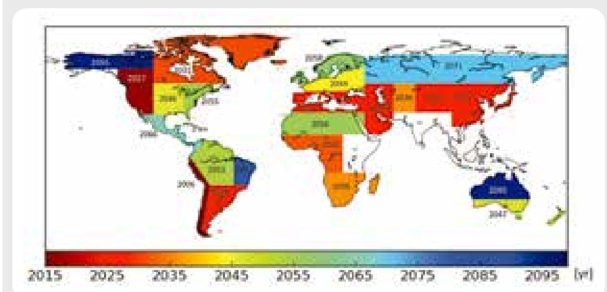


Fig. 3: The year when the largest annual number of drought days in the present climate begins to be a "normal" annual number in the future climate.

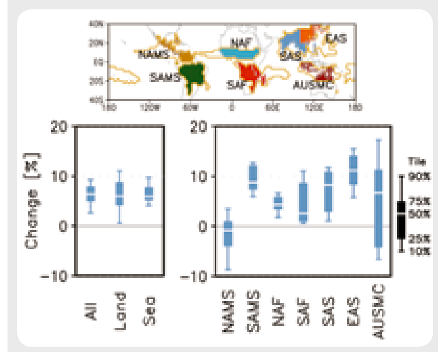


Fig. 4: Future changes in rainy season precipitation in global monsoon regions and land monsoon regions

Predicting strong typhoons and leading for disaster prevention and disaster mitigation

We need a probability typhoon approach to develop policies to mitigate the risks of disasters caused by typhoons because only two or three typhoons make landfall in Japan every year. Figure 5 shows typhoon paths simulated from observation data as part of the development of a typhoon model. This enables us to simulate a sufficient number of pseudo-events involving typhoons for analysis.

On the other hand, calculations based on a precise model are needed in order to develop the strongest-class typhoon scenario for disaster mitigation. Figure 6 shows the cloud and precipitation distribution of the Isewan Typhoon (Typhoon Vera), which is the strongest typhoon that hit Japan in the past. The figure was reproduced by typhoon model CReSS with 2-km horizontal resolution. High-accuracy calculations using such a high-resolution model are required to reproduce and analyze the structure and extent of a super typhoon.

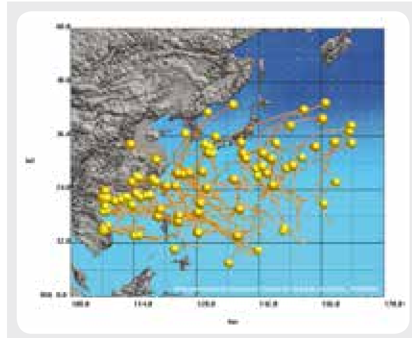


Fig. 5: Typhoon paths simulated from the best tracking data since 1951 issued by the Japan Meteorological Agency

Developing an outlook for the uncertain future

An extreme weather event occurs only rarely, about "once in 20 to 50 years." However, when it does occur, many people's lives are endangered, and significant social and economic damage and confusion ensue. In addition, we cannot devise measures against global warming and other climate changes without knowing the "probability of occurrence and state." Our research results will be useful when devising countermeasures against future global warming, disasters, etc., for the government and municipalities.

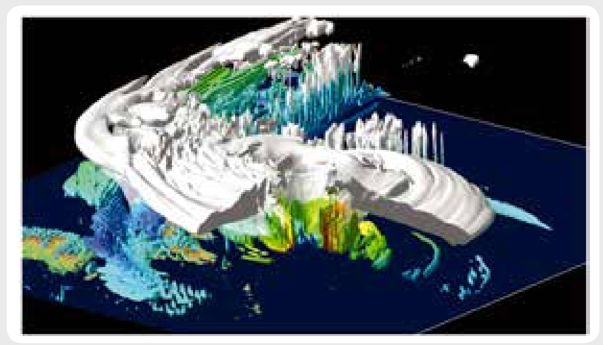


Fig. 6:Three-dimensional spatial structure of Isewan Typhoon (Typhoon Vera) reproduced by a cloud resolving atmospheric model. Clouds are shown in gray shading. Precipitation is depicted in a color gradation from red (strong wind) to blue (weak wind) to indicate the wind speed distribution around the eyewall cloud. The southwestern part of the typhoon is shown in a cross-section view to describe the eye structure of the typhoon.

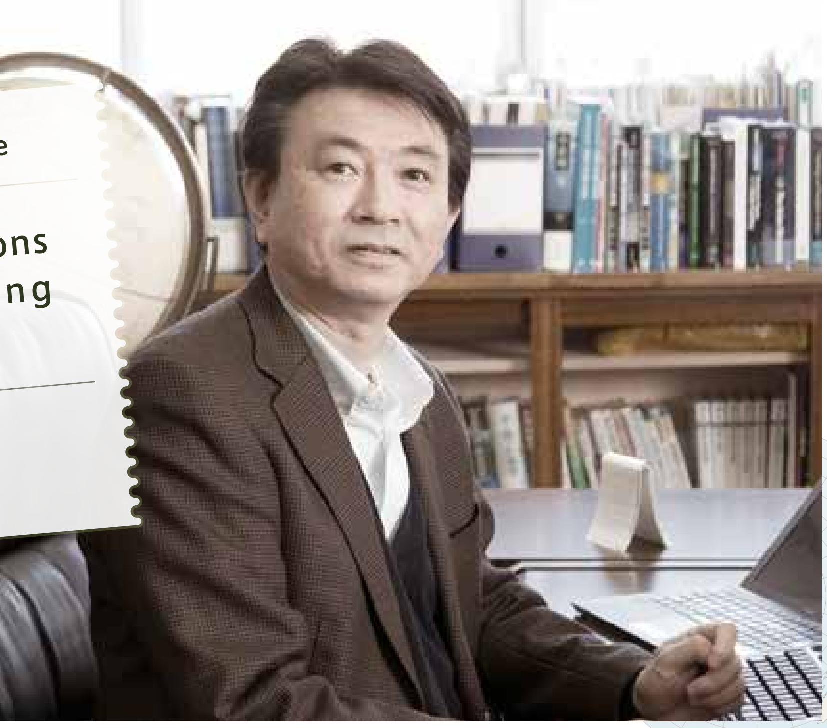
Related Organizations

■ AORI ■ HyARC ■ ISM ■ NIED ■ MRI

Theme D: Precise impact assessments on climate change

How will global warming change typhoons and ecosystems? We tackle oncoming problems that affect all of us.

Representative: Eiichi Nakakita
Vice Director/Professor, DPRI, Kyoto University



How will global warming change typhoons, floods, landslides, and river flows as well as the forests and ocean? This research theme, "Precise impact assessment on climate change," aims to scientifically demonstrate the connection between global warming and natural disasters and to look 100 years into the future to see how serious it may become. For these purposes, we use two analytical methods.

One is a method to quantitatively comprehend how climate changes affect river flows and ecosystems, in addition to natural disasters such as typhoon damage and floods, based on probabilities. We are making efforts to further clarify the impact of climate changes on each of these, based on diverse climate change scenarios and using multiple prediction results simulated by diverse climate prediction models. The other method is one that assesses the impact of climate changes on the worst-case scenario which takes extreme external forces such as super typhoons into consideration. In recent years, "unprecedented disasters" frequently occur not only in Japan but also in countries across the world. We will provide basic information for appropriate countermeasures that will be needed in the future by analyzing, from scientific and engineering perspectives, how much damage the most destructive, unprecedented disasters resulting from climate changes will cause and by extending our understanding to economic damage specifically and numerically.

In this research theme, we are carrying forward research using the above two analytical methods ("probability assessment of future impact" and "future impact assessment based on the worst-case scenario") and are actively exchanging views under the three research sub-themes: "climate change impacts on natural hazards," "climate change impacts on water resources," and "climate change impacts on ecosystems and biodiversity."

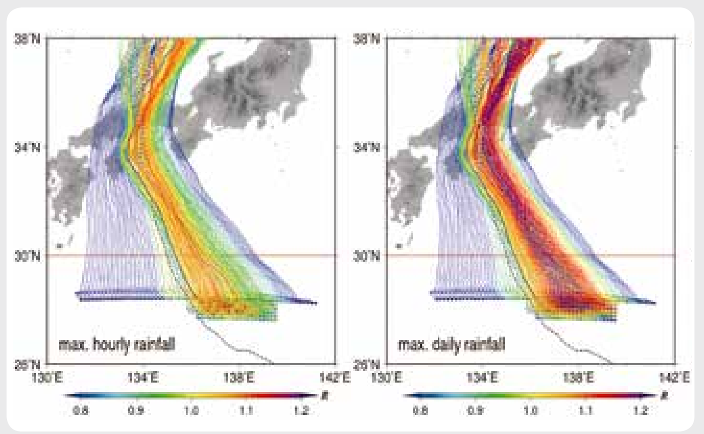


Fig. 1: Setting the worst-case scenario of external climate forces based ensemble simulations of the largest-class typhoon with variant routes:
Analysis of Typhoon No. 12 in 2011: Hourly precipitation (left) and daily precipitation (right) amount differences in the Kii Peninsula as a ratio in comparison with a control experiment

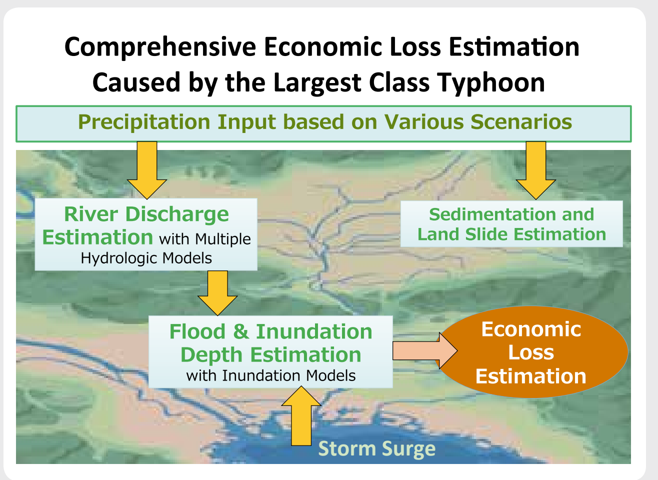


Fig. 2: Impact assessment of a complex disaster, considering river overflows and high tide inundation caused by the largest-class typhoon

Climate change impacts on natural hazards

The first sub-theme, **climate change impacts on natural hazards**, is handled by the Disaster Prevention Research Institute of Kyoto University (DPRI-KU), together with the International Centre for Water Hazard and Risk Management (ICHARM/PWRI). We aim to produce predictions for scenarios covering the worst case particularly for typhoons, which cause the most serious weather-related damage in Japan, concerning the frequency, scale, accompanying precipitation, strong winds, high tides, high waves, and landslides, including during the rainy season.

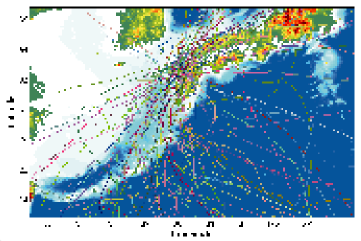


Fig. 3: Path of typhoons calculated by a probability typhoon model

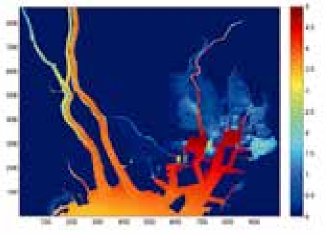
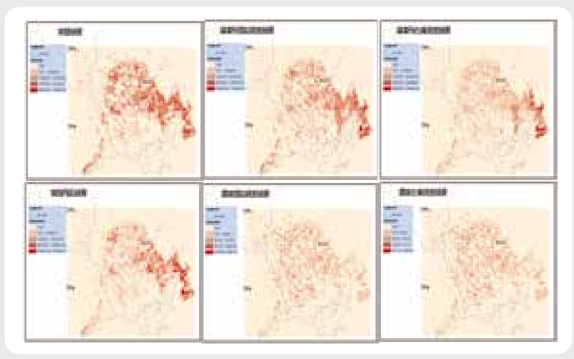


Fig. 4: Pseudo global warming simulation in Ise Bay + High tide inundation under the worst path conditions

Fig. 5: Estimated asset damage amount for Isewan Typhoon (T5915) case



There are approximately 25 typhoons annually and around 10 of those approach or make landfall in Japan. The number of typhoons may not change in the future, but it is known that a small alteration in the path of a typhoon can have an extremely large impact on the amount of rain and wind Japan receives, and as a result, cause immense damage. Specifically, we assess the impact of a complex disaster including precipitation, strong winds, river overflows, and high tide inundation, simulating how different the damage of Isewan Typhoon (T5915) in 1959 would have been if the typhoon had taken a different path, or how powerful or how much damage it would cause if Isewan Typhoon occurs again in the future when the sea surface water temperature has risen due to climate changes (Pseudo global warming experiment; see Fig. 1 to Fig. 5). We also predict and assess how the frequency of "100-year return period" disasters and worst-case damage will change in the coming century. Furthermore, we will use this information to understand the impact on society and for national planning. As shown in Fig. 6, the natural disaster impact assessment covers not only Japan but also major rivers in Southeast Asia, with a special focus on floods and inundations.

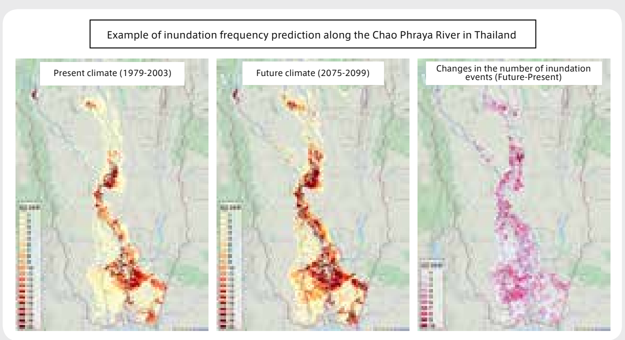


Fig. 6: The number of inundation events in the recent and future 25 years estimated by a rainfall runoff/inundation simulation using MRI-AGCM3.2S (RCP8.5) output

Climate change impacts on water resources

The second sub-theme, **climate change impacts on water resources**, is handled by DPRI of Kyoto University and IIS of Tokyo University. When the climate changes due to global warming, the rain amount and rain patterns change significantly. It is also possible that what formerly fell as snow will change into rain. In Japan, which has many mountainous regions, it is anticipated that this would cause a great change in the "pattern of water flowing into rivers."

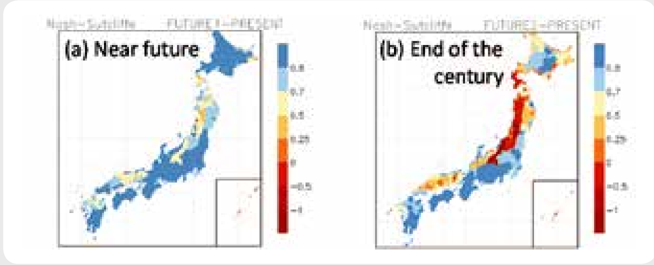
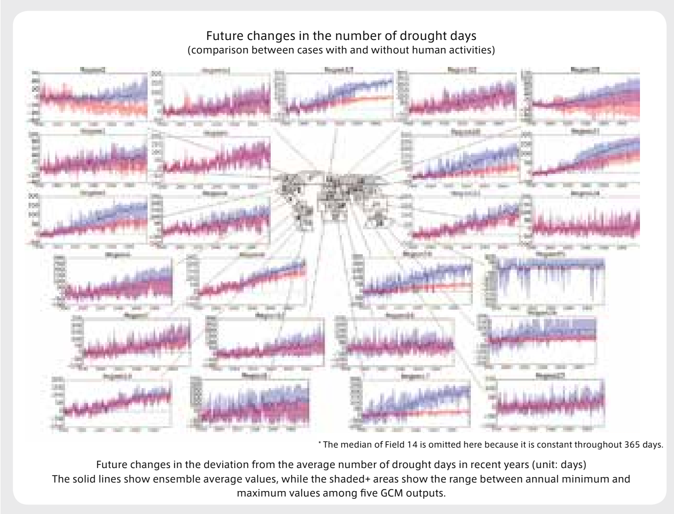


Fig. 7: Prediction of river flow changes in Japan

Related Organizations

■ Hokkaido Univ. ■ Tohoku Univ. ■ Tokyo Univ. ■ Titech ■ HyARC
■ NARO ■ ICHRM ■ NIES

So, the Kyoto University team of this group is predicting and assessing the changes in the flow and supply of water in the main rivers in Japan, the impact on rice farming, etc., and the need for flood control such as dams (see Fig. 7). Similar predictions and assessments are being pursued for the world's major rivers, including in Asia. The University of Tokyo team is predicting and assessing how the actual water cycle will change on a global scale with the addition of artificial modifications. This team is also studying the effectiveness of adaptation strategies (see Fig. 8).



Red: With human activities Blue: Without human activities

Fig. 8: Interannual variability of the number of drought days is small, and the long-term changes in the number are also gradual when human activities (dam operation, water intake, etc.) are taken into consideration.

Climate change impacts on ecosystems and biodiversity

The third sub-theme, **climate change impacts on ecosystems and biodiversity**, is supervised primarily by the Graduate School of Life Sciences at Tohoku University, and other participants include Nagoya University, Hokkaido University, and NIES. We aim to predict and assess whether ecosystems are capable of changing abruptly due to global warming, taking as models the forests of northeastern Japan and the marine life in the ocean near Japan (see Fig. 9). The Tohoku University team is conducting predictions and assessments concerning whether global warming will cause the extinction of alpine plants, the impact of strong wind on forests, the purification effects of forests, changes in tourism resources, etc. The Nagoya University team is conducting predictions and assessments on how climate change alters forest vegetation and then whether the altered forest vegetation affects the climate. The main research sites are Asian rainforests and the eastern boreal in Siberia. The team is studying the changes in the major forests in the world, such as the tundra forest. The team composed of Hokkaido University and NIES focuses on ocean acidification, which occurs when more anthropogenic carbon dioxide dissolves in seawater. The team is predicting and assessing what sorts of changes will occur in coastal marine ecosystems such as coastal reefs and seaweed forests due to global warming and ocean acidification (see Fig. 10).

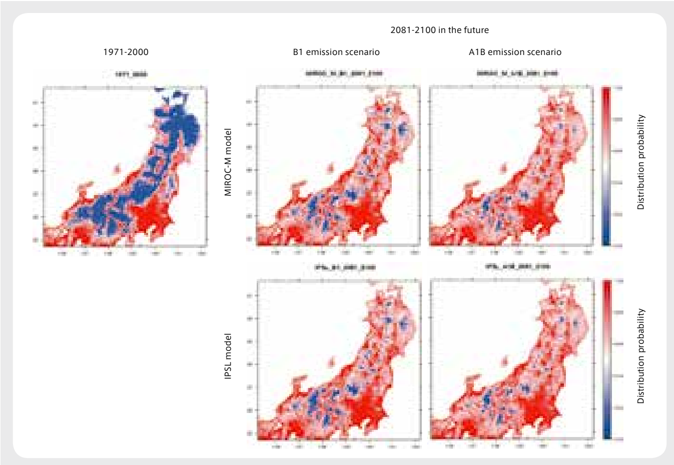


Fig. 9: Expansion of suitable habitats of non-native bamboos (as shown in red) estimated by a species distribution model (random forest)

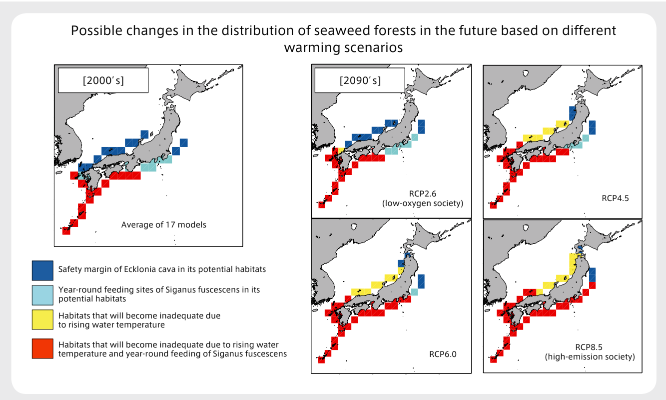


Fig. 10: First future prediction research of temperate seaweed species that form a forest (Ecklonia cava) considering indirect impact of feeding damage in addition to direct impact (stress) of rising water temperature

"A bridge to society" – The Aim of Theme D

Theme D aims to "estimate specific numerical figures of climate change impacts" and to "develop a basic approach which serves as a foundation for adaptation." By providing specific numerical figures, the research can contribute to the adaptation methodology with more concrete ideas. The research results are also expected to be considered as basic data for the government and municipalities to consider how to protect the lives of people in urban and rural areas, coastal areas, and river areas. While predicting the future climate is accompanied by high uncertainty, the participating researchers are pushing forward with their research to generate information required to discover appropriate adaption strategies.

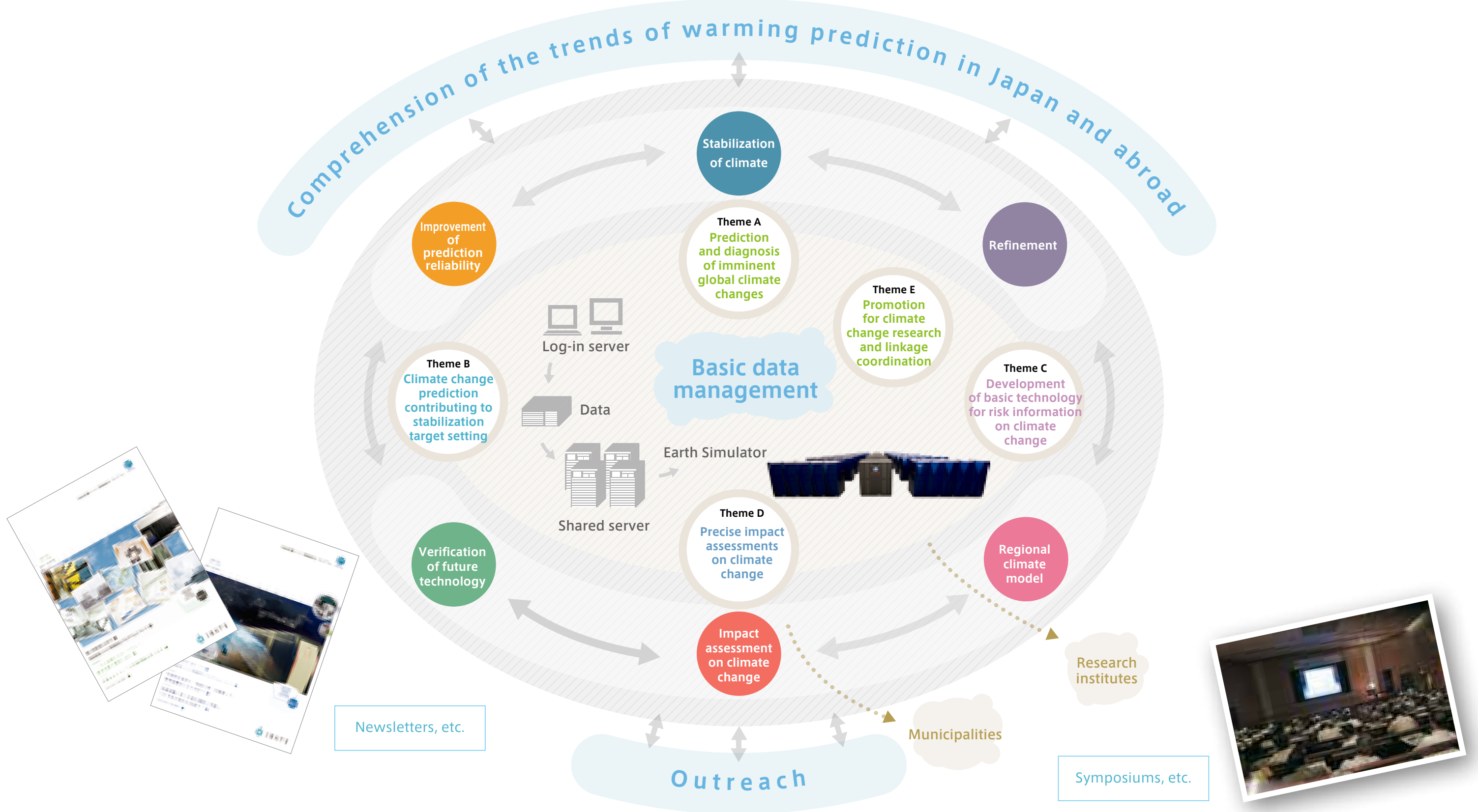
Theme E : Promotion for climate change research and linkage coordination

Summarizing the research result of the SOUSEI Program overall and connecting it to society Theme E plays the role of coordinator

Representative: Michio Kawamiya
Director, Project Team for Risk Information on Climate Change, JAMSTEC

The role of Theme E is to provide coordination and support, including for information collection and publication, in order to derive maximum utilization from the results of the SOUSEI Program and to connect research results to a variety of practical aspects such as disaster prevention and disaster readiness.

Specifically, Theme E comprehends warming prediction trends in Japan and abroad, promotes information sharing among researchers, and coordinates and promotes the linkage of themes A through D to maximize research results efficiently. In addition, Theme E manages risk information obtained through research in a database in an integrated manner and provides opportunities to utilize research results in the real world, using an information network linking all the teams and related institutions. Moreover, Theme E is publishing information on this program by such means as holding symposiums and issuing newsletters, etc.



Outline of Role of Theme E

Theme E serves as a coordinator to ensure the utilization of the research results of the SOUSEI Program for more accurate and precise weather prediction and disaster prevention, including the prediction of extreme weather phenomena, and to make practical use of the results for society.

■ To collect information on the trends of domestic and overseas projects which are closely related to the IPCC and warming prediction, to share such information in this program, and to promote collaboration among researchers by holding Research Coordination Committee meetings, etc.

■ To centralize risk information obtained though research in a database and to classify, organize, and provide technological support for efficient utilization of the data.

■ To conduct public relations activities so that the results of this program become widely known, such as holding public symposiums and issuing newsletters.

List of Research Subjects

Theme A Prediction and diagnosis of imminent global climate change

Representative: Masahide Kimoto
Vice Director/Professor, AORI, the University of Tokyo

Research Subject		Sub-Research Subject	Institutes & Representatives	
(i) Understanding mechanisms of climate variability and change	a	Studies on prediction and predictability of climate variability from interannual to decadal time scales	AORI Associate Professor	Masahiro Watanabe
	b-1	Towards reducing uncertainty in model-based estimation of climate sensitivity	NIES Senior Researcher	Tomoo Ogura
	b-2	Reduction of uncertainty in climate models relevant to climate sensitivity	JAMSTEC Senior Scientist	Masaki Sato
(ii) Development of an integrated prediction system for global climate studies	a	Development of a seamless prediction system for seasonal-to-decadal time scales	MRI Senior Researcher	Masayoshi Ishii
	b	Development of data assimilation technology for optimizing initial and boundary conditions	JAMSTEC Research Unit Leader	Yukio Tanaka

Theme B Climate change projection contributing to stabilization target setting

Representative: Michio Kawamiya
Director, Project Team for Risk Information on Climate Change, Strategic Research and Development Area, JAMSTEC

Research Subject		Sub-Research Subject	Institutes & Representatives	
(i) Long-term global change projection based on diverse scenarios	a	Development of an earth system model dealing with variations of greenhouse gasses, land use change, etc.	JAMSTEC Research Unit Leader	Shingo Watanabe
	b-1	Information gathering and examination on socio-economic scenarios toward stabilization target setting	JAMSTEC Deputy Research Unit Leader	Kaoru Tachiiri
	b-2	Integrated assessment on climate projection experiments and socio-economic scenarios	CRIEPI, Environmental Science Research Laboratory Deputy Associate Vice President	Jyunichi Tsutsui
(ii) Obtaining scientific perceptions on large-scale variations and modifications of climate	a	Development of technologies for numerical investigations on tipping elements and irreversibility of environmental changes (ice sheet collapse, etc.)	JAMSTEC Director	Michio Kawamiya
	b	Development of technologies for numerical investigations on geoengineering (stratospheric aerosol injection, etc.)	JAMSTEC Director	Michio Kawamiya

Theme C Development of basic technology for risk information on climate change

Represenrative: Izuru Takayabu
Director, Atmosperic Environment and Applied Meteorology Research Department, Meteorological Research Institute

Research Subject		Sub-Research Subject	Institutes & Representatives	
(i) Probabilistic climate projection for risk assessment	a	Efficient approach for climate ensemble experiment	NIED Senior Researcher	Koji Dairaku
	b	Development of statistical methodology of ensemble data on climate change	ISM Associate Professor	Genta Ueno
	c	Improvement in cost-efficiency of dynamical downscaling for ensemble data	AORI Associate Professor	Kei Yoshimura
(ii) Producing a standard climate scenario by using super high resolution models	a	Development of quantification method for reliability and uncertainty of climate change information	Tsukuba Univ. Professor	Hiroaki Ueda
	b	Downscaling of the change in future weather extremes by using high-resolution models	MRI Director	Izuru Takayabu
	c	Development of a coupled ocean-atmosphere non-hydrostatic model for typhoon research	HyARC Professor	Kazuhisa Tsuboki

Theme D Precise impact assessments on climate change

Represenrative: Eiichi Nakakita
Vice Director/Professor, DPRI, Kyoto University

Research Subject		Sub-Research Subject	Institutes & Representatives	
(i) Climate change impacts on natural hazards	a	Risk assessment of meteorological disasters under climate change	DPRI, Kyoto Univ. Associate Professor	Tetsuya Takemi
	b	Risk assessment of water-related disasters under climate change	Kyoto Univ. Professor	Yasuto Tachikawa
	c	Risk assessment of coastal disasters under climate change	DPRI, Kyoto Univ. Associate Professor	Nobuhito Mori
	d	Measuring socio-economic impacts of climate change and effectiveness of adaptation strategies	DPRI, Kyoto Univ. Professor	Hirokazu Tatano
	e	Development of risk assessment and adaptation strategies for water-related disaster in Asia	ICHARM Deputy Director	Atsushi Suzuki
(ii) Climate change impacts on water resources	a	Assessment of socio-economic impacts on water resources and their uncertainties under changing climate	DPRI, Kyoto Univ. Associate Professor	Kenji Tanaka
	b	Assessment of climate change impacts on the social-ecological systems of water resources and hydrological cycles	IIS Professor	Taikan Oki
(iii) Climate change impacts on ecosystem and biodiversity	a	Assessment of climatic impacts on ecosystem and biodiversity	Graduate School of Life Science, Tohoku Univ. Professor	Toru Nakashizuka
	b	Economic evaluation of ecosystem science	Graduate School of Life Science, Tohoku Univ. Professor	Toru Nakashizuka
	c	Eco-climate system in Northeastern Eurasia and Southeastern Asian tropics: Impacts of global climate change	HyARC Associate Professor	Tomo'omi Kumagai
	d	Assessment of multiple effects of climate change on coastal marine ecosystem	Hokkaido Univ. Graduate School of Environmental Science Professor	Yasuhiro Yamanaka

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