Climate Change in South Asia

Outputs from GCM

環境省
Ministry of the Environment

Himalaya Mountains

Coffee fruit/India

Ganges river in morning haze

Rainy season in Bangladesh

Paddy field in Bangladesh

1. Outline

1.1 Climate change projections and the need for adaptation

In the 40th session of the International Panel on Climate Change (IPCC) held in October 2014, the Synthesis Report of the Fifth Assessment Report (AR5) of the IPCC was published. In the report, the importance of coping with risks of future climate change was once again pointed out, and it was demonstrated that both mitigation and adaptation measures are essential. A climate change projection dataset (CMIP5) based on a number of climate change projection models was used for the AR5, and the data have served as an important information source for quantitative projections and assessments of uncertainties.

In climate change projections, as well as impact assessments and adaptations performed and undertaken by each country in response to global approaches, the importance of quantitative assessments based on projection data has been increasing. For that reason, each country is using the above-mentioned CMIP5 data after downscaling them, or by establishing its own projection data.

Although climate change is affecting various sectors, the degree of certainty and the time scale of impacts vary from sector to sector. To establish appropriate adaptation strategies in such a situation, it is important to perform risk assessments and cost-benefit analyses, by appropriately handling and analyzing quantitative projection data.

1.2 Outline of global climate change projection data and its intention

Outline of the data

The Ministry of the Environment, with the cooperation of Japan Meteorological Agency, created a climate change projection dataset with a view to performing impact assessments and drawing up adaptation measures in Japan. This dataset is composed of two types of model output: global climate model outputs and regional climate model outputs. The global climate model outputs (hereinafter referred to as “GCM data”) are the results of calculations using an atmospheric model covering the entire world with an image resolution of about 60 km. The periods covered by the data are “20 years of the present climate” and “20 years of the future climate” (the end of the 21st century).

The most important feature of the dataset is that the results of calculations based on multiple cases are provided. We performed calculations on three cases for the present climate, and on three cases each for RCP2.6, RCP4.5 and RCP6.0 scenarios with different emissions scenarios, and on nine cases for RCP8.5 scenario, totaling 21 cases. The reason for performing calculations on multiple cases for the same scenario is to take into consideration uncertainties associated with future sea surface temperature patterns and a simulation method (which is called the “cumulus convection scheme”) of climate change projection models.

Intention of the data

Although the data is created mainly for performing impact assessments required to establish the climate change adaptation plan in Japan, the GCM data is based on projections covering the entire world. Therefore, basically the data are available in any countries.

The GCM data has the following features, compared to the results of other existing climate change projections.

- The GCM data has higher image resolution, compared to that of CMIP5’s global model outputs. The purpose of increasing image resolution is to enhance the reproducibility of orographic meteorological phenomena and tropical phenomena such as tropical cyclones.
- While model outputs by many organizations are available on CMIP5, the GCM dataset is based on projection results by a single model. However, multiple cases are calculated in the dataset in considearation of uncertainties, therefore, it is possible to assess uncertainties to a certain degree by the GCM data only.

2. Overview of climate change and its impacts in South Asia

We briefly review climatic conditions and observed climate change and its impacts in South Asia as below, based on reports prepared by India[1] and Bangladesh[2] .

2.1. Climate change and its impacts in India

Climatic conditions

The Himalaya Mountains lie in the northern part of mainland India. The country is surrounded by the Bay of Bengal to the southeast, by the Indian Ocean to the south, and by the Arabian Sea to the southwest. The total land area is about 3,280,000 km^2. Climatic conditions vary widely from region to region. While the difference in temperatures between summer and winter in the northern region is very large due to the influence of the continental climate, the climate in the coastal region is mild throughout the year with a lot of precipitation. The patterns of rainfall vary from region to region. The distribution of annual precipitation ranges widely from 13 mm to 1,187 mm.

Observed climate change

During the period 1901-2007, an increase in the annual mean temperature of 0.56℃ was observed. In particular, the increase of temperature has been accelerating abruptly in recent years. Temperature increases in winter and in the post-monsoon period are especially conspicuous. During the past 100 years, the temperature has increased 0.70℃ in winter and 0.52℃ in the post-monsoon period.

Although the amount of precipitation during the monsoon season has been increasing across India, the rate of increase is not significant. However, observed values of daily precipitation show the fact that the number of occurrences of localized torrential rains is increasing in various parts of India, and cases of localized torrential rains have increased since 1980 in particular.

Climate change impacts

- Impact on water resources: After floods, climate extremes with drought occur frequently and have impacts on the usability of water.
- Impact on the Himalayan glacier: The glaciers in the Himalaya Mountains have been rapidly melting in recent years, and it is confirmed by studies that glaciers have diminished at all observation points during the past 30 years.
- Impact on forest resources and biodiversity: Forests are diminishing due to explosive increases of harmful insects and wildfire in forest due to temperature rising, in addition to human impacts such as excessive deforestation.
- Impact on human health: The frequency of heat waves lasting for more than several days has been increasing during the past 100 years. There are also concerns about increasing incidences of infectious diseases such as malaria, dengue fever, and yellow fever, caused by growing mosquito populations due to temperature rising.

1 Descriptions about India are based on the following literature.
"Second Communication to the United Nations Framework Convention on Climate Change", prepared by the Ministry of Environment & Forests, Government of India (2012)
2 Descriptions about Bangladesh are based on the following literature.
"Second National Communication of Bangladesh to the United Nations Framework Convention on Climate Change", prepared by the Ministry of Environment and Forests, Government of the People's Republic of Bangladesh (October 2012)

2.2. Climate change and its impacts in Bangladesh

Climatic conditions

Bangladesh is bounded by India to the west, to the north and to the northeast. It borders on Myanmar to the southeast and faces the Bay of Bengal to the south. The Himalaya Mountains lie on the northern border. The Tropic of Cancer runs through the center of the country. Its land area is about 147,570 km^2.

Except for the northern region bounded by the Himalaya Mountains and the northeastern and southeastern regions surrounded by hills, Bangladesh is essentially a low elevation flatland, and 80% of the territory is in the floodplain of three major rivers. The country has a semi-tropical monsoon climate, and the annual mean temperature of the entire land area is about 25℃. The country' s annual mean precipitation is about 2,200 mm, and about 85% of annual precipitation is recorded during the months from April to September. There is a distinct difference in the amount of precipitation between the rainy season and the dry season.

Observed climate change

According to weather observations, the annual mean temperature increased 0.016℃ each year, the annual mean highest temperature increased 0.02℃ each year, and the annual mean lowest temperature increased 0.012℃ each year, during the period between 1977 and 2008. Regarding the change in the amount of precipitation, there is a tendency for it to vary from season to season. While the amount of precipitation during the pre-monsoon period (March-May) is on a decreasing trend, that during the monsoon season (June-September) and the post-monsoon period (October-December) is on an increasing trend. During the period 1977-1998, the average sea level increased 5.05-7.4 mm/year.

Climate change impacts

- Impact on the frequency and the power of cyclones: In recent years, strong cyclones have hit the country successively with short intervals, and according to some viewpoints, there has been affected by increases in sea surface temperatures.
- Impact on forest resources and biodiversity: In the Sundarbans, which is the world's largest mangrove forest and a treasure house of biodiversity, habitats of plants and animals are being affected by the impacts of cyclones and seawater immersion on the ecosystem.
- Impact on human health: With an increasing number of mosquitoes due to increasing temperature and humidity, there have been serious cases of the dengue fever epidemic in the three cities of Dacca, Chittagong, and Khulna since the summer of 2000.
- Impact on urban areas: In Dacca, where urbanization is progressing, the urban heat island phenomenon is being exacerbated. There are also serious cases of landslides in urban areas due to extreme torrential rain.

Paddy field in India

3. Climate change projections in South Asia

Based on GCM data, we calculated future changes in temperatures and precipitation in India and Bangladesh.

3.1. Projections of temperature

Fig. 1 shows changes in temperatures in the entire South Asian region. Temperature has an increasing tendency in all scenarios and cases. There is a difference in patterns of temperature increase among regions, and the magnitude of temperature increase at high latitudes and around the Himalaya Mountains is large.

Fig. 2 shows changes in average temperatures in India and Bangladesh. In every scenario, there is a significant tendency of temperature increase. In the case of the RCP8.5 scenario, in which emissions are the largest, the magnitude of temperature increase is about 3-5℃. (For reference, the increase in global mean temperatures based on the same data is about 3.5-4℃.)

3.2. Projections of precipitation

Fig. 3 shows changes in annual precipitation in the entire South Asian region. Unlike the case of temperature, there are both areas where the amount of precipitation shows an increasing tendency and where it shows a decreasing tendency; also, there are many areas with high uncertainties (areas where no meshing is provided on the map). Under the RPC8.5 scenario, there is a tendency that precipitation will generally increase in various regions in India and Bangladesh.

Fig. 4 shows the amount of precipitation in India and Bangladesh. In every scenario, precipitation is following an increasing tendency on the average, but the actual tendency is not significant because of the existence of large uncertainties.

Fig. 5 shows the tendency of changes in precipitation by season under the RCP8.5 scenario. The difference of tendencies by season is large, and precipitation from September to November follows an increasing tendency and that from December to February a decreasing tendency.

3.3. Reference: Reproducibility of the present climate

To verify the validity of the climate model, we compared the mean temperature and precipitation at the present period to an observation data (Fig. 6). Relative tendencies within the South Asian region seem to be reproduced well generally, however there are some differences in the local scale.

Field mustard in Bangladesh

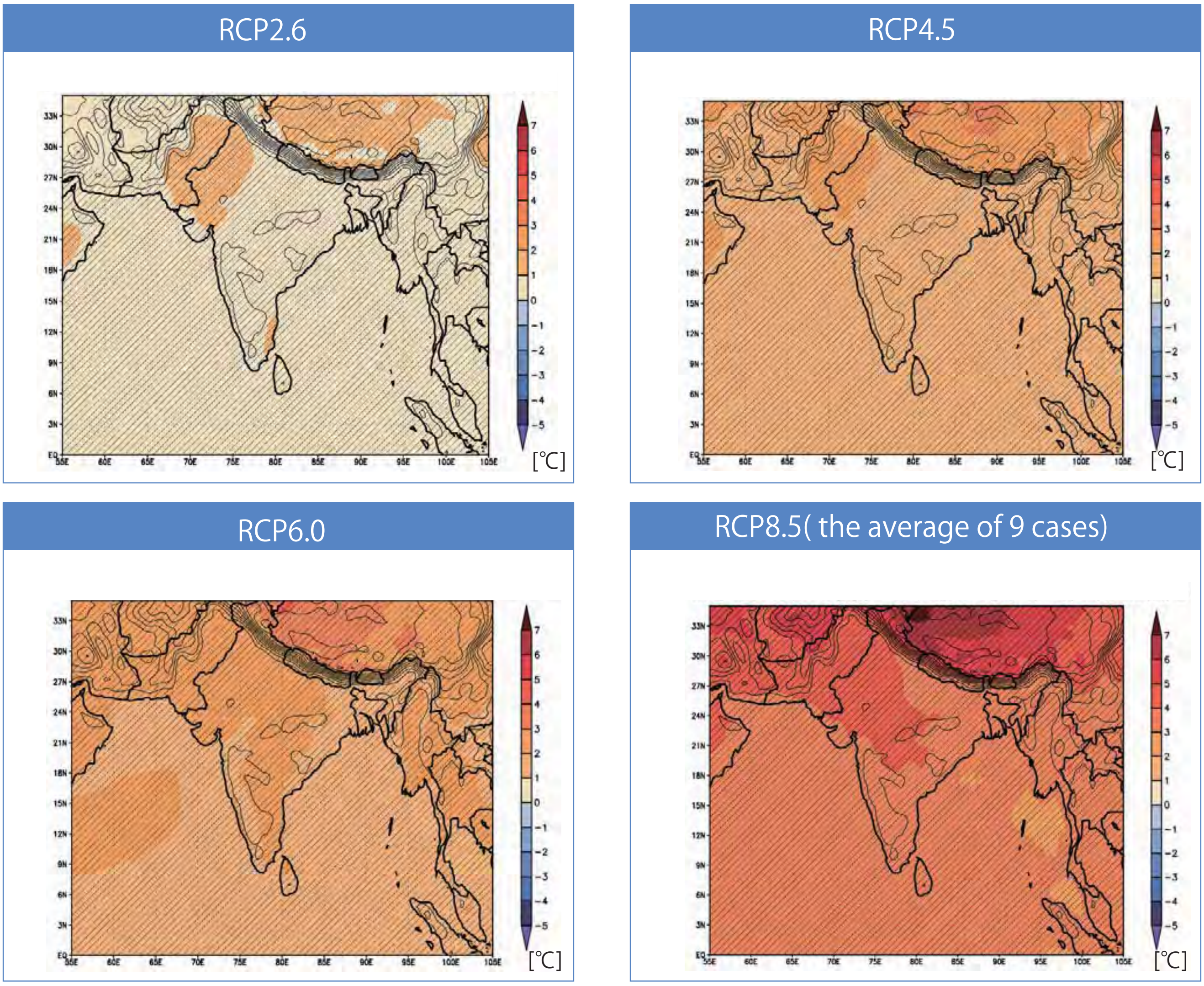

Fig. 1 Changes in annual mean surface temperatures (℃) in South Asia under each RCP scenario
Differences in temperatures between present climate (1984-2004) and future climate (2080-2100) are shown. Colors indicate average values of the three cases under the RCP2.6, 4.5, and 6.0 scenarios, as well as those of the nine cases under the RCP8.5 scenario, and the meshing indicates the areas where the tendency of future changes agrees among all cases (areas with high confidence). For reference, the topography of the climate model is shown with contour lines (the topography is modeled; therefore, it may differ from the actual topography).

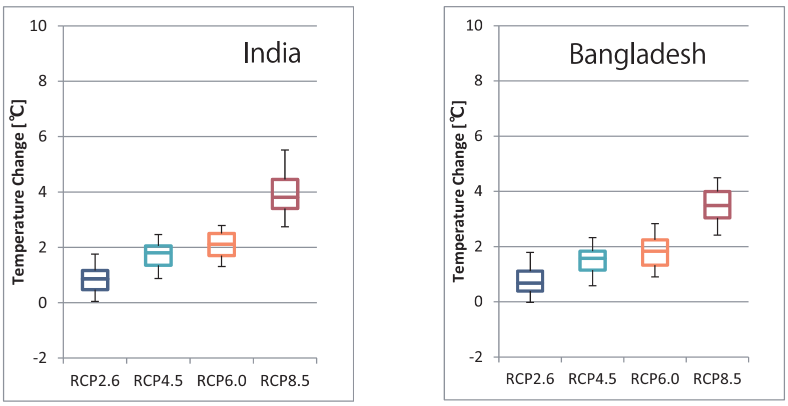

Fig. 2 Changes in annual mean surface temperatures (℃) under each RCP scenario in India (left) and Bangladesh (right)
Summary of the magnitude of temperature increases for each RCP scenario. Box plots indicate 25-75 percentile ranges and central values, and error bars indicate 5-95 percentile ranges. The magnitude of temperature changes is indicated by the difference from the mean temperatures of the present climate (1984-2004). For each RCP scenario, aggregations are made for all years and for all cases.

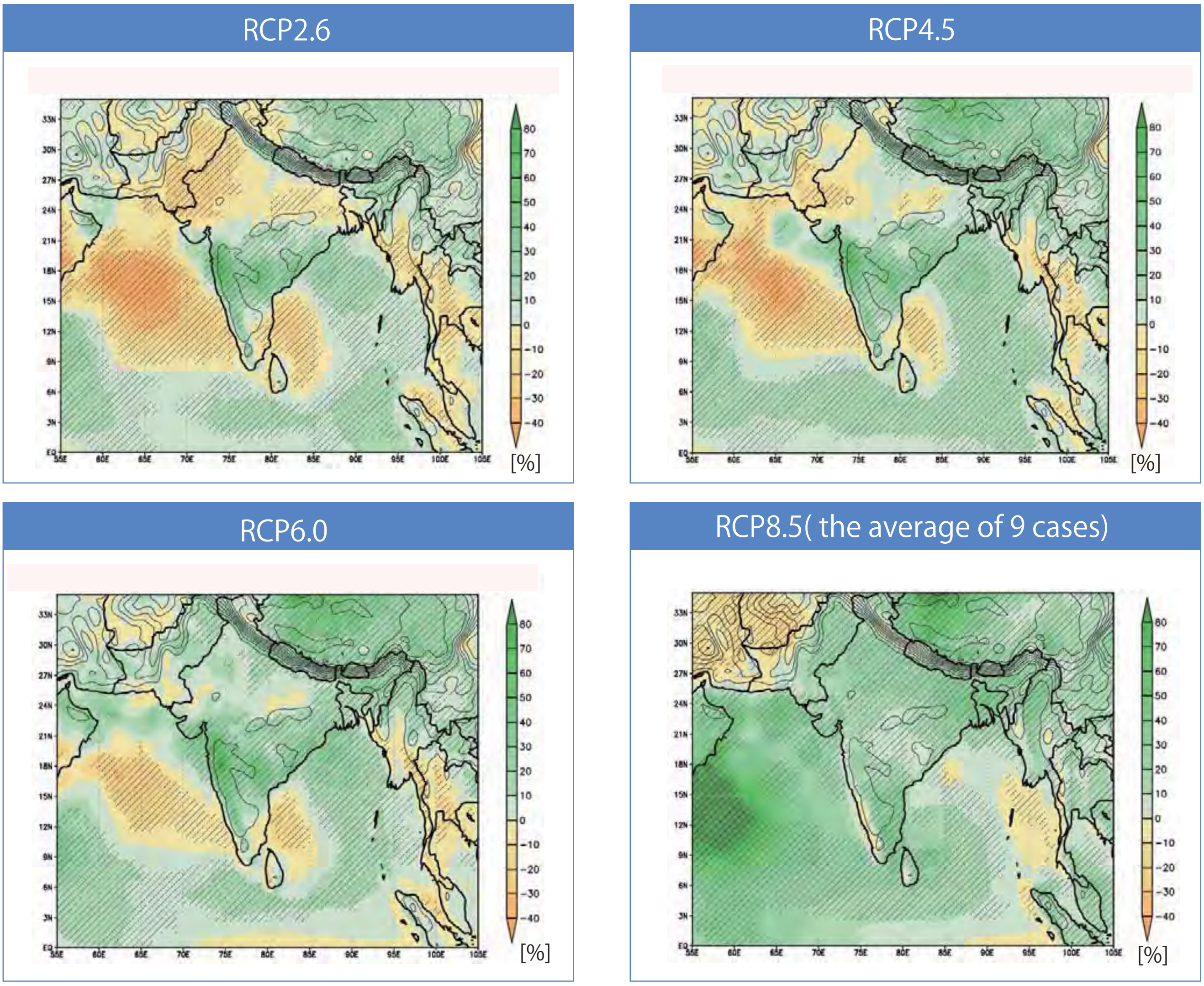

Fig. 3 Changes (%) in annual mean precipitation under each RCP scenario in South Asia
Differences in precipitation between present climate (1984-2004) and future climate (2080-2100) are shown. Colors indicate average values of the three cases under the RCP2.6, 4.5, and 6.0 scenarios, as well as those of the nine cases under the RCP8.5 scenario, and meshing indicates the areas where the tendency of future changes agrees among all cases (areas with high confidence). For reference, the topography of the climate model is shown with contour lines (the topography is modeled; therefore, it may differ from the actual topography).

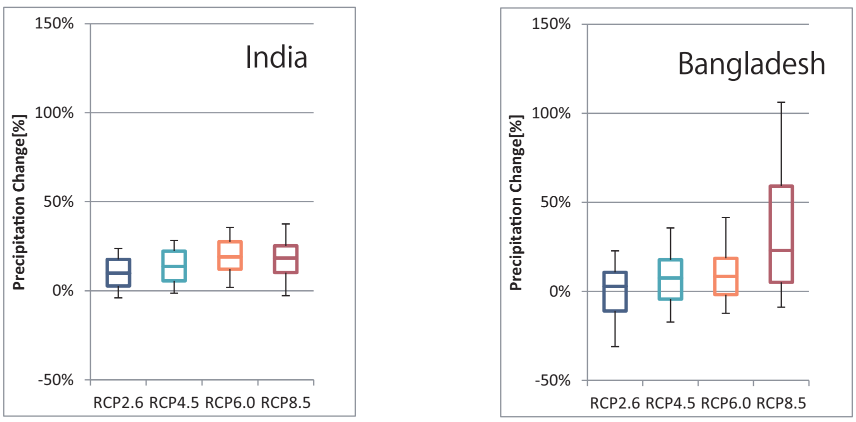

Fig. 4 Changes (%) in annual mean precipitation under each RCP scenario in India (left) and Bangladesh (right)
Summary of the changes in annual mean precipitation for each RCP scenario. Box plots indicate 25-75 percentile ranges and central values, and error bars indicate 5-95 percentile ranges. The magnitude of precipitation changes is indicated by the difference from the mean precipitation of the present climate (1984-2004). For each RCP scenario, aggregations are made for all years and for all cases.

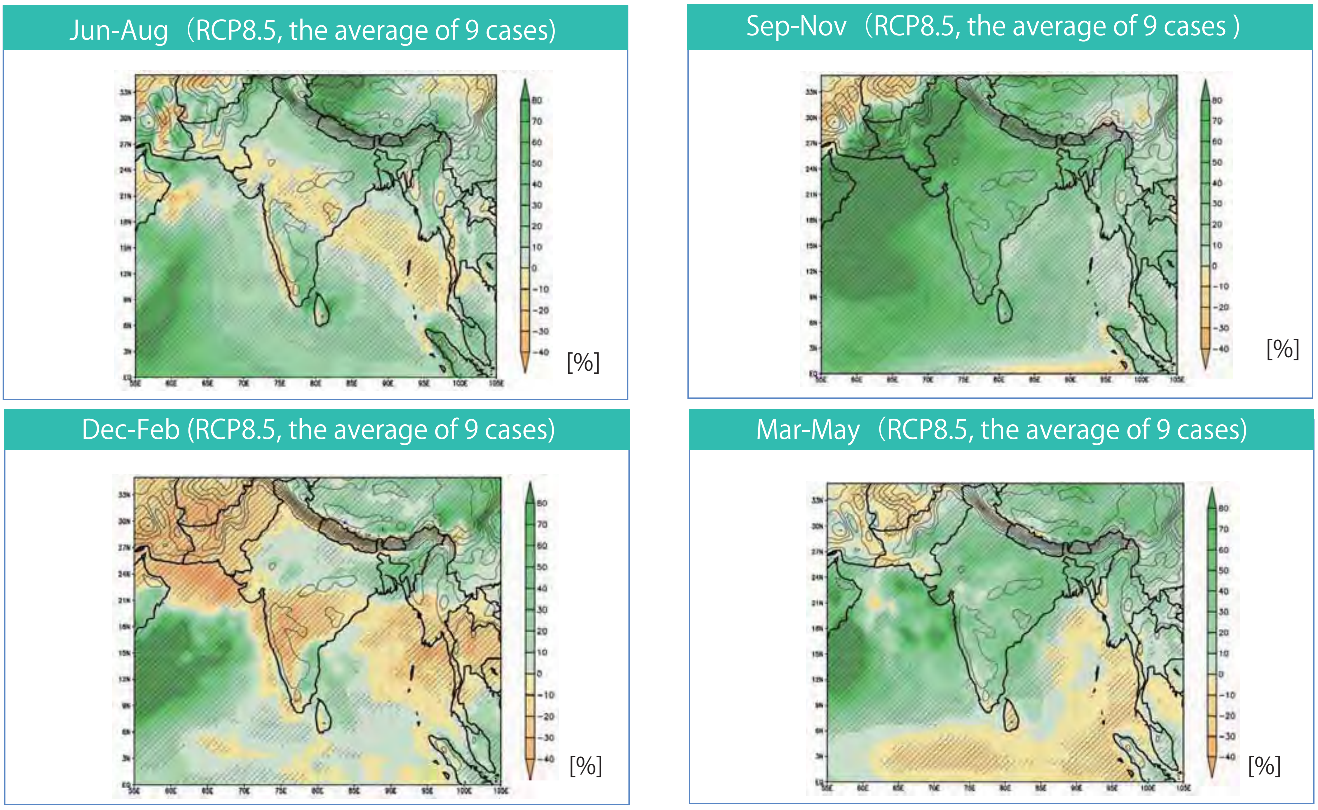

Fig. 5 Changes (%) in precipitation by season in South Asia
Differences between present climate (1984-2004) and future climate (2080-2100) under the RCP8.5 scenario are shown. The meshing indicates the areas where the tendency of future changes agrees among all cases (areas with high confidence). For reference, the topography of the climate model is shown with contour lines (the topography is modeled; therefore, it may differ from the actual topography).

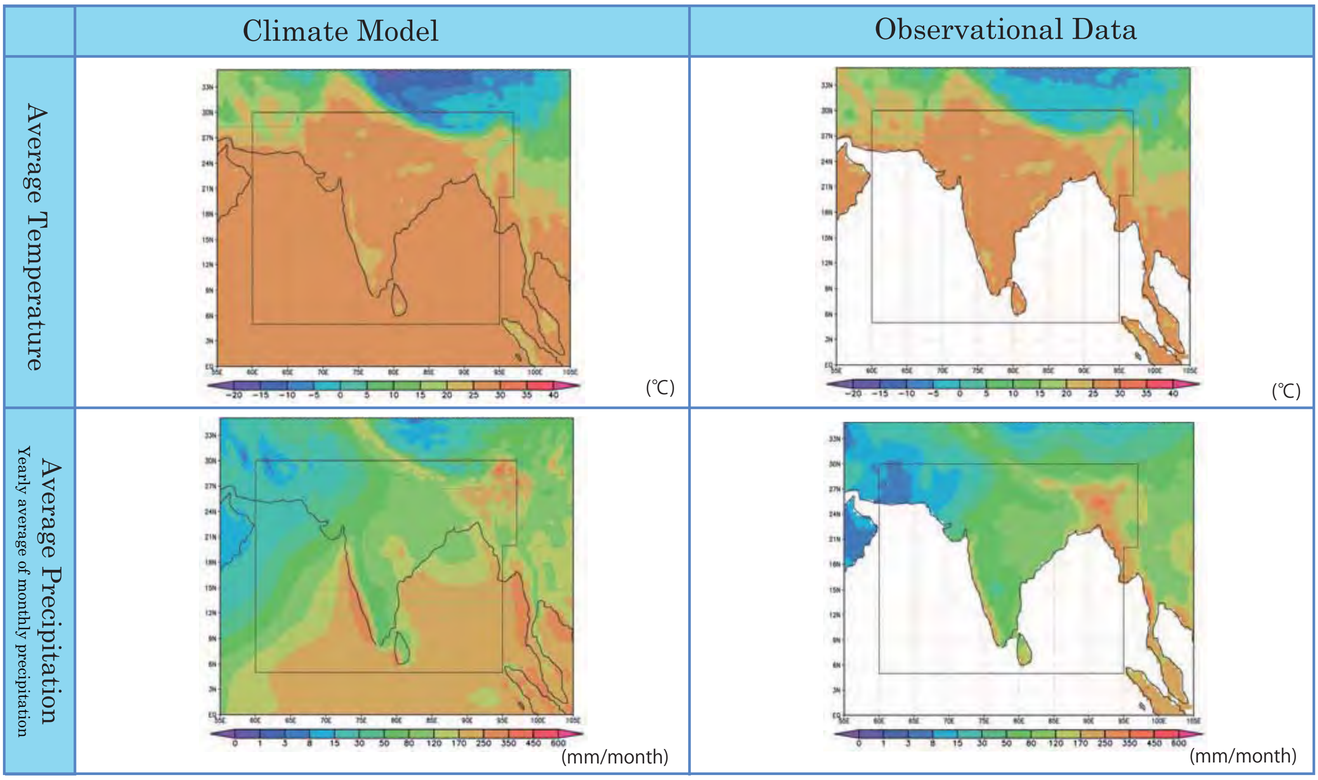

Fig. 6 Reproducibility of temperatures and precipitation in the present climate
Comparison between the average values of the present climate (1984-2004) based on the climate model and observed data during the same period (CRU_TS3.21). There are differences between model altitude data and actual altitude data, but no altitude corrections are made on these maps. Accordingly, we need to note that some differences in temperature may be generated because of such differences in altitude data.

4. Summary

As can be seen from the results in this publication, it is possible to grasp future climate changes in each region based on GCM data. Although the results use only fundamental variables, the dataset contains other variables as well.

The results in this publication do not replace the existing dataset (CMIP5 etc.), but rather can be used complementarily. From the features of the data that resolution is relatively high and multiple cases are studied, we consider that it can be used as a good dataset to grasp the situation of climate change in individual countries, and also as input data for climate change impact assessments.

The Ministry of the Environment Japan (MOEJ) hopes that this dataset will contribute to promoting climate change adaptation planning in all countries in the world.

■ Specifications of GCM data and data access

Specifications of calculation of climate projections

(Published in FY2014)

Name	Global Climate Change Projection Data by MOEJ (in cooperation with JMA)
Model name	MRI-AGCM3.2H
Model type	Atmospheric model
Horizontal resolution	About 60 km
Emissions scenarios	RCP2.6, RCP4.5, RCP6.0, and RCP 8.5
Calculation period	Present climate: September 1984 - August 2004 Future climate: September 2080 - August 2100
Grid points	640 × 320 (horizontal) and 60 layers (vertical)
Cumulus convection scheme	Yoshimura scheme/Kain-Fritsch scheme/ Arakawa-Schubert scheme
Main input conditions	Concentration of greenhouse gasses, ozone, and aerosols, sea surface temperature, sea ice concentration, and sea ice thickness

Data access

- This dataset is stored in the “Data Integration and Analysis System” (DIAS) implemented by the “Program for Integration and Fusion of Earth Environment and Observation Information” of the Ministry of Education, Culture, Sports, Science and Technology, and is published. Registered users of DIAS can access and acquire data on the following website.
- Data access website (registration required)
  Global Climate Model Calculation Results (dataset ID: GCM60_ADAPT2013)

  http://dias-dss.tkl.iis.u-tokyo.ac.jp/dl/storages/filelist/dataset:214

Tea cultivation in South Asia

Tea garden in India

Orchid (Paphiopedilum venustum) in India

Acknowledgements

To create this publication, research experts from Atmospheric Environment and Applied Meteorology Research Department and Climate Research Department of the Meteorological Agency kindly gave guidance and instructions, from their technical perspectives, about how to conduct climate projection analysis using GCM and how to compile the calculation results. Their precious comments and advices are highly appreciated.

Planning：Ministry of the Environment, Japan
Editing：Mitsubishi Reserach Institute, Inc.
Design：D Japan, Inc.

Climate Change
in South Asia

Outputs from GCM

Cover: Paddy field in South Asia

Contact

Ministry of the Environment (Japan)
Global Environment Bureau, Policy Planning Division, Research and Information Office
17th Floor Daido Seimei Kasumigaseki Building1-4-2 Kasumigaseki Chiyoda-ku, Tokyo 100-0013 Japan
Tel: +81 3 5521 8247