

*Climate Change*

*in Mongolia*

*Outputs from GCM*





Edelweiss/Meadow in Mongolia



Winter in Mongolia



Pasturing of horse



Desert of Gobi



Yurts in meadow

## 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 consideration 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 Mongolia

We briefly review climatic conditions and observed climate change and its impacts in Mongolia as below, based on a report prepared by Mongolia.

### 2.1. Climatic conditions in Mongolia

Mongolia is a landlocked country surrounded by Russia and China and it is located at between 41° 35' and 52° 06' north latitude, and at between 87° 47' and 119° 57' east longitude. Its total land area is 1,564,116 km<sup>2</sup>. It is surrounded by high mountains and it is located on a highland over 1,500 meters above sea level (the average altitude: 1,580m).

The country has distinct four seasons, large temperature fluctuations, and little precipitation. The climate varies widely from region to region, not only due to differences in altitude, but those in latitude. The annual mean temperature is between -8°C and 6°C, and the annual mean precipitation is between 50 mm (Gobi Desert) and 400 mm (Northern mountain district). About 85% of the annual precipitation is recorded during the months from April to September. And the annual mean temperature has increased by 2.14 °C for the years from 1940 until 2000.

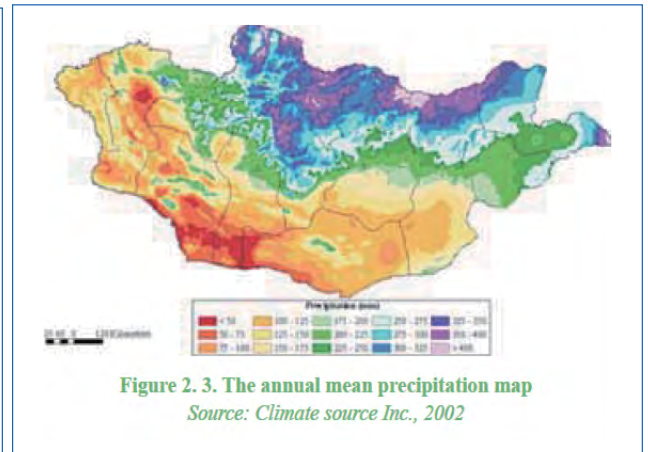
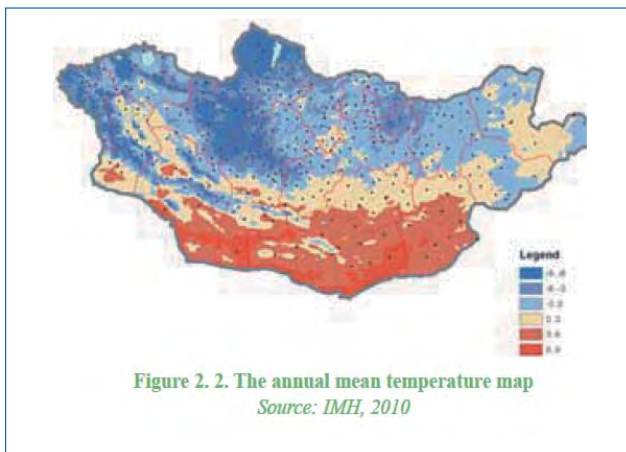


Fig. 1 Annual mean temperature (left) and annual mean precipitation (right) in Mongolia (Mongolia Second National Communication, 2010, p.41)

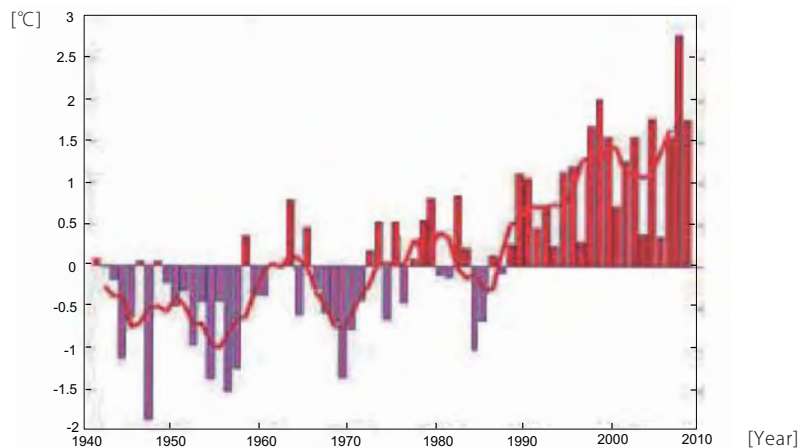


Fig. 2 Change in annual mean temperature in Mongol (Anomaly from mean temperature between 1961 and 1990) (Mongolia Second National Communication, 2010, p.98)

## 2.2. Observed climate change

According to weather observations, an increase in temperature of 2.14°C is confirmed between 1940 and 2008. Regarding rainfall, there is a tendency for precipitation in winter to decrease, while that in summer to increase.

The number of days of dust storms has increased significantly. The number, which was just 18 days in 1960, increased to 57 days in 2007. It is said that this is attributed to the weather being drier than before.

Livestock of nomads is susceptible to changes in the natural environment. Cold and snow damage called "Zud" (extremely cold situation where the temperature goes down to the range of 40-50°C below zero) causes enormous economic damage when it occurs. Fig.3 shows chronological fluctuations of Zud indices. The figure demonstrates that as the value increases, snow damage increases (thus, economic damage increases). The frequency of Zud followed a decreasing tendency until the early-1990s, but it has been increasing since then.

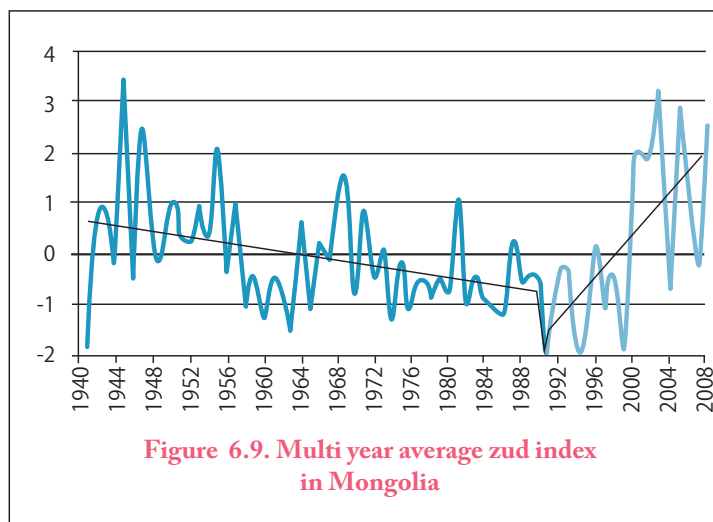


Fig. 3 Interannual fluctuations of Zud index in Mongolia (Mongolia Second National Communication, 2010, p.101)

## 2.3. Observed climate change impacts

In Mongolia, the following climate change impacts have been confirmed in each sector.

- Ecosystem: Between 1992 and 2006, the area of barren land (land without grasses) expanded 3 times, while the area of woodland decreased by 26%.
- Rangeland: During the past 40 years, biomass in the rangeland decreased by 20-30%.
- Pasture insects and rodents: The number of pasture insects and rodents has been increasing due to climate change, droughts, and climate extremes. Increases in the numbers of grasshoppers and rodents are especially conspicuous.
- Desertification: About 70% of the grassland in the country is under the influence of desertification.
- Water resources: In 2003 and 2007, surface water inventory was investigated, and it was found that many rivers, lakes and ponds had run dry.
- Cryosphere: The annual average snow depth during the past 30 years is following a decreasing tendency in the northern mountain areas, while it is following an increasing tendency in the eastern and southern regions. The timing at which accumulated snow disappears has advanced by about one month. Snow accumulation zones are predicted to decrease in the future.

### 3. Climate change projections in Mongolia

Based on GCM data, we calculated future changes in temperatures and precipitation in the East Asian region and Mongolia.

#### 3.1. Projections of temperature

Fig. 4 shows changes in temperatures in the area of Asia including the East Asian region and the Tibetan Plateau. 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. 5 shows changes in average temperatures in Mongolia. Changes during the period 2080-2100 for each case are shown in the figure to the left, and aggregated ranges of temperature changes in the figure to the right. In every scenario, there is a clear tendency of a temperature increase. In the case of the RCP8.5 scenario, in which emissions are the largest, the magnitude of temperature increase is about 5-6°C. (For reference, the increase in global average temperatures based on the same data is about 3.5-4°C.)

#### 3.2. Projections of precipitation

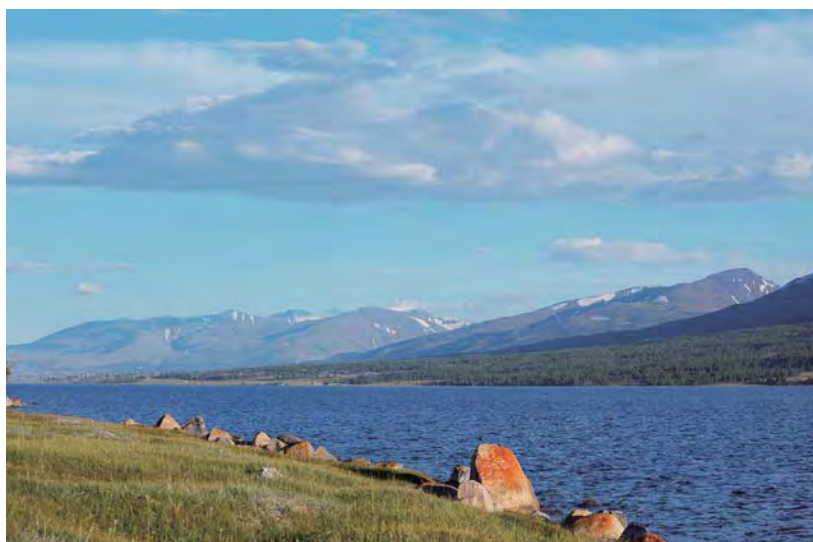
Fig. 6 shows changes in annual precipitation in the area of Asia including the East Asian region and the Tibetan Plateau. Changes are expressed in terms of the ratio against the present climate. Unlike the case of temperature, there are both regions where the amount of precipitation shows an increasing tendency and where it shows a decreasing tendency; furthermore, there are many areas with high uncertainties (areas where no meshing is provided on the map). Under the RCP8.5 scenario, there is a tendency that precipitation will generally increase in areas around Mongolia.

Fig. 7 shows the amount of precipitation within Mongolia. Changes during the period 2080-2100 for each case are shown in the figure on the left, and the aggregated ranges of temperature changes in the figure on the right. In every scenario, the degree of uncertainty is high, and in the case of the RCP8.5 scenario, precipitation has a tendency to increase.

Fig. 8 shows the tendency of changes in the amount of precipitation by season under the RCP8.5 scenario. Precipitation has a tendency to increase in every season in Mongolia, and the increase rate in winter is especially high.

#### 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. 9). Relative tendencies within the Asian region seem to be reproduced well generally, however there are some differences in the local scale.



Lake in field

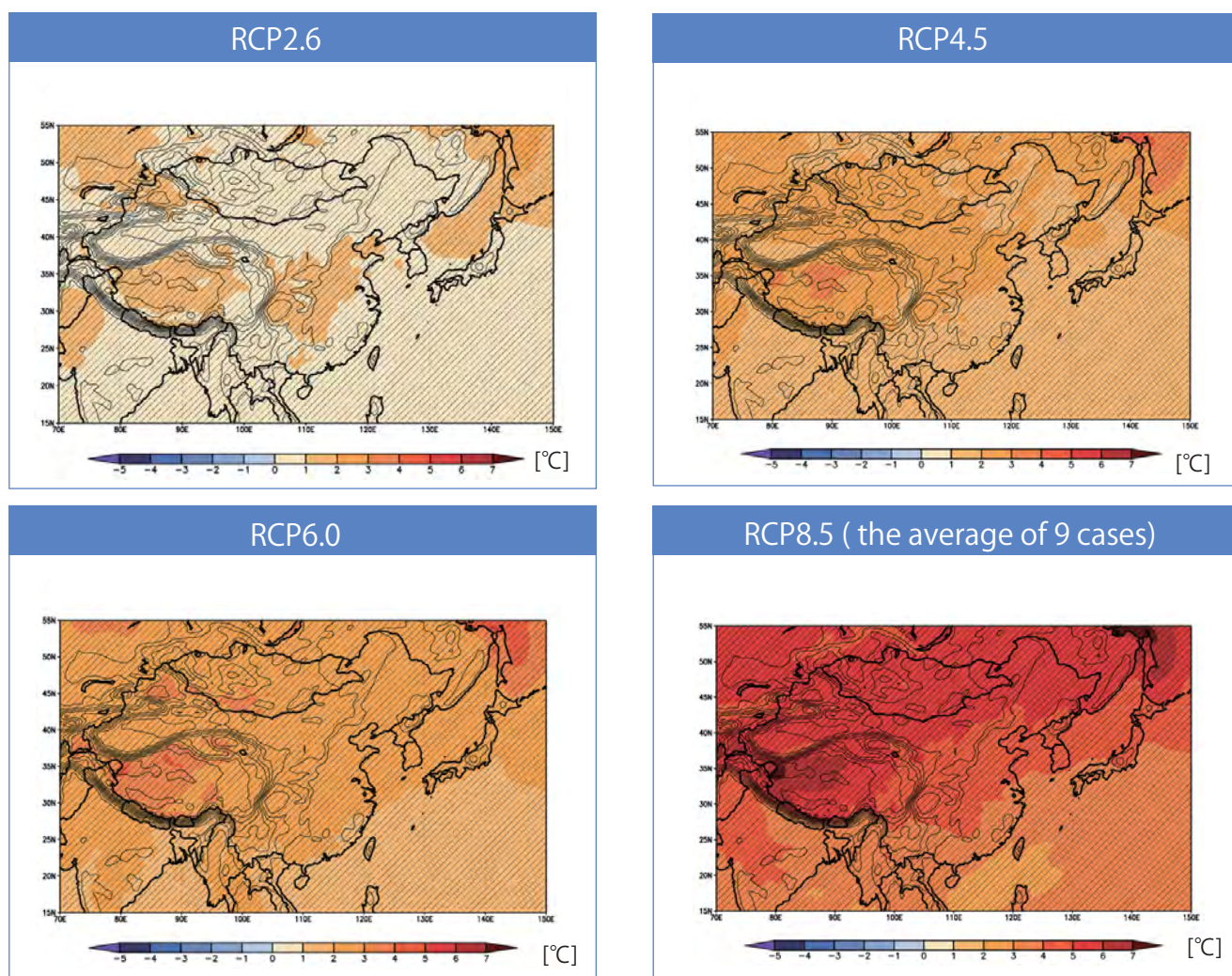


Fig. 4 Changes in annual mean surface temperatures (°C) in Mongolia under each RCP scenario. Differences in temperatures between present climate (1984-2004) and future climate (2080-2100) are shown. Colors indicate average values of the three cases under the RCP2.6, 4.5, and 6.0 scenarios, as well as 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).

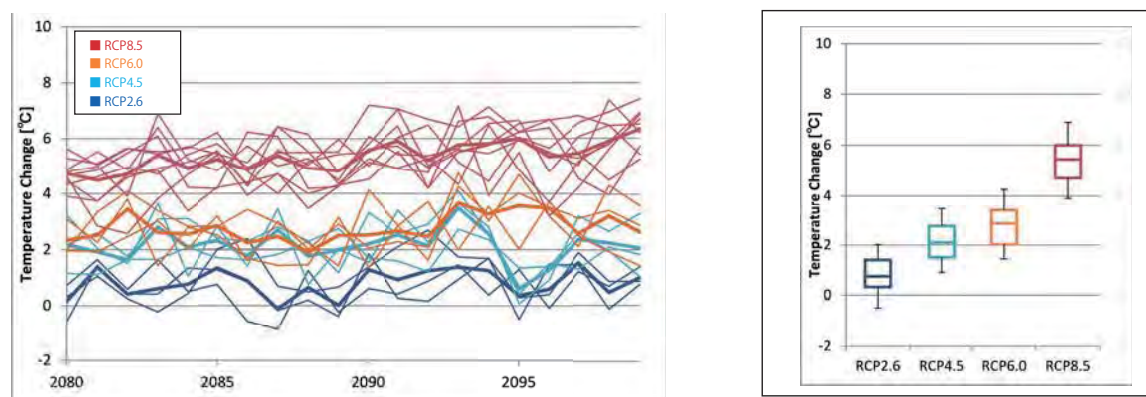


Fig. 5 Changes in annual mean surface temperatures (°C) under each RCP scenario in Mongolia. Left: Chronological changes in annual temperatures. Thin lines indicate the results of each case and thick lines indicate the mean values of multiple cases. Right: Summary of the magnitude of temperature increases 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.

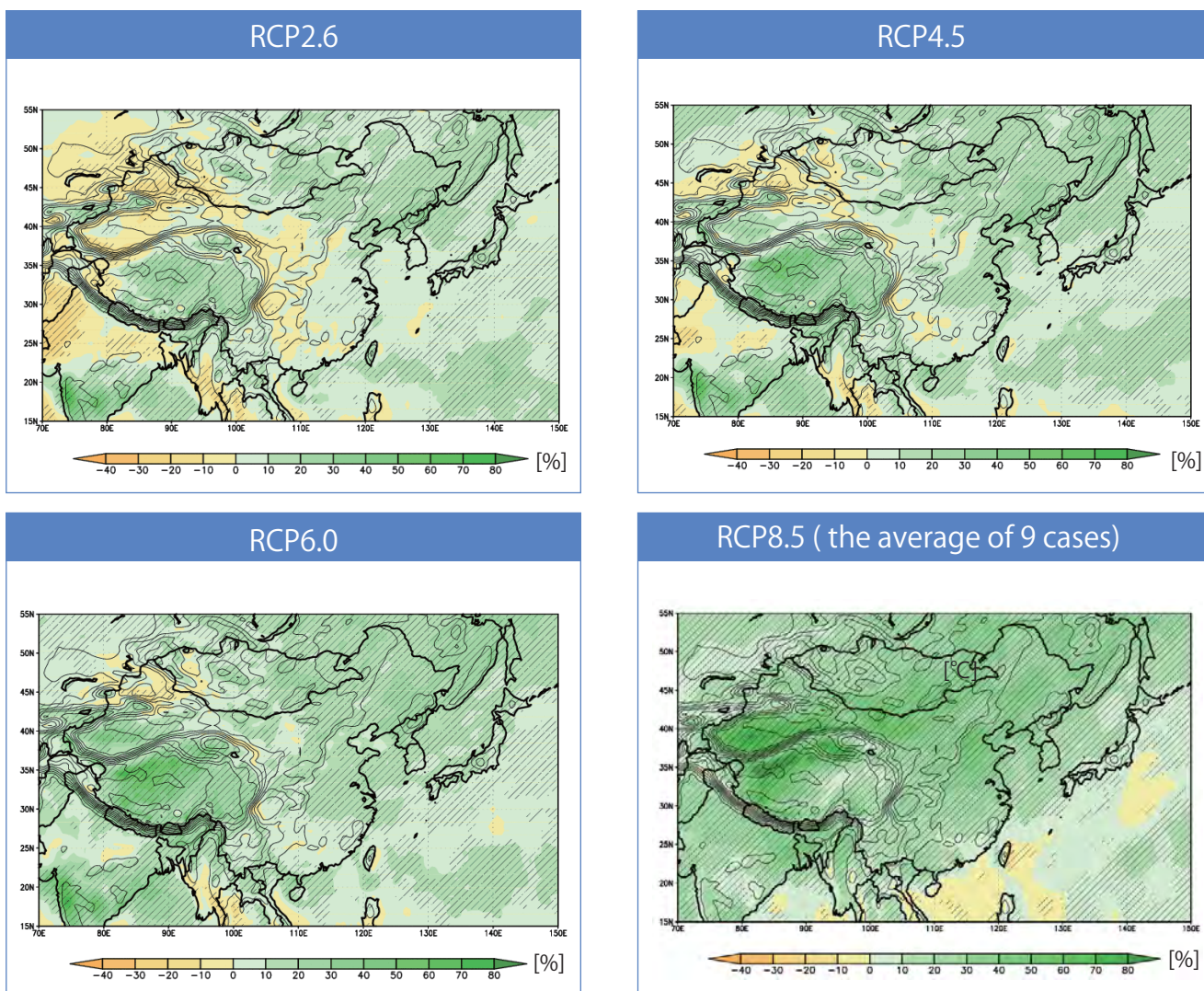


Fig. 6 Changes (%) in annual mean precipitation under each RCP scenario in Mongolia. Differences in precipitation between present climate (1984-2004) and future climate (2080-2100) are shown. Colors indicate average values of the three cases under the RCP2.6, 4.5, and 6.0 scenarios, as well as those 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).

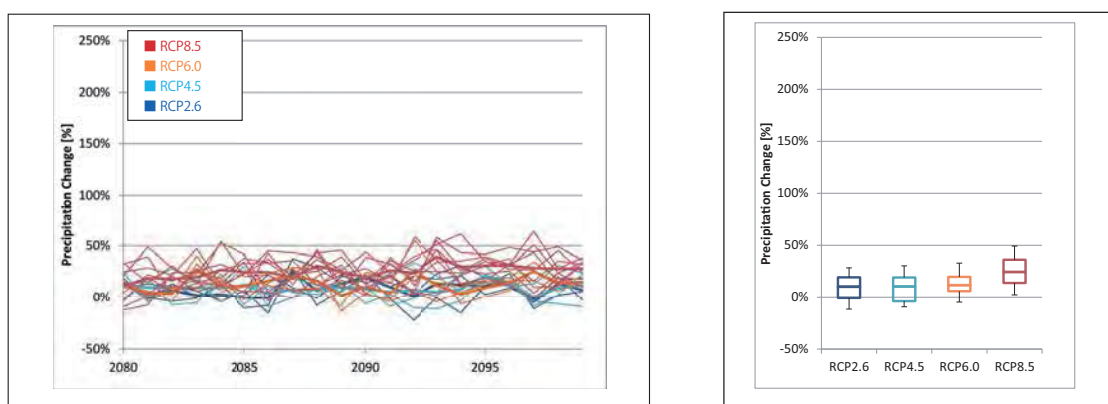


Fig. 7 Changes (%) in annual mean precipitation under each RCP scenario in Mongolia. Left: Chronological changes in annual precipitation. Thin lines indicate the results of each case and thick lines indicate the average values of multiple cases. Right: Summary of the changes in annual mean precipitation 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.



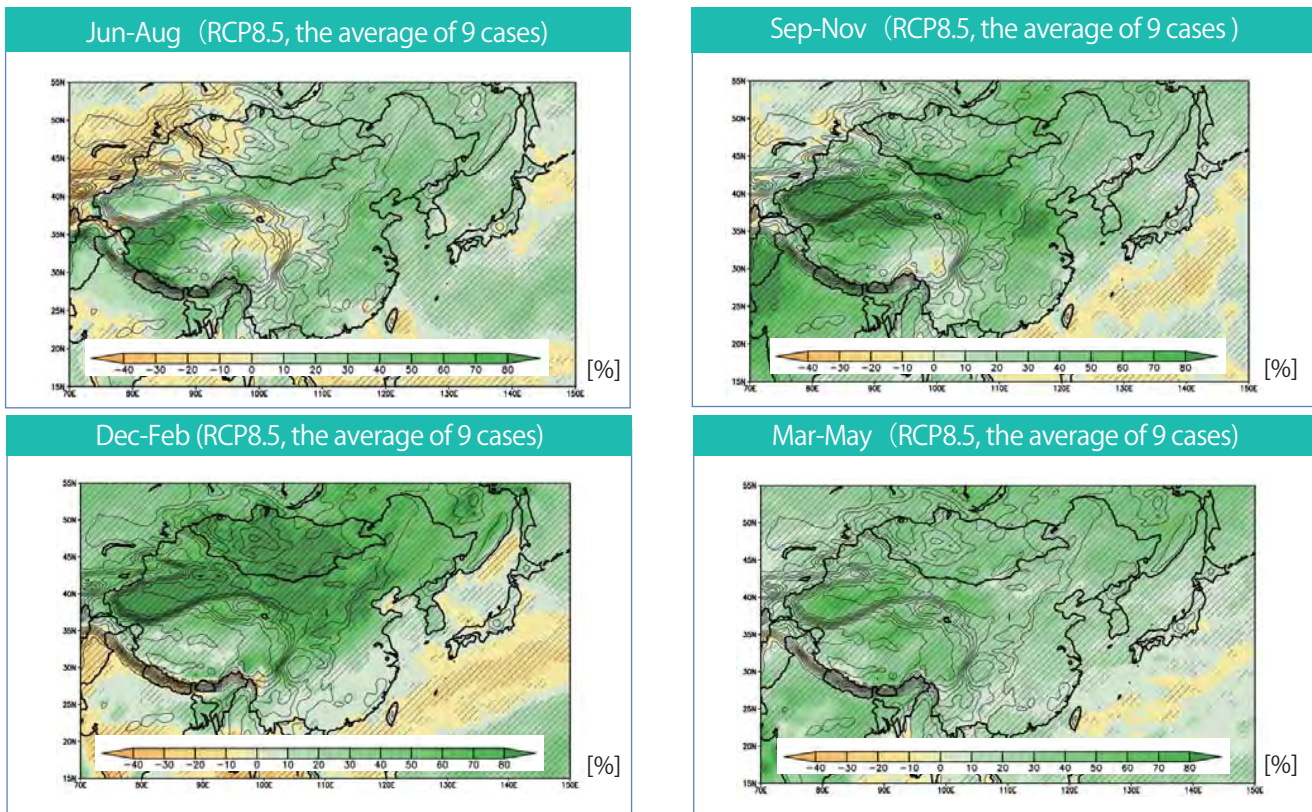


Fig. 8 Changes (%) in precipitation by season in Mongolia. Differences between present climate (1984-2004) and future climate (2080-2100) under the RCP8.5 scenario are shown. The meshing indicates the areas where the tendency of future changes agrees among all cases (areas with high confidence). For reference, the topography of the climate model is shown with contour lines (the topography is modeled; therefore, it may differ from the actual topography).

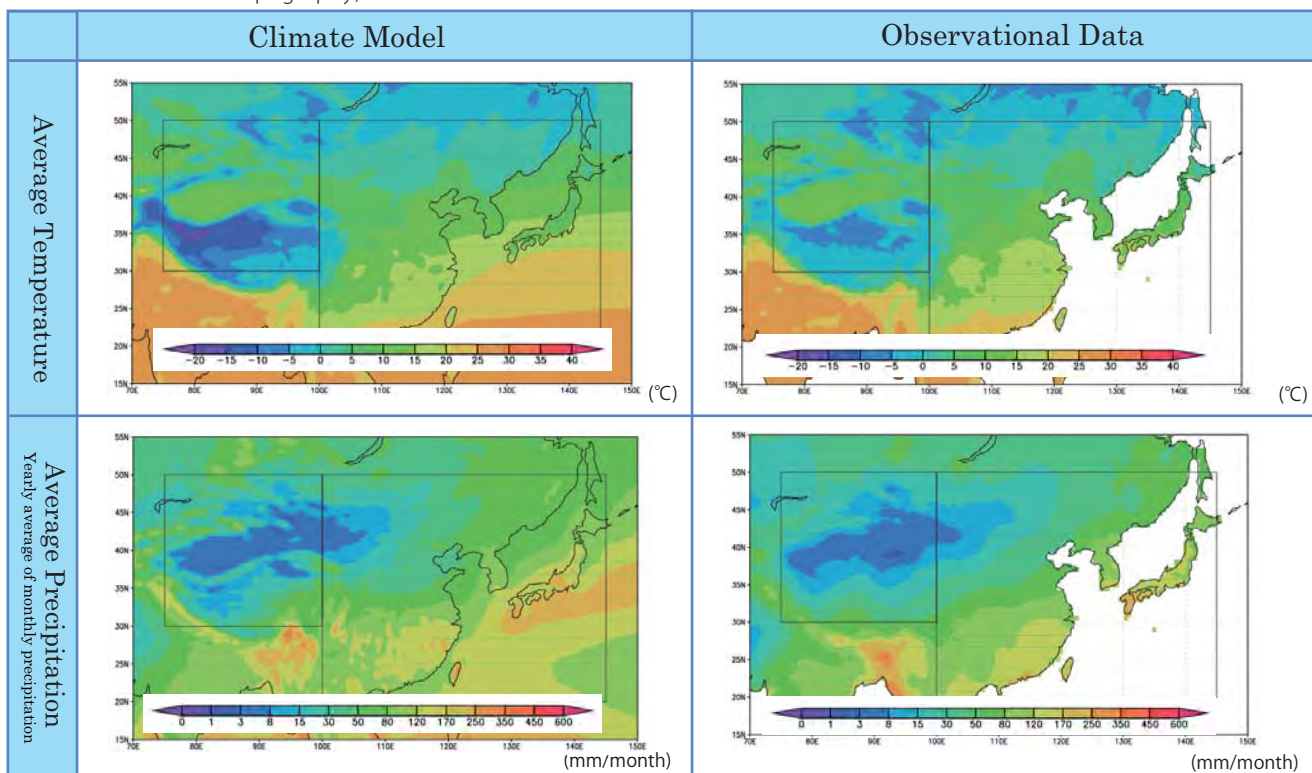


Fig. 9 Reproducibility of temperatures and precipitation in the present climate. Comparison between the average values of the present climate (1984-2004) based on the climate model and observed data during the same period (CRU\_TS3.21). There are differences between model altitude data and actual altitude 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)

Item	Content
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>



Aster alpinus L. (*Iwaazumagiku*)



Grassland in morning haze



City in grassland, Ulan Bator

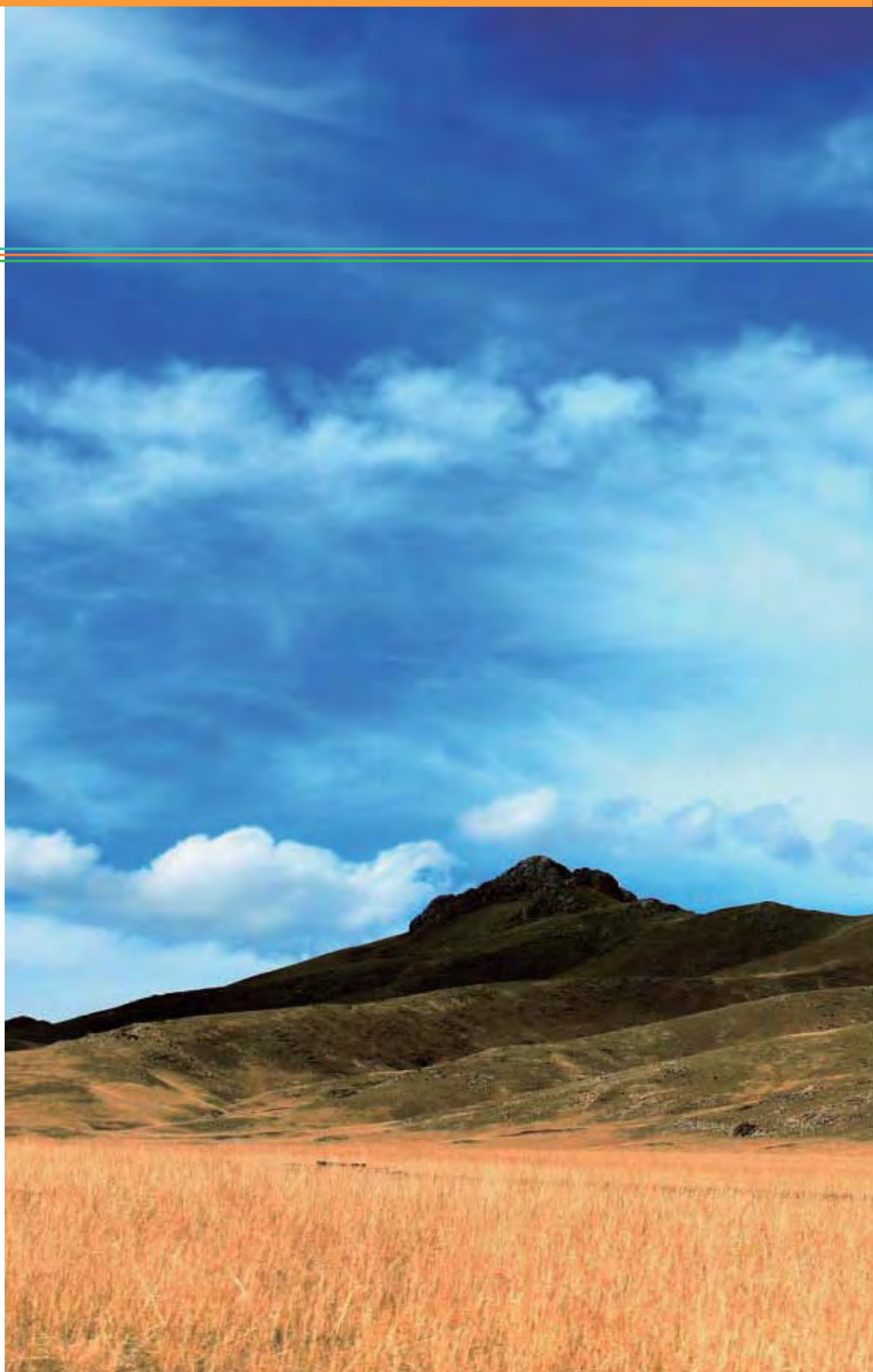
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# *Climate Change in Mongolia*

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Cover: Meadow of autumn in Mongolia

## **Contact**

Ministry of the Environment (Japan)  
Global Environment Bureau, Policy Planning Division, Research and Information Office  
17th Floor Daido Seimei Kasumigaseki Building 1-4-2 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013 Japan  
Tel: +81 3 5521 8247