Specifications of Climate Change Projection Calculations

What conditions vary in the projections?

Outline of climate models used in this climate projection

The projection calculations are carried out using the Global Climate Model (GCM)[13] and the Regional Climate Model (RCM)[14], both developed by Meteorological Research Institute of Japan Meteorological Agency.

The GCM takes input data such as concentrations of greenhouse gases (GHG), ozone, and aerosols, sea surface temperature, sea-ice concentration, and sea ice thickness. The model requires sea surface conditions (i.e. sea surface temperature and sea ice), which are obtained from observations (for the present climate) and Coupled Model Intercomparison Project Phase 5 (CMIP5) model outputs (for the future climate).

To drive RCM with a higher resolution in a smaller region near Japan, we need GHG concentration and climatic conditions at regional boundaries as input data. The climatic boundary conditions are extracted from the results of calculations on the entire globe based on the GCM.

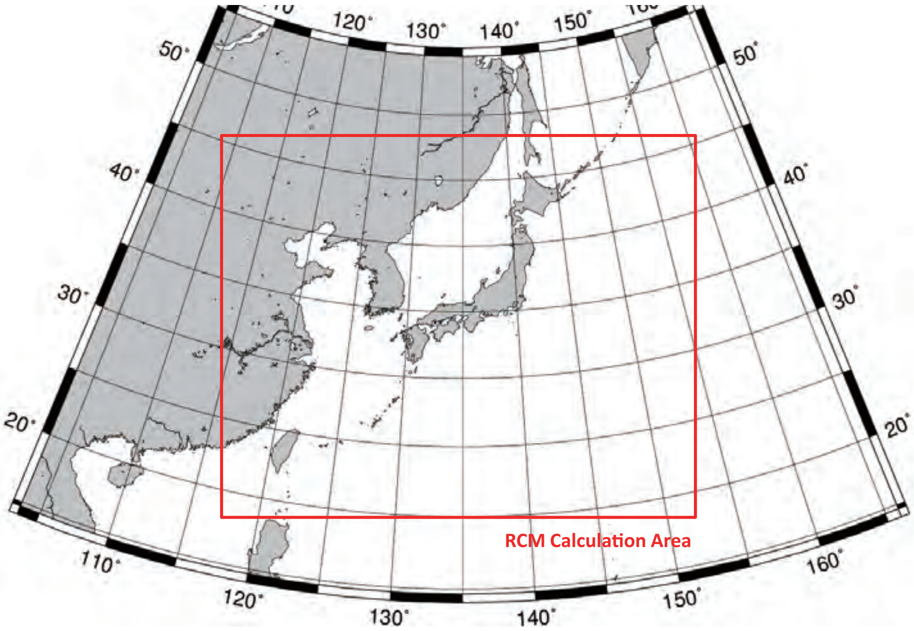
The present and future climates are reproduced and projected, respectively, with a spatial interval of approximately 60 km (i.e. resolution of the GCM) for the entire globe and with an interval of 20 km (i.e. resolution of the RCM) for Japan and its vicinity.

Major specifications of climate-change projection models

	Global Climate Model (GCM)	Regional Climate Model (RCM)
Model name	MRI-AGCM3.2H	MRI-NHRCM20
Spatial resolution	Approx. 60 km	20km
Area subject to calculation	Entire globe	Japan and its vicinity
Number of grids	640 × 320 (horizontal) 60 layers (vertical)	211 × 175 (horizontal) 40 layers (vertical)
Cumulus convection scheme	Yoshimura scheme Kain-Fritsch scheme Arakawa-Schubert scheme	Kain-Fritsch scheme
Main input conditions	Concentrations of greenhouse gases (GHG), ozone and aerosols, sea surface temperature, sea-ice concentration, sea-ice thickness	Concentrations of greenhouse gases (GHG), ozone and aerosols, GCM calculation results

(for imformation about abbreviations for sea surface temperature and cumulus convection scheme, see p.20 and 21)

13----- For details, refer to Mizuta et al.(2012) and Endo et al.(2012).
14----- For details, refer to Sasaki et al.(2011) and Sasaki et al.(2012).



Calculation region of the Regional Climate Model

Projection calculations with multiple case-settings

Case-settings for projection scenarios

We carried out calculations for 21 cases, which consist of three cases for the present climate and 18 cases for the future climate. The case-settings are shown below.

Case-settings of projection scenarios

No.	Case name	Period[15]	Emission scenario	Sea surface temperature	Cumulus convection scheme
1	HPA_m02	(Present experiment) Sept.,1984- Aug.,2004	Observed value	Observed value	YS
2	HPA_kf_m02				KF
3	HPA_as_m02				AS
4	HFA_rcp85_c1	(Future experiment) Sept.,2080- Aug., 2100	RCP8.5	SST1	YS
5	HFA_kf_rcp85_c1				KF
6	HFA_as_rcp85_c1				AS
7	HFA_rcp85_c2			SST2	YS
8	HFA_kf_rcp85_c2				KF
9	HFA_as_rcp85_c2				AS
10	HFA_rcp85_c3			SST3	YS
11	HFA_kf_rcp85_c3				KF
12	HFA_as_rcp85_c3				AS
13	HFA_rcp60_c1		RCP6.0	SST1	YS
14	HFA_rcp60_c2			SST2	
15	HFA_rcp60_c3			SST3	
16	HFA_rcp45_c1		RCP4.5	SST1	
17	HFA_rcp45_c2			SST2	
18	HFA_rcp45_c3			SST3	
19	HFA_rcp26_c1		RCP2.6	SST1	
20	HFA_rcp26_c2			SST2	
21	HFA_rcp26_c3			SST3	

(for imformation about abbreviations for sea surface temperature and cumulus convection scheme, see p.20 and 21)

15---- In the actual calculations, we carried out preparatory calculations (spin-up calculations) preceding the above periods to reduce the influences of initial conditions. The periods of spin-up calculations are approximately one year for the GCM and approximately 40 days for the RCM. The reason for setting the starting month at September is to reduce the influences of initial snow accumulation.

To quantify uncertainties in global warming projections, we conducted ensemble experiments[16], in which calculations are performed a number of times for the same target period based on different conditions.

We used observed values of sea surface temperature (SST), sea-ice concentration, and sea-ice thickness for the experiments on the present climate. With respect to the experiments on the future climate, we used estimated values[17], which were obtained by combining climate values and interannual variations. The climate values were created by adding future changes of model outputs to observed values used in the present climate experiments. The interannual variations were based on observed values.

Emissions Scenarios

The future climate depends on GHG emissions scenarios. To take into account uncertainties among different emissions scenarios, we set input conditions such as future changes in sea surface temperature and GHG concentration levels, from the CMIP5 Model experiments based on the following four scenarios used in the Working Group I contribution to the IPCC Fifth Assessment Report (AR5) (IPCC, 2013). (For details of RCP scenarios, see p.23)

- RCP8.5 (high-level reference scenario)
- RCP6.0 (high-level stabilization scenario)
- RCP4.5 (intermediate-level stabilization scenario)
- RCP2.6 (low-level stabilization scenario)

Although AR5 presents the results of multiple model calculations based on RCP scenarios, this projection assumes average-level temperature increases among the AR5 calculation results, and carries out calculations for multiple cases based on average-level temperature increases. Therefore, it should be noted that the projection results in this publication do not reflect the entire uncertainty range of temperature increases of each RCP scenario. For example, the results reflect only part of the uncertainty range of the entire RCP2.6 scenario presented in AR5 when in this publication it is stated that the RCP2.6 scenario is equivalent to a specific temperature increase (see p.4).

Future sea surface temperature change patterns

In climate change projections, sea surface temperature is a very important condition. The sea surface temperature condition is so important that the tendency of atmospheric temperature near the land surface, in particular, can be roughly determined by the condition.

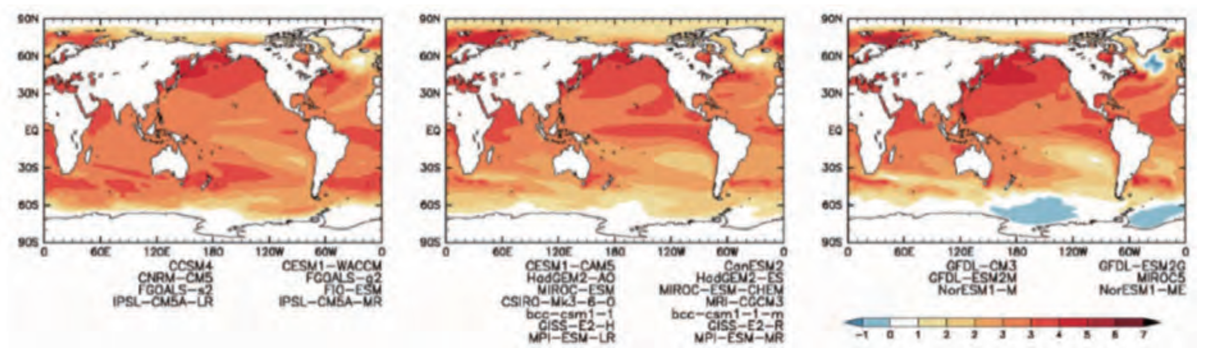
Changes in the distribution of sea surface temperature also influence the climate in East Asia to a large extent through changes in the distribution of precipitation in tropical and monsoon regions. To take into consideration some of the uncertainties associated with the projections by evaluating influences due to differences in the distribution of sea surface temperatures, we analyzed a number

16----- In climate change studies, calculations to reproduce the present climate and project the future climate are called "experiments." Hereinafter, we refer to climate projection calculations as experiments when it is preferable in order to be academically precise.

17----- The methodology to construct ensemble experiments is based on the outcome of "Program for Risk Information on Climate Change: Theme C: Development of basic technology for risk information on climate change," conducted under the auspices of the Ministry of Education, Culture, Sports, Science and Technology.

of Atmosphere-Ocean General Circulation Models presented by CMIP5, and categorized the model sea surface temperatures obtained into three patterns (SST1, SST2, and SST3). Due to normalization in this categorization process, the global average of sea surface temperature changes is almost the same for all three patterns. It should be noted here that uncertainties in sea surface temperature changes are not reproduced in these projection calculations[18] .

In SST2, greater warming is found in the central and eastern tropical Pacific than the other patterns. SST2 reflects the average characteristics to a larger degree than the other patterns. In contrast, SST1 shows less warming in the eastern tropical Pacific, which is the opposite to the characteristic of SST2. In addition, warming in the Southern Hemisphere is greater in SST1, to the extent that warming in the midlatitudes (~40°) is about the same between both hemispheres. SST3 has greater warming in the western North Pacific. Warming is greater than the other patterns also around the northern Indian Ocean and the North Atlantic. In contrast, warming in the Southern Hemisphere is smallest, so the interhemispheric contrast is large.



Three sea surface temperature change patterns (unit: K)
SST1: to the left; SST2: middle; SST3: to the right

Cumulus convection parameterization

For climate change projections covering Japan and its vicinity, it is considered to be especially important to assess uncertainties associated with projections of precipitation. To express uncertainties, calculations are performed using three types of cumulus convection parameterization (i.e. Yoshimura (YS) scheme, Kain-Fritsch (KF) scheme, and Arakawa-Schubert (AS) scheme)[19] in projection calculations based on the GCM.

In the case of the RCM, however, the same cumulus convection scheme (Kain-Fritsch (KF) scheme) is used for all experiments. KF is known to be a scheme that can accurately depict convective activities around Japan. Its reproducibility for various climatic phenomena around Japan has been examined.

■ Cumulus convection parameterization

Cumulus clouds (a type of cloud with a cotton-like form, which often appears on clear days) typically appear and grow in tropical regions, transport moisture in an upward vertical direction. The moisture then condenses. The condensed moisture falls as rain or is released as cloud water. As a result, cumulus clouds play an important role as heat sources in the atmosphere, and have large influences on atmospheric circulation.

Currently available climate models usually do not have a sufficient resolving capability to directly depict cumulus clouds, except in some cases where well-developed cumulus clouds are described by localized models. Therefore, a mechanism for numerical forecasting models to redistribute heat and moisture in the vertical direction is adopted. This mechanism is called “cumulus convection parameterization.”

Source: Partially modified quotation from "Japan Meteorological Agency (2012): Modified quotation from NumericalWeather Prediction (2012)"

18----- The detailed procedure for the categorization of sea surface temperature is as follows: (1) for each of the CMIP5 models, the annual-mean SST change from the present-day (historical experiment) to the end of the 21st century (RCP8.5 experiment) is computed; (2) the computed mean SST change is normalized by the tropical (30°S—30°N) mean SST change; (3) the multi-model ensemble mean of the normalized change is subtracted from that for each model experiment; (4) then, the inter-model pattern correlation over the tropics (30°S—30°N) is computed; and (5) distances are defined with the correlation and the cluster analysis is performed using these distances. For details, refer to Mizuta et al. (2014).

19----- Refer to Yoshimura et al. (2014), Kain and Fritsch (1993), and Randall and Pan (1993) for YS, KF, and AS, respectively.

Cumulus congestus cloud: Cumulonimbus. It often exists when the atmosphere is unstable, and takes time for cumulus to become cumulonimbus. The height above the bottom of the cloud reaches several thousand meters or sometimes reaches 10,000 meters.

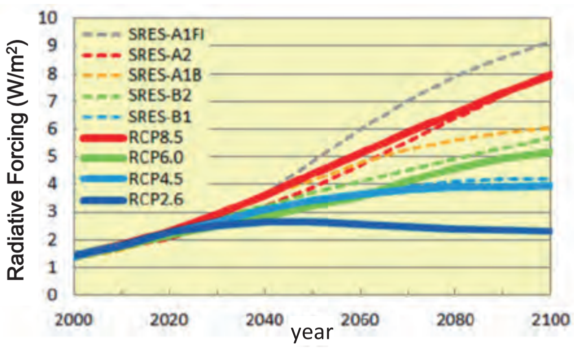
Towering cumulus: Cumulus climbs toward the sky by the upward current when the atmosphere is unstable. It often starts raining when the towering cumulus comes out.

Future scenarios for projection (RCP scenarios)

RCP scenarios are a set of selected scenarios of stabilization levels of greenhouse gas (GHG) concentrations in the future, as well as representative pathways to get to those levels, on the basis of implementation of political GHG mitigation (reduction) measures. Intergovernmental Panel on Climate Change (IPCC) started conducting climatic projections and impact assessments based on the above scenarios in the Fifth Assessment Report (AR5). Based on these scenarios, it has become possible to develop and examine multiple target-driven socioeconomic scenarios unlike projections based on the preceding SRES scenarios[20].

The numerical values following the term RCP indicate approximate total radiative forcing (RF)[21] in the year 2100 against that in the year 1750 (unit: W/m^2) for each scenario. This means that the larger the value is, the stronger the radiative force is in the year 2100 (scenarios with higher GHG emissions levels).

Source: Partially modified quotation from "IPCC (2014): Climate Change 2013 – The Physical Science Basis – Summary for Policymakers"



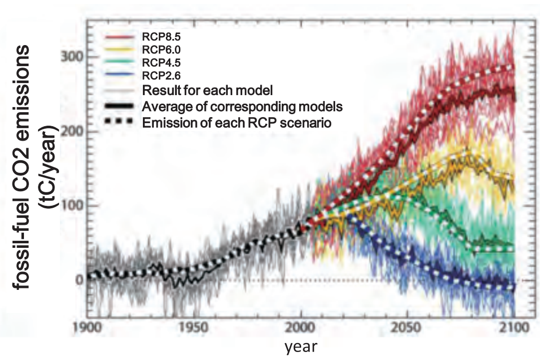


Chart to the left: Radiative forcing (RF) based on RCP scenarios (Pathways of four kinds of RF defined in RCP scenarios are shown by solid lines. RF obtained based on SRES is shown with dotted lines for reference.)
Chart to the right: CO2 emissions from fossil fuels corresponding to RCP scenarios (Results of inverse calculation based on the Earth System Model. Fine lines: Results of individual model calculations. Thick lines: Average of multiple model calculations.)
Source: Based on the briefing material for mass media, jointly issued by MEXT, METI, JMA and MOE.

According to AR5, relationships among the four RCP scenarios and the magnitudes of global average temperature increases during the period 2081-2100 (compared to values for the period 1986-2005) are shown below. It can be said that as the values become smaller, the global-warming mitigation measures taken in the scenario become stricter.

Taking less strict mitigation measures

RCP8.5: 3.7℃ (2.6 to 4.8℃)
RCP6.0: 2.2℃ (1.4 to 3.1℃)
RCP4.5: 1.8℃ (1.1 to 2.6℃)
RCP2.6: 1.0℃ (0.3 to 1.7℃)

Taking stricter mitigation measures

The range of temperatures in parentheses indicates the 5-95% model range projected from the results of AR5 model calculations. The ranges are calculated taking into account differences in levels of uncertainties and confidence among models.

Source: "IPCC (2014): Climate Change 2013 – The Physical Science Basis – Summary for Policymakers"

20----- SRES scenarios: Set of scenarios used for "IPCC's Fourth Assessment Report," in which a variety of social, economic, and technological changes are first assumed, then a set of scenarios is developed based on estimated future GHG emissions corresponding to assumed levels of changes.
21----- Radiative forcing is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface, while negative forcing tends to cool it.