Dynamical Downscaling of Climate Projection Data

Akihiko Murata

Meteorological Research Institute / Japan Meteorological Agency

Aug 28, 2023

SENTAN
advanced studies of climate change projection
気候変動予測先端研究プログラム

Webinar Series on Climate Change Projection for Disaster Risk Reduction in Asia-Pacific Region

Contents

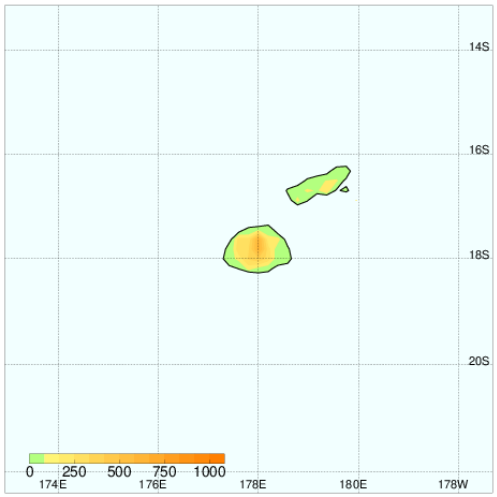
- Overview of dynamical downscaling
- Practical examples of dynamical downscaling
  - Analyses for present climate
  - Analyses for future climate
- Research program: SENTAN

1. Overview of dynamical downscaling

What is downscaling?

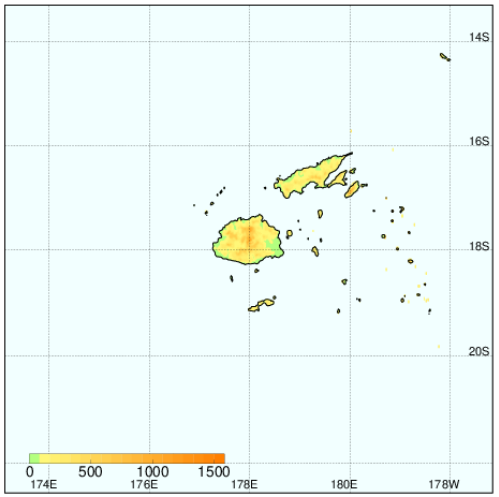
- Purpose
  - To project future climate on regional and local scales

20-km resolution



x 10

2-km resolution

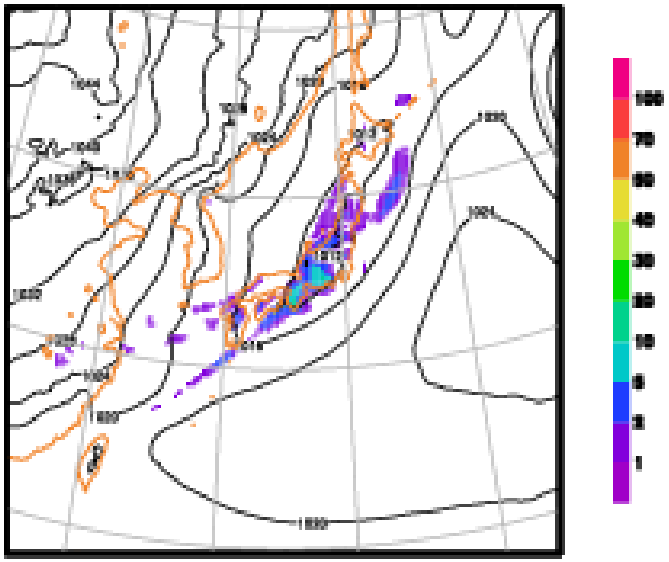


- Two types
  - Statistical downscaling: Based on statistical knowledge
  - Dynamical downscaling: Based on numerical simulations

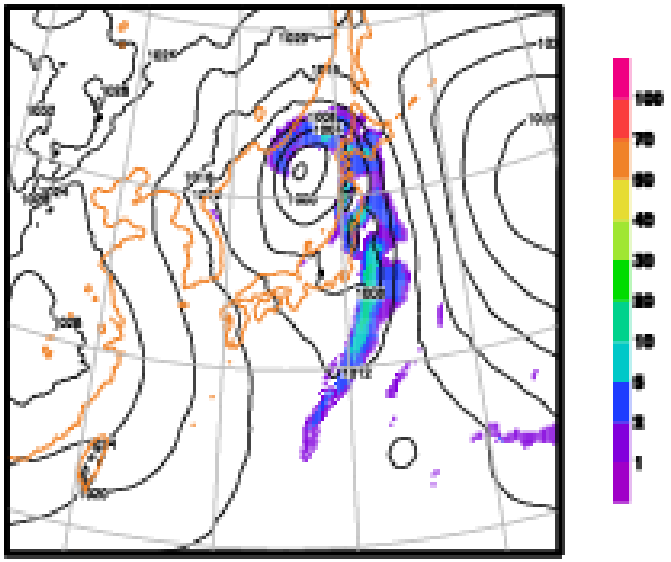
Regional Climate Model (RCM)

- Similar to numerical prediction model for weather forecast
- But for regional- and local-scale climate (not weather)

Present-day climate



Future climate (e.g., the end of 21C)



Experimental design

Numerical Model:

NonHydrostatic Regional Climate Model (NHRCM; Sasaki et al. 2008),
based on Japan Meteorological Agency NonHydrostatic Model (JMA-NHM; Saito et al. 2006)

Present climate

Integration period: 20 years
Sep 1980 – Aug 2000
(1-year time slice:
Sep – next Aug)

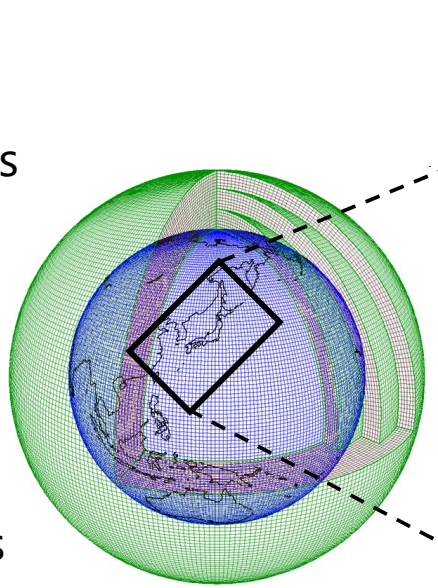
Future climate

Integration period: 20 years
Sep 2076 – Aug 2096
(1-year time slice:
Sep – next Aug)

Scenario: RCP8.5

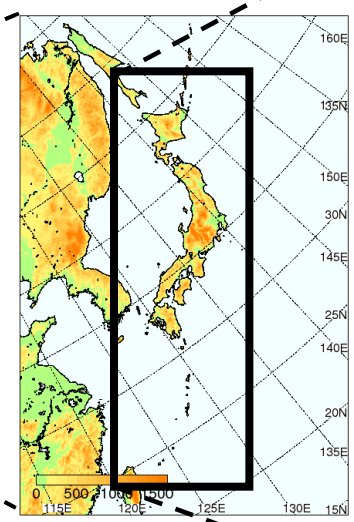
SST: Change + Trend + Variability

Ensemble of boundary conditions (4 members)

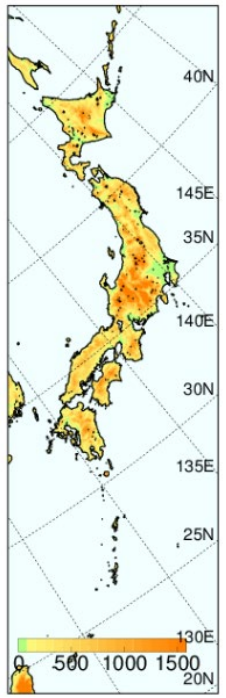


(Image: JMA)

20-km mesh (AGCM20)



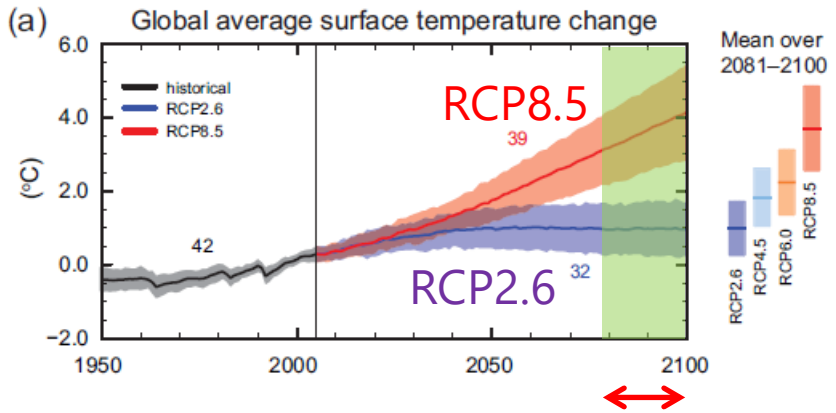
5-km mesh



2-km mesh (convection permitting)

Downscaling methods

- Scenario in terms of greenhouse gases
  - Shared Socioeconomic Pathways (SSP)
  - Representative Concentration Pathways (RCP)
- Time sliced
  - e.g., Around the end of this century: 2080-2100
- Using high-speed supercomputer
  - e.g., Earth Simulator



IPCC (2013)

Time sliced

Earth Simulator

http://www.jamstec.go.jp/es/jp/output/gallery/images/es3/org/002.jpg

2. Practical examples of dynamical downscaling

2-1 Analyses for present climate

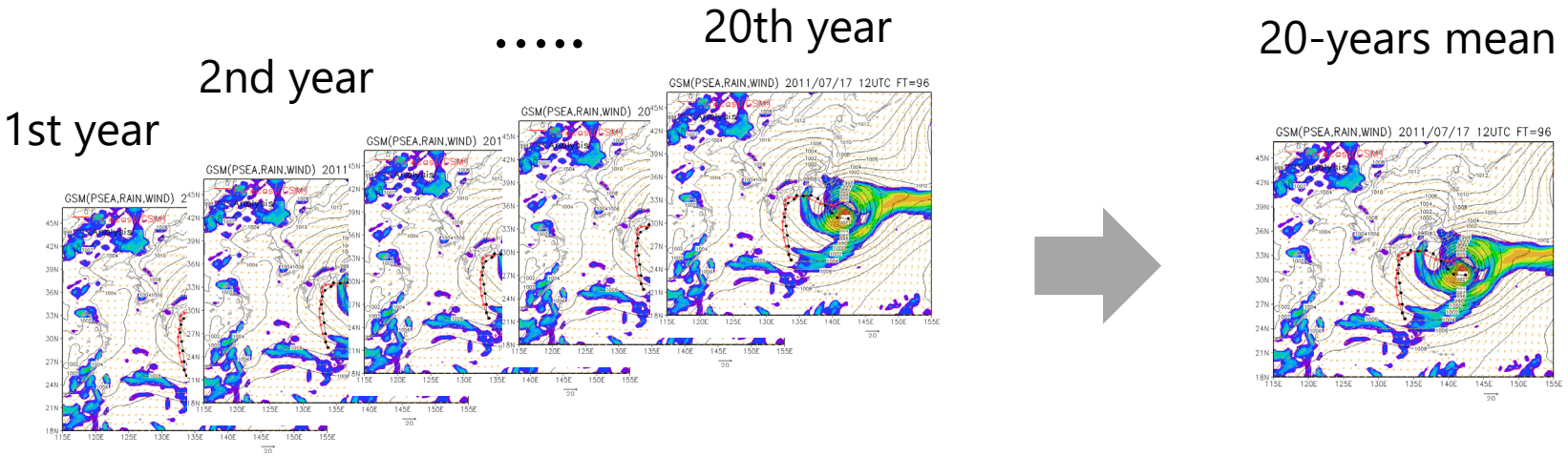
2-2 Analyses for future climate

2-1 Analyses for present climate

- Remarks:
  - Climate simulation is different from weather forecast
  - In general, date in climate simulations does not represent real date, month, and year
  - Not possible to compare model and observed results for specific date, month, and year
- Calculation of long-term mean
  - 20 years (30 years) or so
  - Compare model climate with observed one
    - Both 20-years mean
- Therefore, calculate long-term mean first

Calculation of monthly, seasonal, and annual mean

- (20-years mean of) Monthly mean



- Similarly …
- (20-years mean) of Seasonal mean
  - DJF, MAM, JJA, SON, and so on
- (20-years mean of) Annual mean

Validate simulated mean values

- Using observational data
- For example: Station data



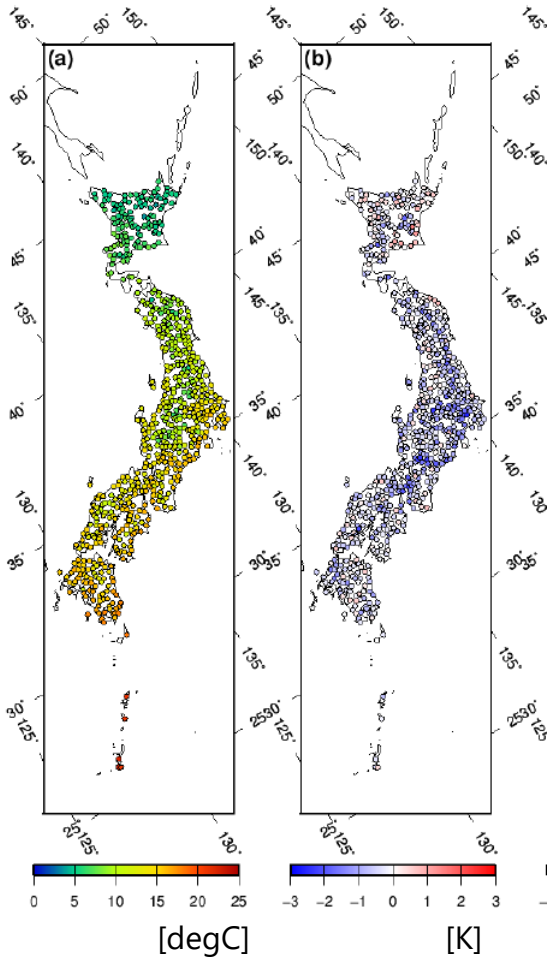
- Modeled values for comparison
  - At the grid point nearest to an observational point
- Bias, RMSE, and Correlation

Difference between model and observational results

Surface air temperature

Model

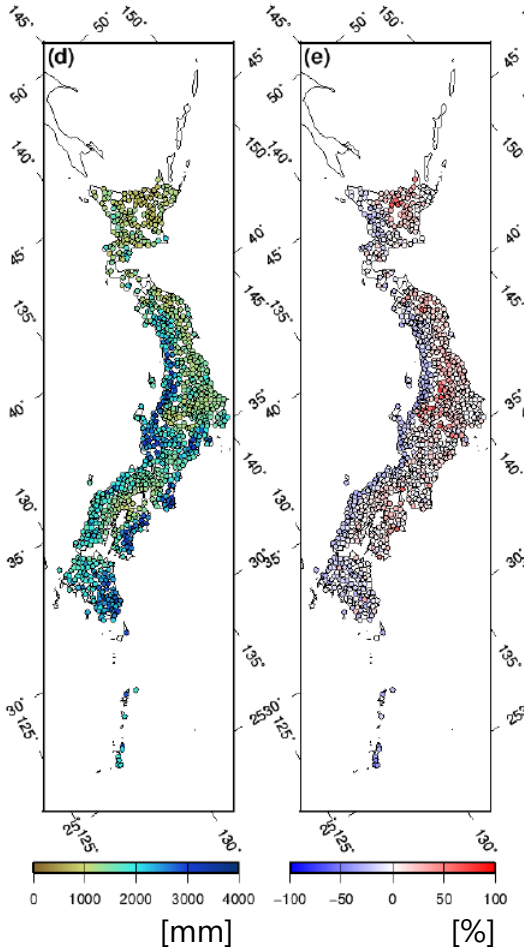
Model - Obs



Precipitation

Model

100 x (Model/Obs-1)

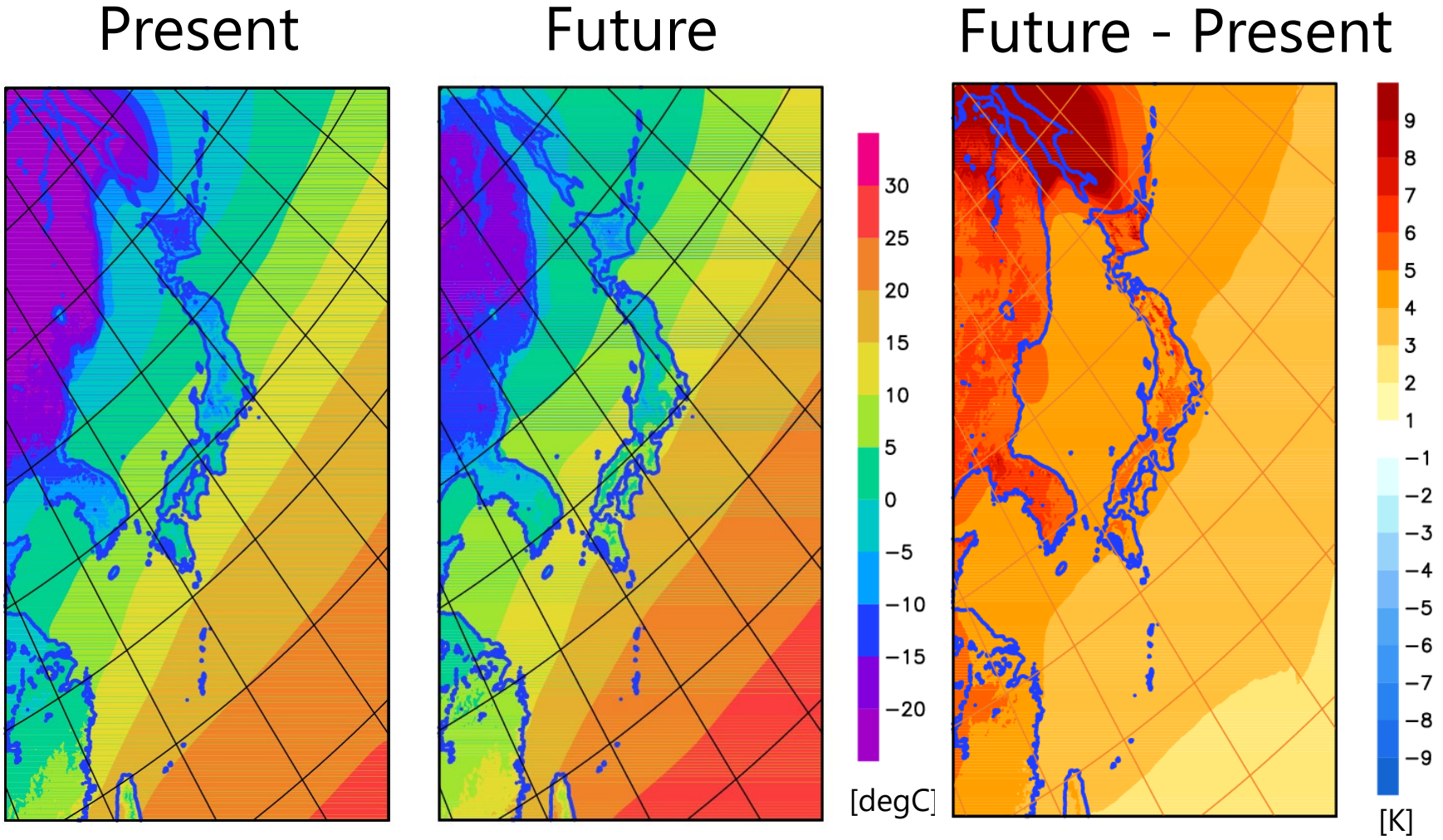


Murata et al. (2015)

2-2 Analyses for future climate

- Remarks:
  - Climate simulation is different from weather forecast
  - In general, date in climate simulations does not represent real date, month, and year
  - Not possible to compare model results (present and future) for specific date, month, and year
- Calculation of long-term mean
  - 20 years (30 years) or so
  - Compare model future climate with present one
    - Both 20-years mean
- Therefore, calculate long-term mean first

Difference between future and present surface air temperature

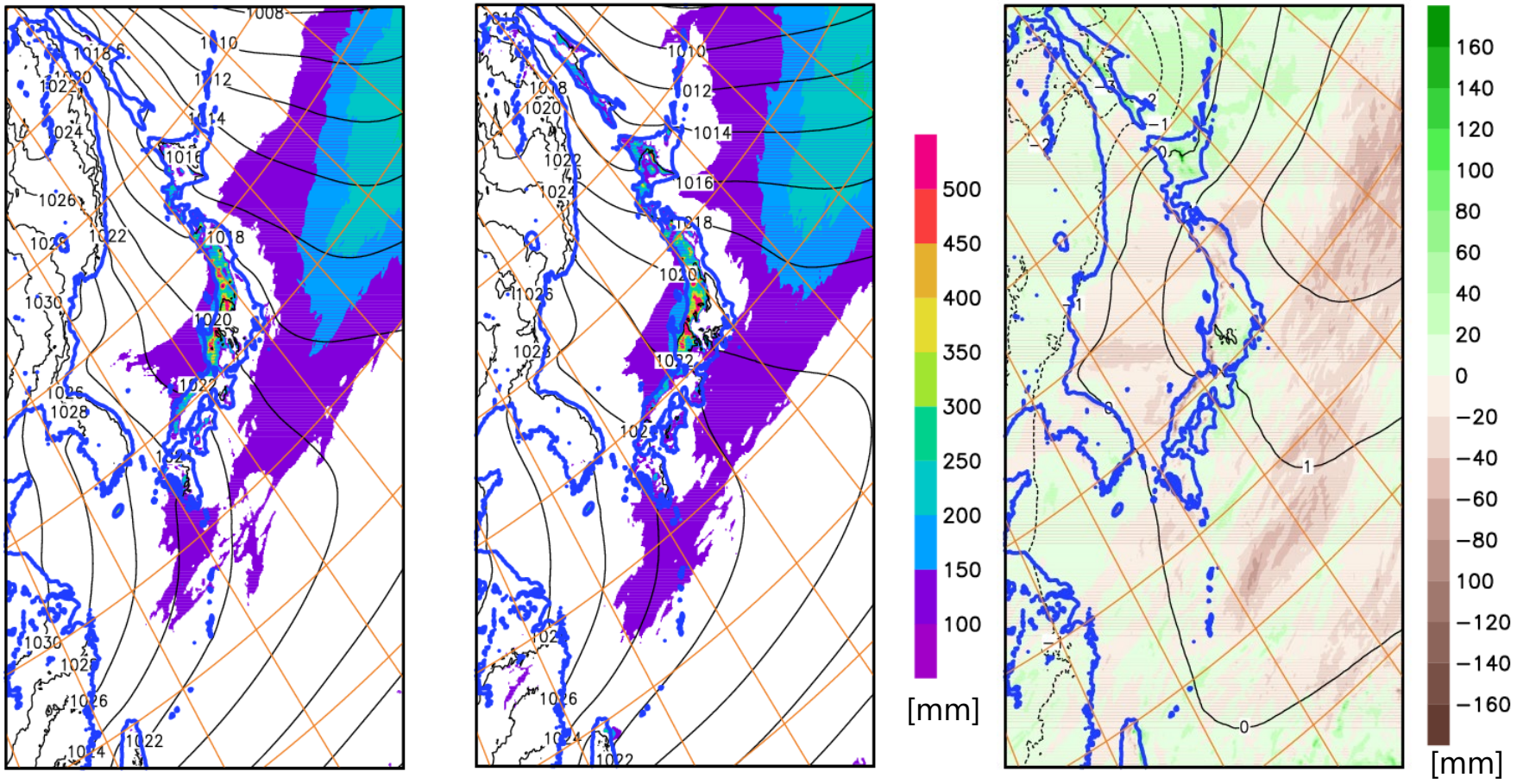


Difference between future and present precipitation

Present

Future

Future - Present



3. Research program: SENTAN

Special scientific programs

- Sponsored by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan
  - KYOUSEI project (FY2002-2006)
  - KAKUSHIN program (FY2007-2011)
  - SOUSEI program (FY2012-2016)
  - TOUGOU program (FY2017-2021)
  - SENTAN program (FY2022-2026)

文部科学省

MEXT

MINISTRY OF EDUCATION, CULTURE, SPORTS, CE AND TECHNOLOGY-JAPAN

統合的気候モデル高度化研究プログラム
Integrated Research Program for Advancing Climate Models (TOUGOU)

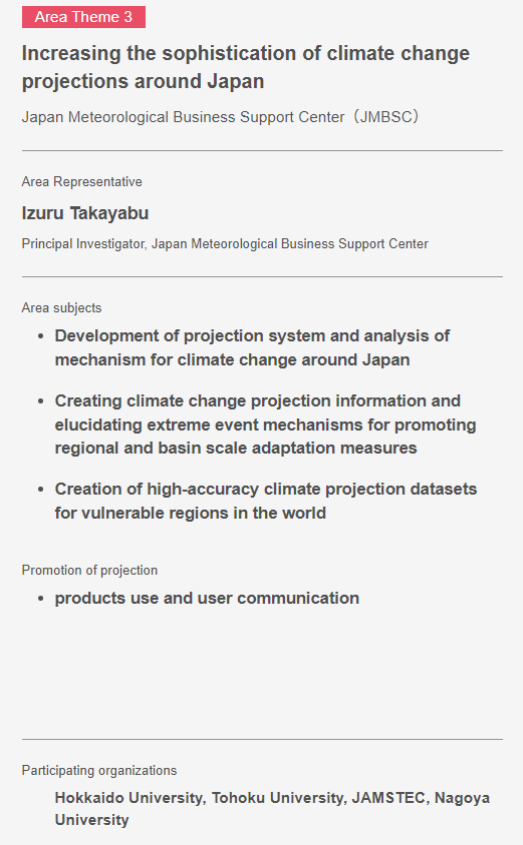
SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

KAKUSHIN

SENTAN
advanced studies of climate change projection
気候変動予測先端研究プログラム

SENTAN program web

- https://www.jamstec.go.jp/sentan/eng/



Creation of high-accuracy climate projection datasets for vulnerable regions in the world

Research themes

Advancing international collaboration through the application of a high-performing climate model over many countries in the Asia-Pacific region

Climate change projection in areas vulnerable to global warming

- Collaborative research with CORDEX-SEA participants
- Global warming projection support in vulnerable areas
- Human resource development in developing countries
- Evaluation of future water resource availability
- Cooperation with other projects

International comparison of climate change projection experiment results due to global warming

- Participation in High-Res-MIP
- Participation in CORDEX-EA
- Comparison of experiment results with other countries

- Enhancement of presence in Japanese climate models
- Improve accuracy of global warming projection near Japan

Cooperation between projects

Model Development: Improvement of reproducibility of regional climate models in tropical and subtropical regions

Climate Scenarios: Application of climate scenario development system in overseas

http://www.jmbsc.or.jp/tougou/EN/research.html#

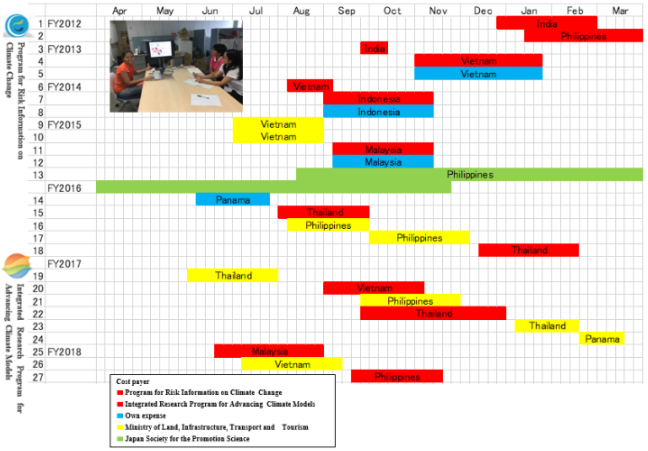
DDS conducted under the framework of the programs

- High-resolution RCM simulations have been performed for CORDEX-SEA using RCM called NHRCM

Schedules for invited researches

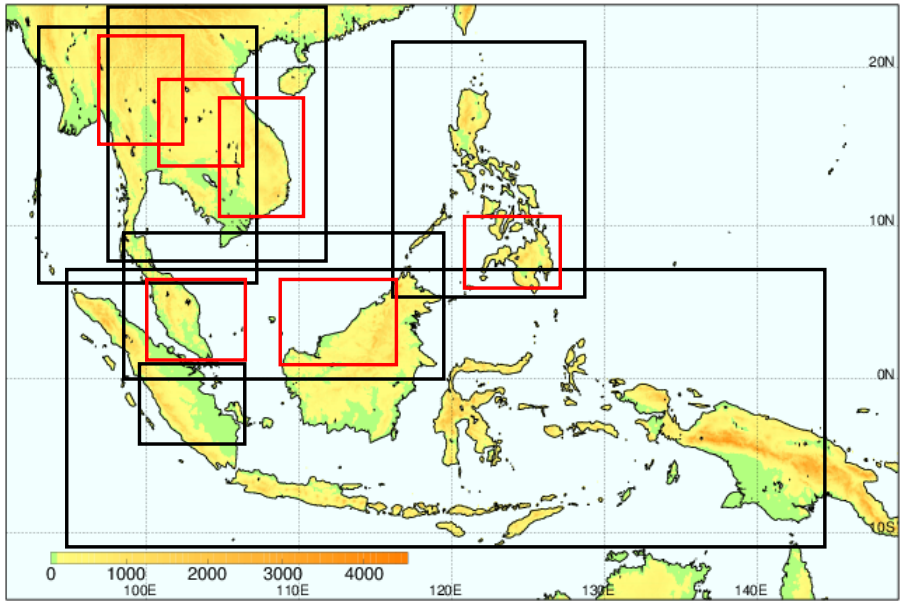
2. Research collaboration

The MRI has invited researchers from the collaborating countries to the MRI in Tsukuba, Japan, for two months to implement custom downscaling technology with a super computer for each region and to adjust the NHRCM program (source code) to improve reproductivity of local climate conditions. Thus far, meteorology/climatology or environment researchers with knowledge of LINUX, Fortran, and meteorological/climatological dynamics have participated in the joint study. This research collaboration has been supported by the Ministry of Land Infrastructure Transport and Tourism (MILT), Japan Society for the Promotion Science (JSPS), Program for Risk Information on Climate Change, and Integrated Research Program for Advancing Climate Models operated by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT). A schedule of joint study is indicated in Figure 3, and relevant organizations are shown in Figure 4.



Model domains

5-km mesh NHRCM 2-km mesh NHRCM



Studies for each country

- Arpornrat, T., S. Ratjiranukool, P. Ratjiranukool, and H. Sasaki, 2018: Evaluation of southwest monsoon change over Thailand by high-resolution regional climate model under high RCP emission scenario, J. Phys.: Conf. Ser., 1144, 012112.
- Cruz, F. T., H. Sasaki, and G. T. Narisma, 2016: Assessing the sensitivity of the Non-Hydrostatic Regional Climate Model to boundary conditions and convective schemes over the Philippines. J. Meteor. Soc. Japan, 94, 165–179.
- Cruz, F. T, and H. Sasaki, 2017: Simulation of present climate over Southeast Asia using the Non-Hydrostatic Regional Climate Model. SOLA, 13, 13–18.
- Jamaluddin, A. F., F. Tangang, J. X. Chung, L. Juneng, H. Sasaki, and I. Takayabu, 2018: Investigating the mechanisms of diurnal rainfall variability over Peninsular Malaysia using the non-hydrostatic regional climate model. Meteor. Atmos. Phys., 130, 6, 611–633.
- Kieu-Thi, X., H. V. U.-Thanh, T. Nguyen-Minh, D. Le, L. Nguyen-Minh, I. Takayabu, H.Sasaki, and A. Kitoh, 2016: Rainfall and tropical cyclone activity over Vietnam simulated and projected by the Non-Hydrostatic Regional Climate Model – NHRCM. J. Meteor. Soc. Japan, 94A, 135–150.
- Ngai, S. T., H. Sasaki, A. Murata, M. Nosaka, J. X. Chung, L. Juneng, Supari, E. Salimun, and F. Tangang, 2020: Extreme rainfall projections for Malaysia at the end of 21st century using the high resolution non-hydrostatic regional climate model (NHRCM), SOLA, 16, 132–139.
- Mau, N. D., N. M. Truong, H. Sasaki, and I. Takayabu, 2017: Rainfall projection for seasonal rainfall over Vietnam by the end of 21st century under RCP8.5 scenario by the NHRCM model. Vietnam Journal of Hydrometeorology, pp 7–13.
- Mau, N. D., H. Sasaki, and I. Takayabu, 2018: A study of seasonal rainfall in Vietnam at the end of 21st century according to the Non-Hydrostatic Regional Climate Model, Vietnam Journal of Science, Technology and Engineering, 60, 3, 89–96.

Summary

SENTAN
advanced studies of climate change projection
気候変動予測先端研究プログラム

- Our activity at Meteorological Research Institute (MRI) for inviting researchers from Southeast Asian countries to Japan is explained
  - Dynamical downscaling for their countries using a non-hydrostatic RCM, called NHRCM, has been conducted
  - High-speed computer system, called the Earth Simulator, can be used
- This activity continues in the present scientific program, called SENTAN program