Dynamical Downscaling of Climate Projection Data

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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

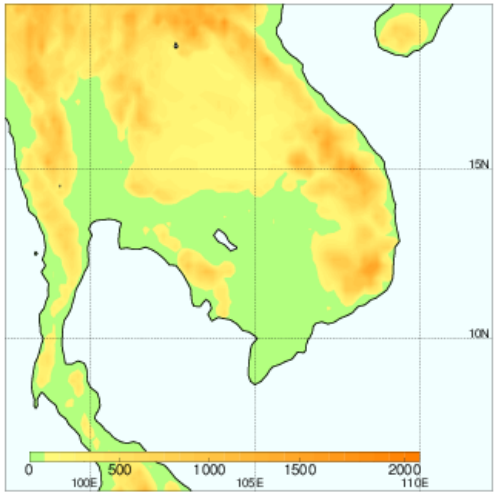
- Overview of dynamical downscaling
- Practical examples of dynamical downscaling
  - Analyses for present climate
  - Analyses for future climate
- Research program: SENTAN

1. Overview of dynamical downscaling

What is downscaling?

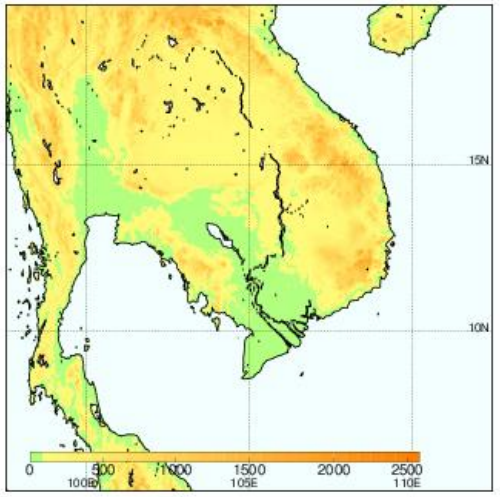
- Purpose
  - To project future climate on regional and local scales

20-km resolution



x 10

2-km resolution

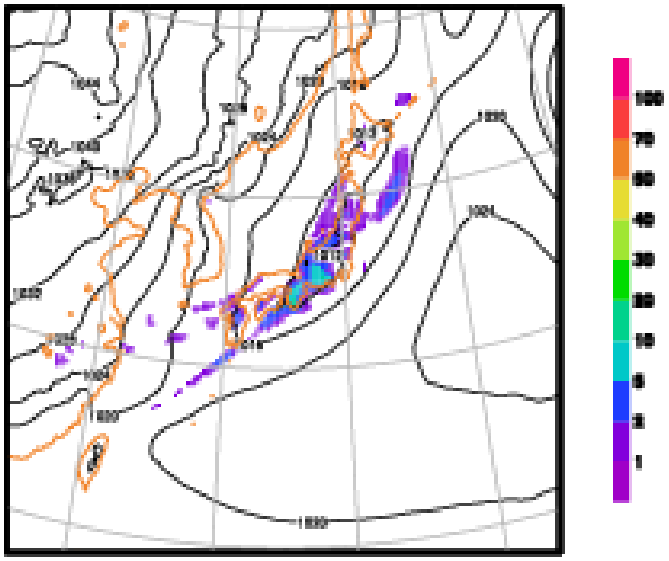


- Two types
  - Dynamical downscaling: Based on numerical simulations
  - Statistical downscaling: Based on statistical knowledge

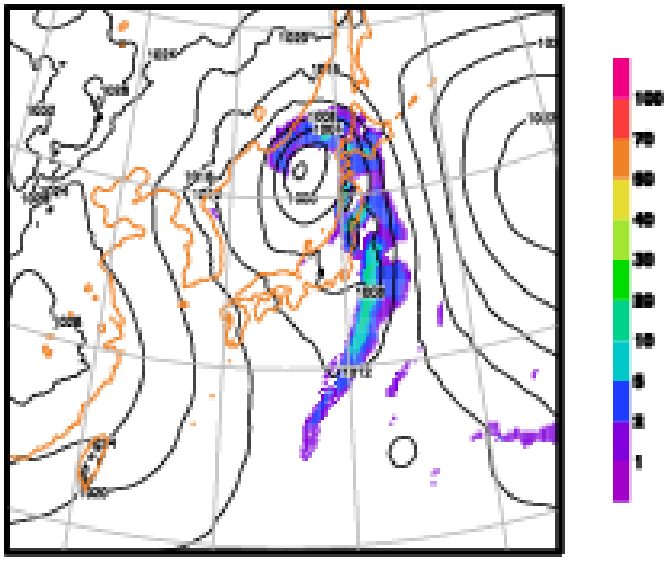
Regional Climate Model (RCM)

- 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)

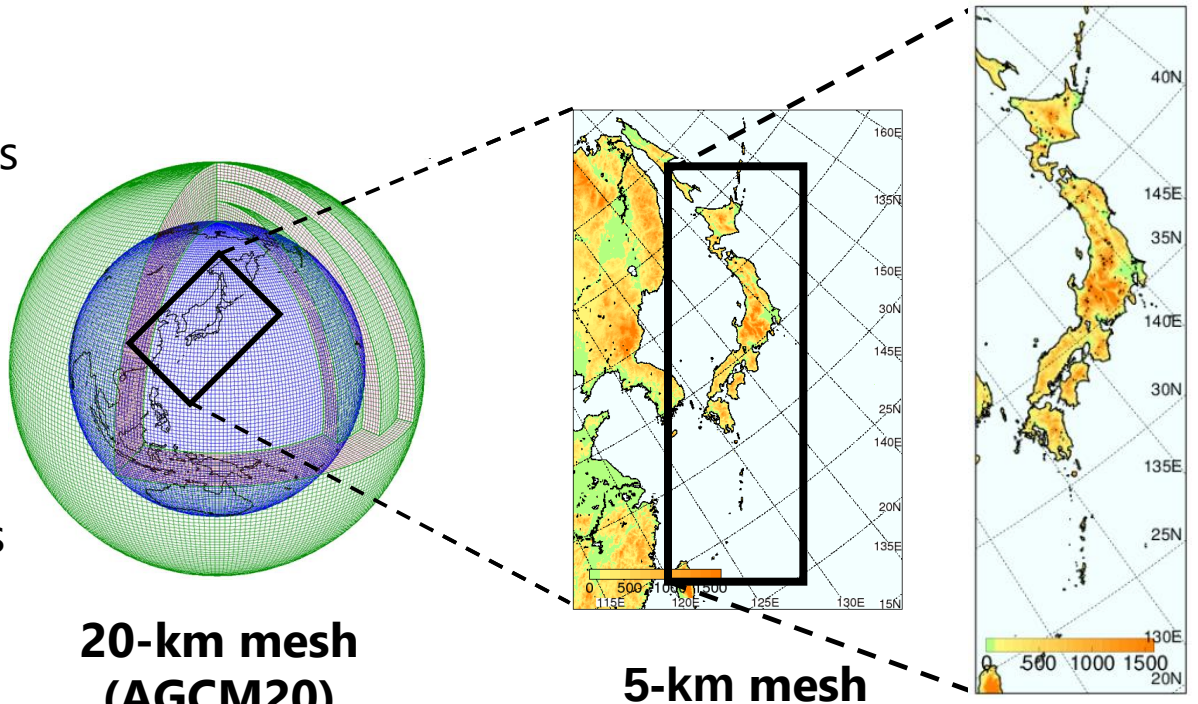
Present climate

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

Future climate

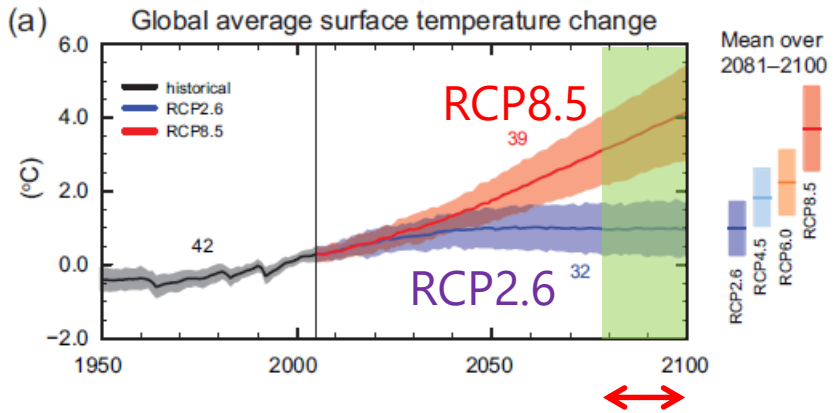
Integration period: 20 years
Sep 2076 – Aug 2096
(1-year time slice:
Sep – next Aug)

Scenario: RCP8.5
SST: Change + Trend + Variability
Ensemble of boundary conditions (4 members)



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

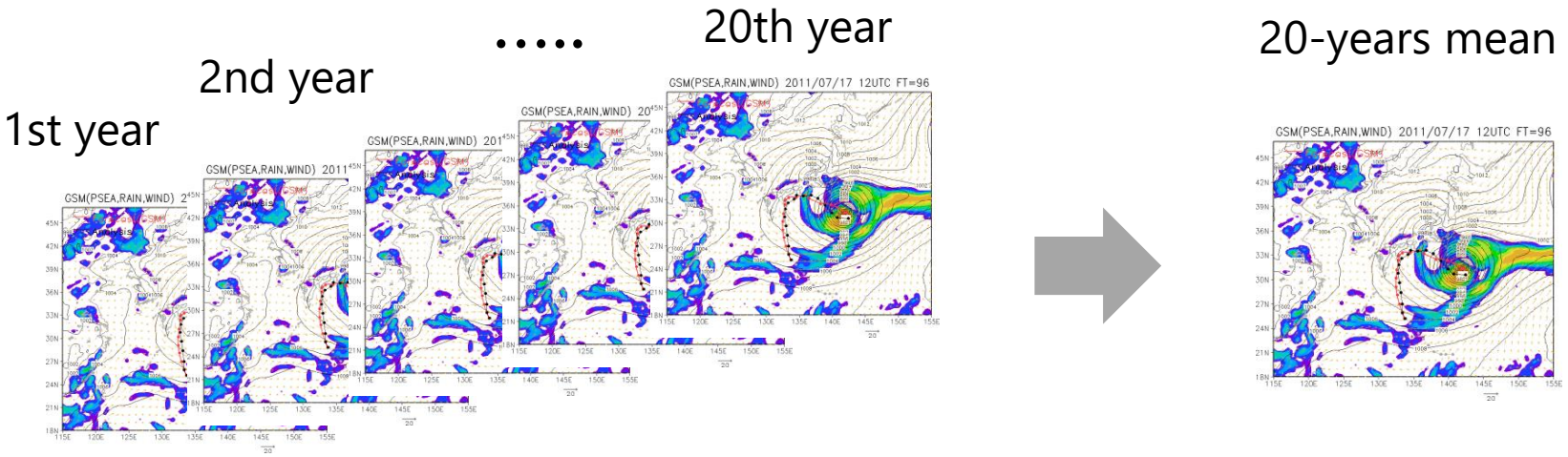
2-2 Analyses for future climate

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

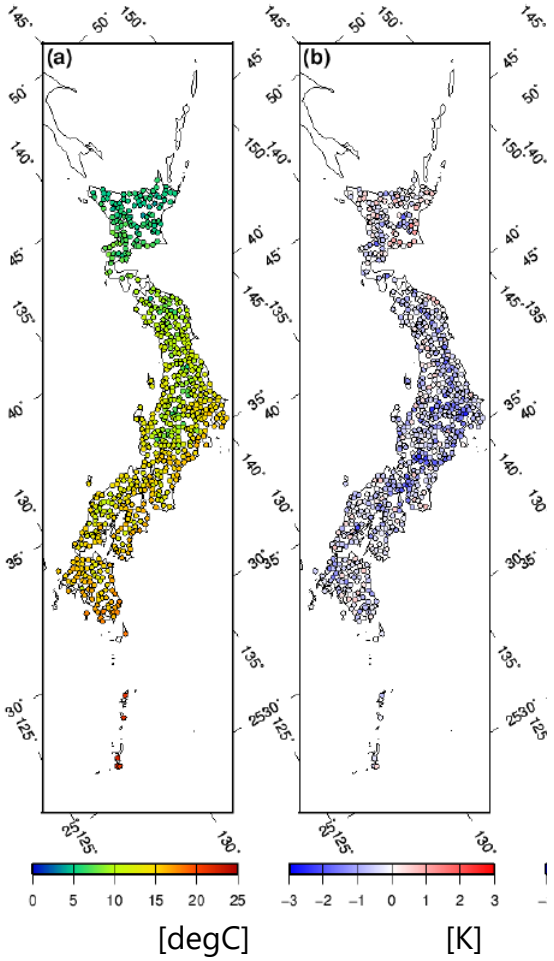


- Modeled values for comparison
  - At the grid point nearest to an observational point
- Bias, RMSE, and Correlation

Difference between model and observational results

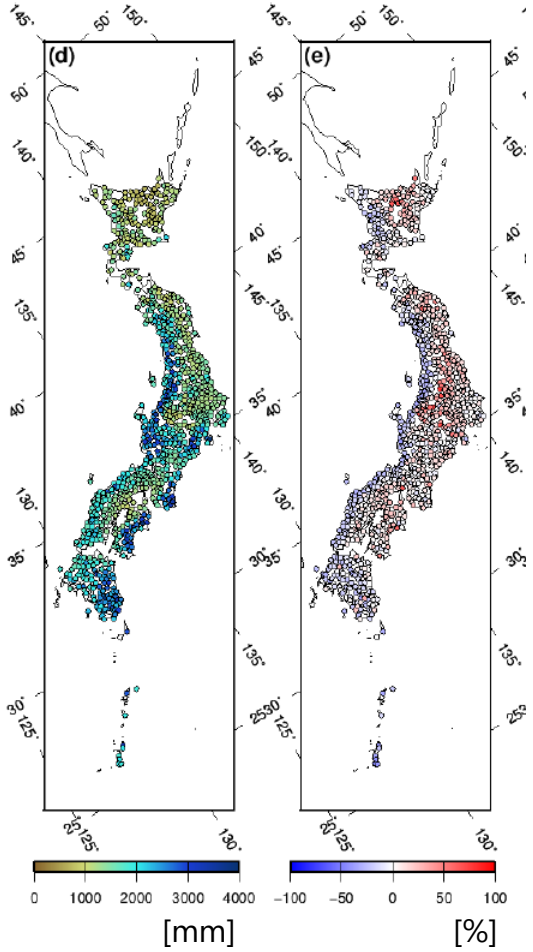
Surface air temperature

Model　　Model - Obs



Precipitation

Model　　100 x (Model/Obs-1)

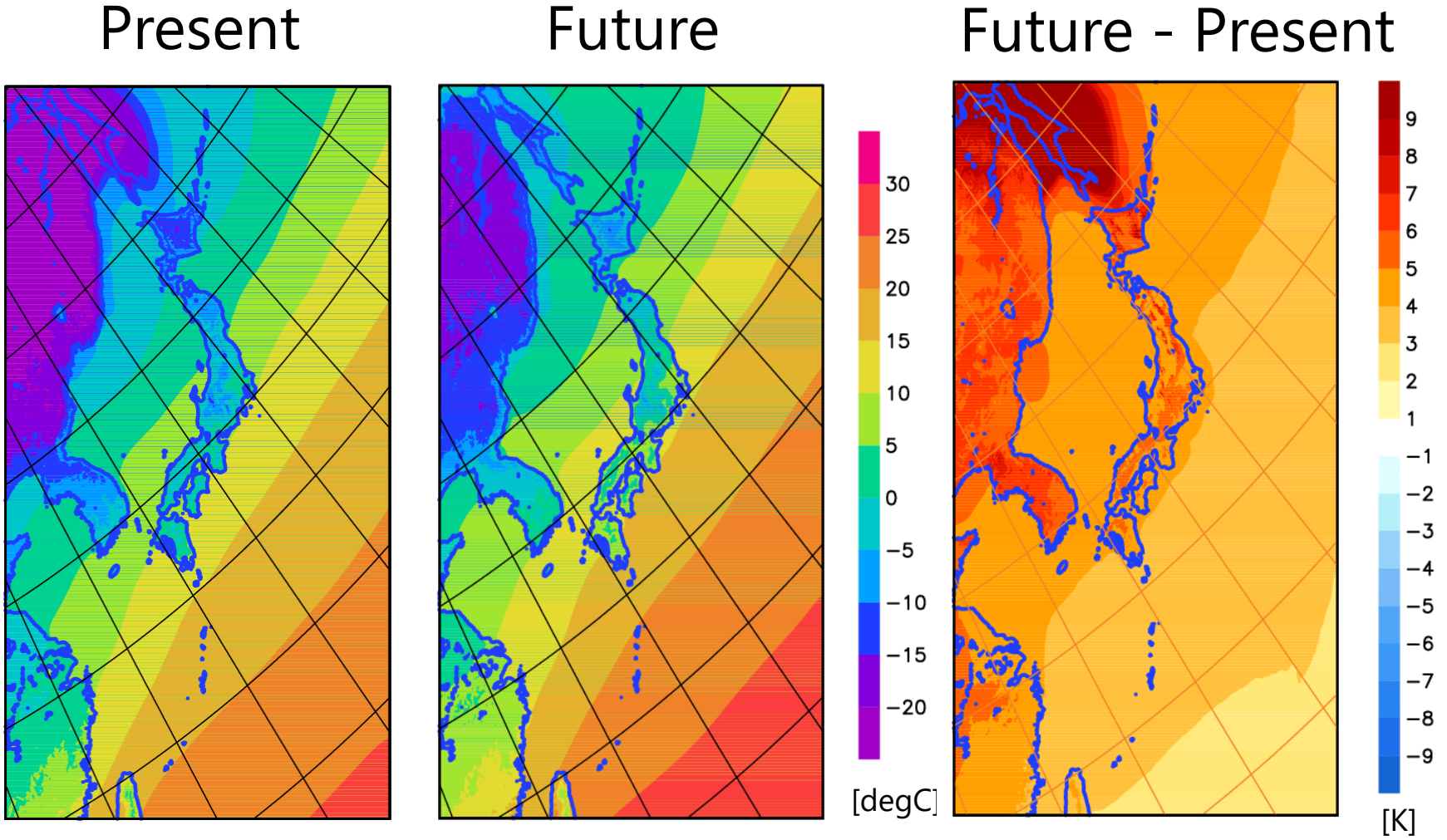


Murata et al. (2015)

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

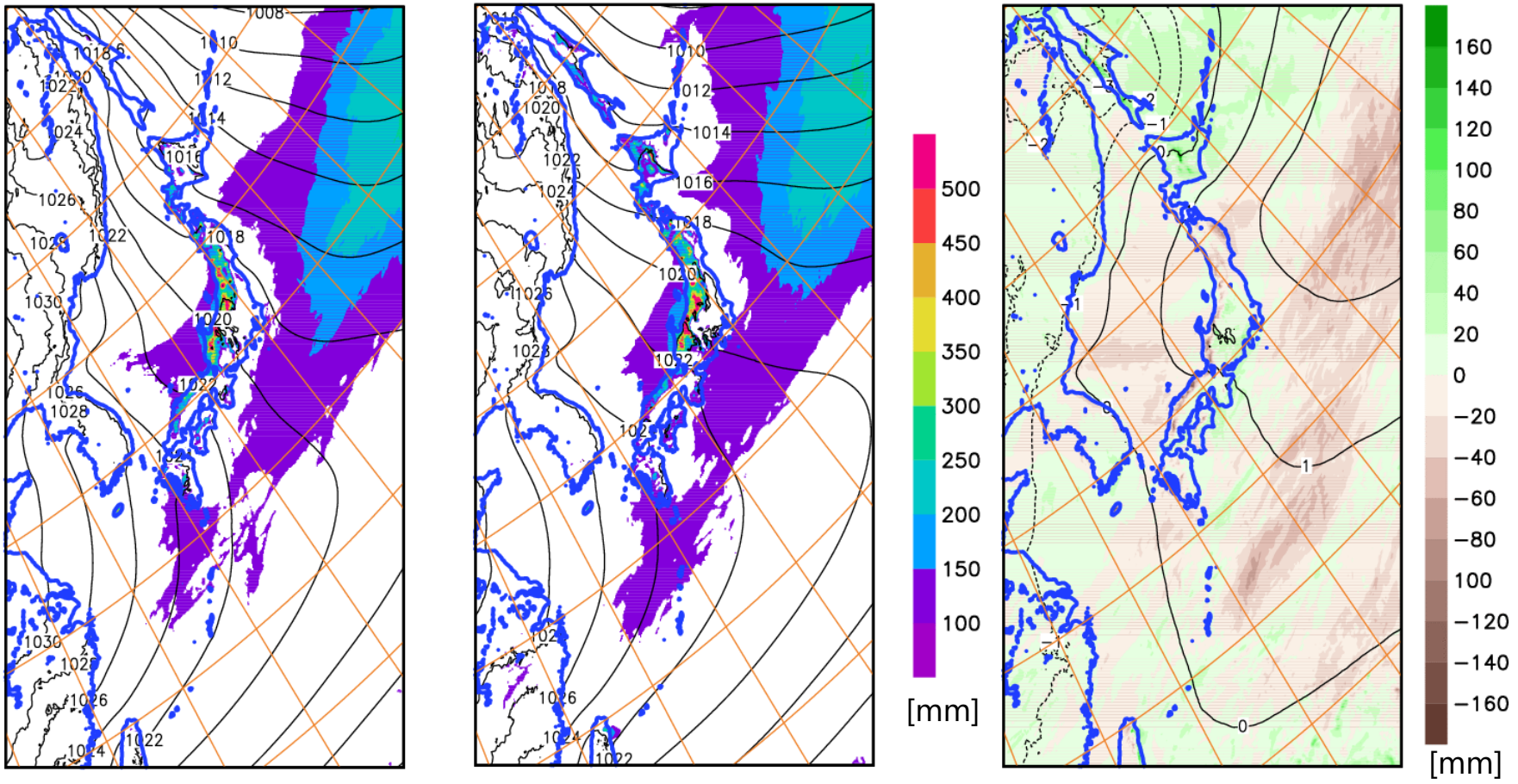


Difference between future and present precipitation

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

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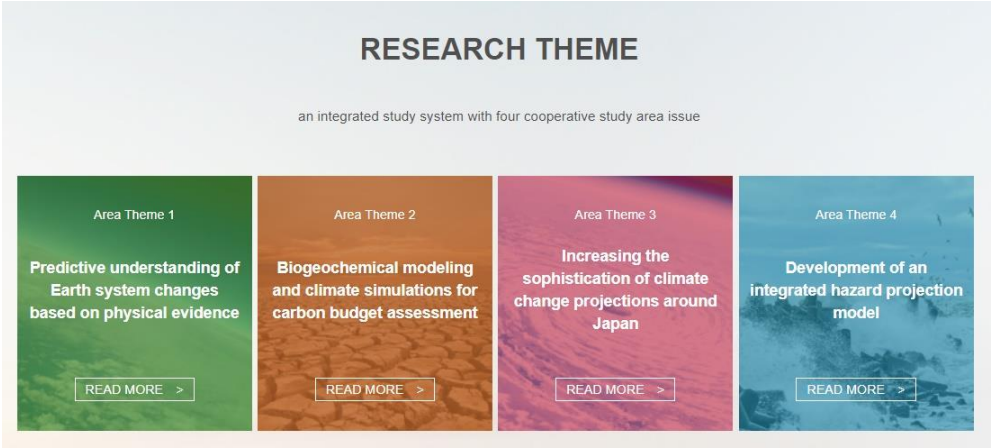
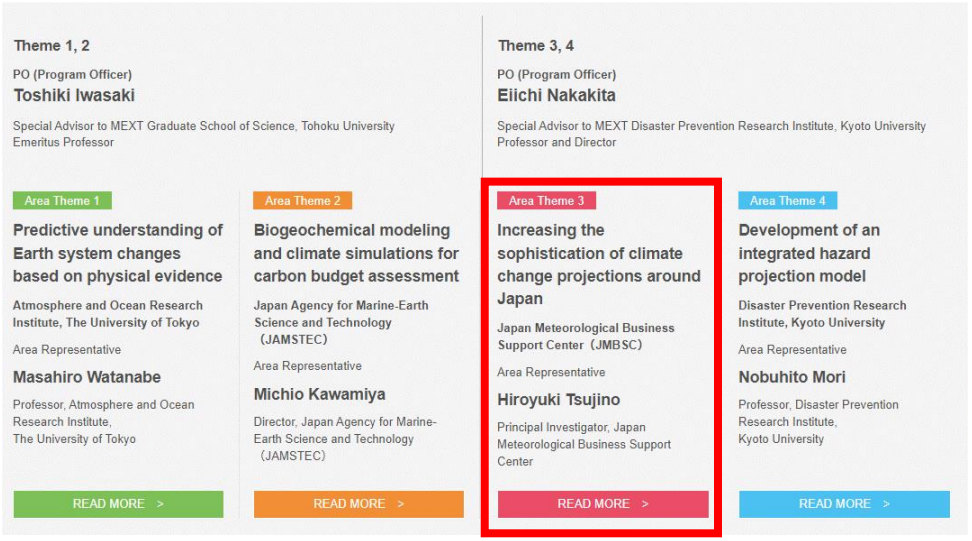
SENTAN program web

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





- Four research themes
- Theme No. 3: Increasing the sophistication of climate change projections around Japan

Area theme No. 3 of SENTAN program

Area Theme 3

Increasing the sophistication of climate change projections around Japan

Japan Meteorological Business Support Center（JMBSC）

Area Representative

Hiroyuki Tsujino

Principal Investigator, Japan Meteorological Business Support Center

Area subjects

- **Development of projection system and analysis of mechanism for climate change around Japan**
- **Creating climate change projection information and elucidating extreme event mechanisms for promoting regional and basin scale adaptation measures**
- **Creation of high-accuracy climate projection datasets for vulnerable regions in the world**

Promotion of projection

- **products use and user communication**

Participating organizations

Hokkaido University, Tohoku University, JAMSTEC, Nagoya University

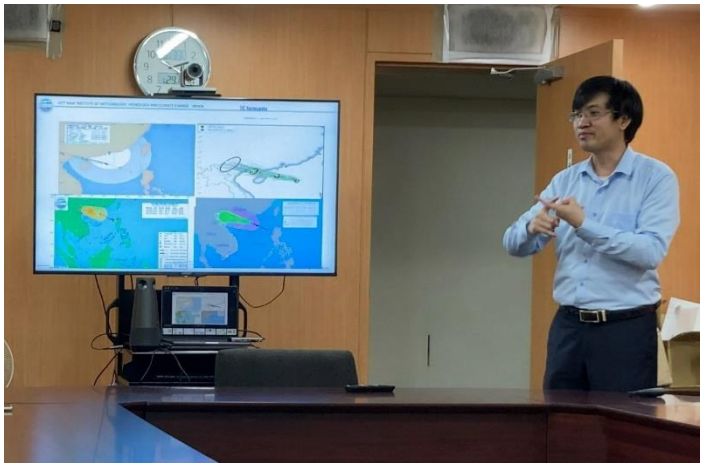
- Three sub-themes
- Sub-theme No. 3:
  - Creation of high-accuracy climate projection datasets for vulnerable regions in the world
  - International collaboration through inviting researchers to MRI

MEXT-Program for The Advanced Studies of Climate Change Projection(SENTAN)

International collaboration

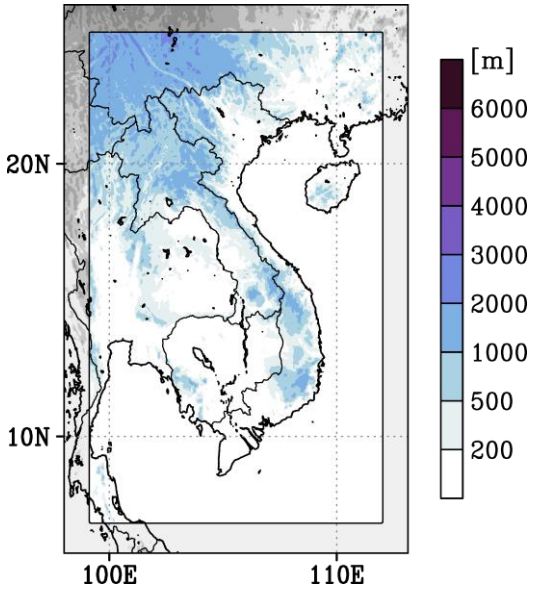
- High-resolution climate projection datasets for their countries have been made by using a regional climate model, called NHRCM.
  - 3-km horizontal resolutions (Convection permitting)
- The datasets can be used for climate change impact assessment and adaptation strategies

An invited researcher



(By courtesy of Dr Kien)

Model domains



(By courtesy of Dr Fukui)

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

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