Evaluation of present climate in non-hydrostatic regional climate simulations for SOUSEI program

Akihiko MURATA

(Meteorological Research Institute, Japan)

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1. Introduction: Sousei program

- Program for Risk Information on Climate Change
- The aim of this program
  - To generate basic information required for managing various risks resulting from climate change.
- Four themes
  - A: Prediction and diagnosis of imminent global climate change
  - B: Climate change projection contributing to stabilization target setting
  - C: Development of basic technology for risk information on climate change
  - D: Precise impact assessments on climate change

1. Introduction (cont.)

- The purpose of this study
  - To project future climate and evaluate uncertainty of the projection in Japan
- The purpose of this presentation
  - To evaluate the present climate
    - Surface air temperature
    - Precipitation

Contents

NHRCM: NonHydrostatic Regional Climate Model

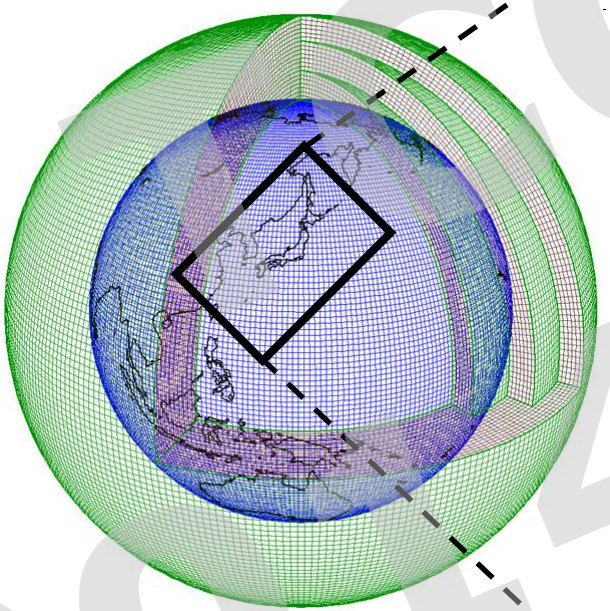
Horizontal grid spacing	5 km
Grids	527 × 804 × 50
Basic equations	Full compressible system (Flux form)
Radiation	Shortwave: Two stream with delta-Eddington Longwave: Table look-up and k-distribution
Cloud microphysics	Bulk scheme
Cumulus	Kain-Fritch scheme
Nesting	Spectral boundary conpling
Turbulent closure	Improved Mellor-Yamada (MYNN) Level 3
Land surface model	Simple Biosphere (SiB)

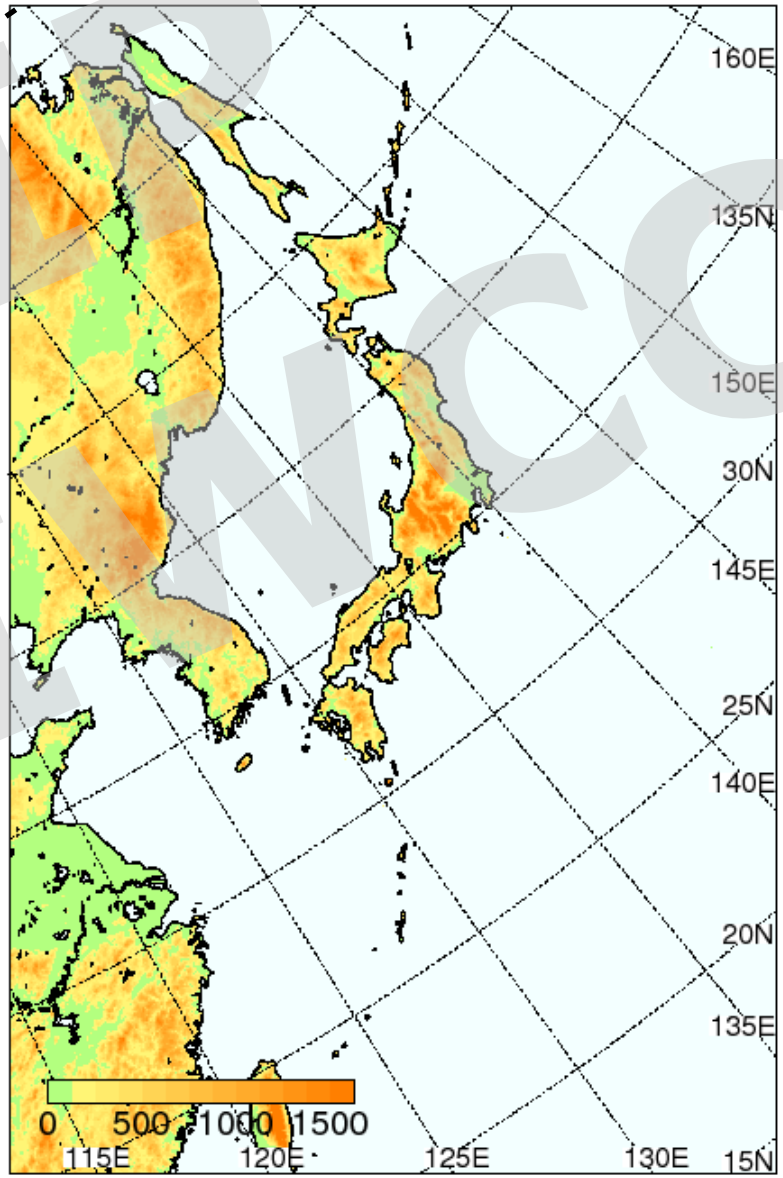
- New schemes
  - Unfrozen water under the ground by Mitsuo Oh'izumi
  - Improved Kain-Fritsch convection scheme around islands by Teruyuki Kato

Model domain

5 km-mesh NHRCM

20 km-mesh AGCM





Integration period:

20 years

(Sep 1980 – Aug 2000)

SST:

Observed (monthly)

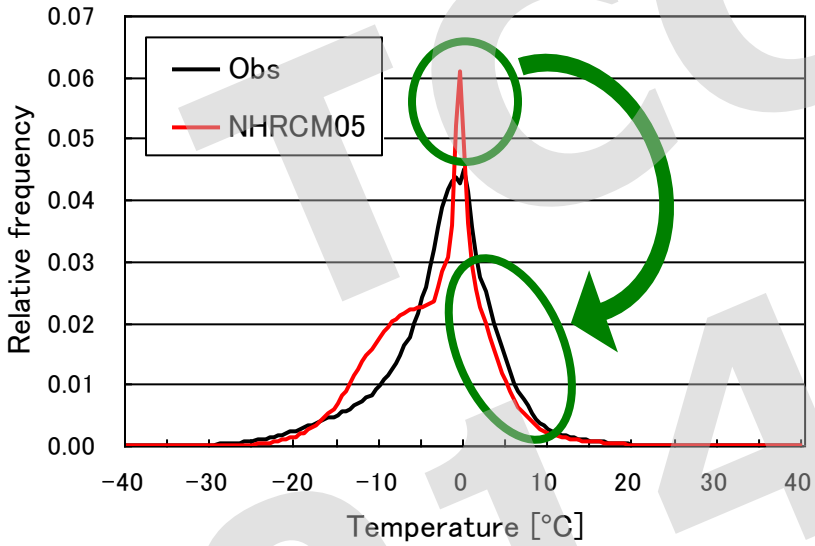
Observational data for evaluating model results

- Observations: AMeDAS
  - High-resolution surface observations
  - Horizontal resolution: 17 km
- Modeled values for comparison
  - At the grid point nearest to an observational point
  - Surface air temperature is corrected (0.65K/100m) because of difference between modeled and actual heights

Contents

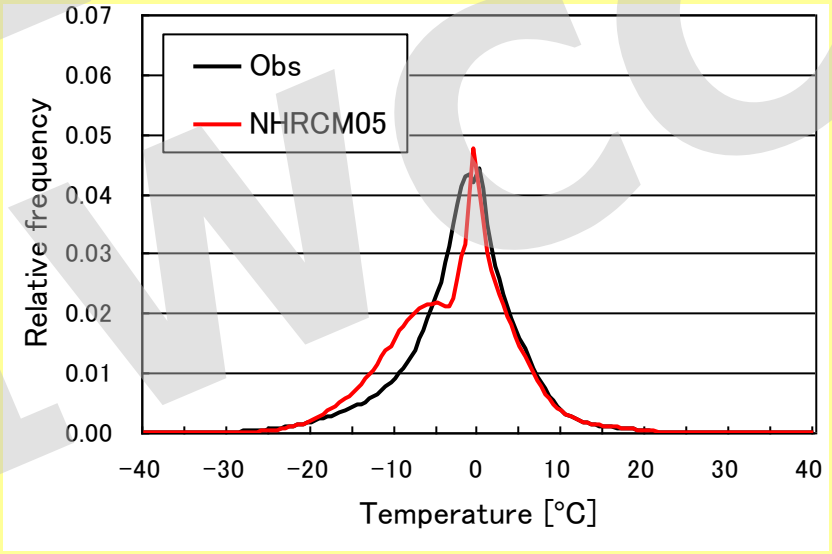
Relative frequency distribution (from Dec to Feb)

Original 5km-mesh NHRCM



- Frequency around zero degrees C is overestimated.
- Frequency above zero degrees C is slightly underestimated.

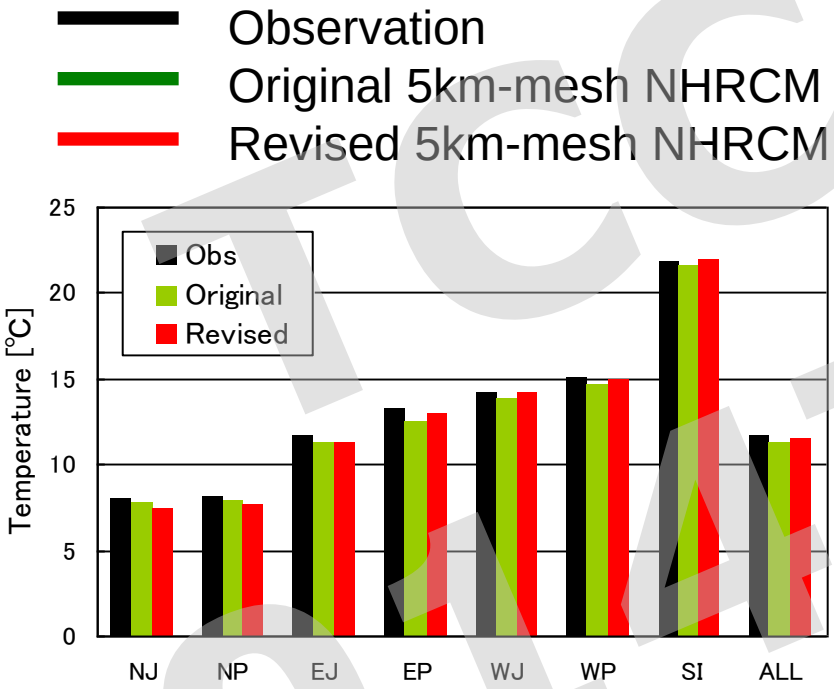
Revised 5km-mesh NHRCM



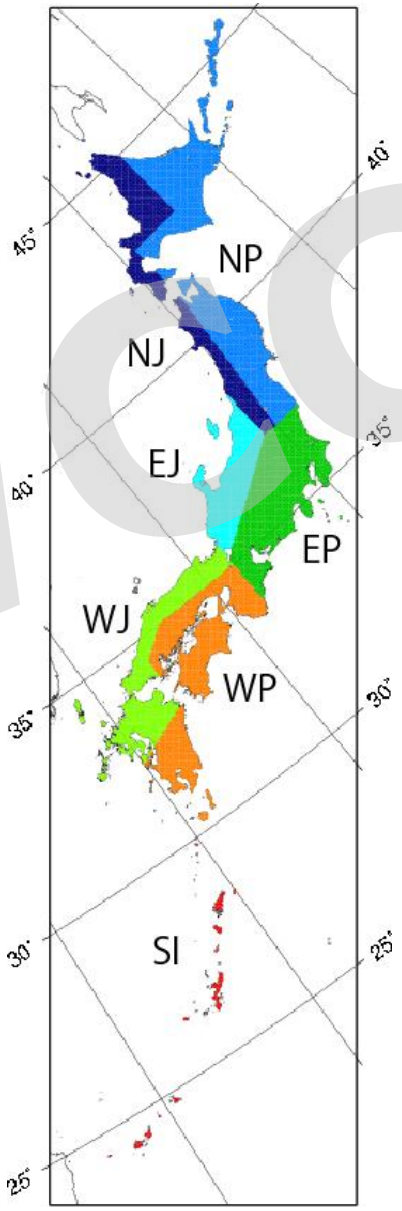
- The excessive frequency around zero degrees C is almost eliminated.
- The underestimation above zero degree C is also eliminated.

Only stations where difference in height between observation stations and model grid points are small (within 200 m) are used.

Annual mean temperature for each region

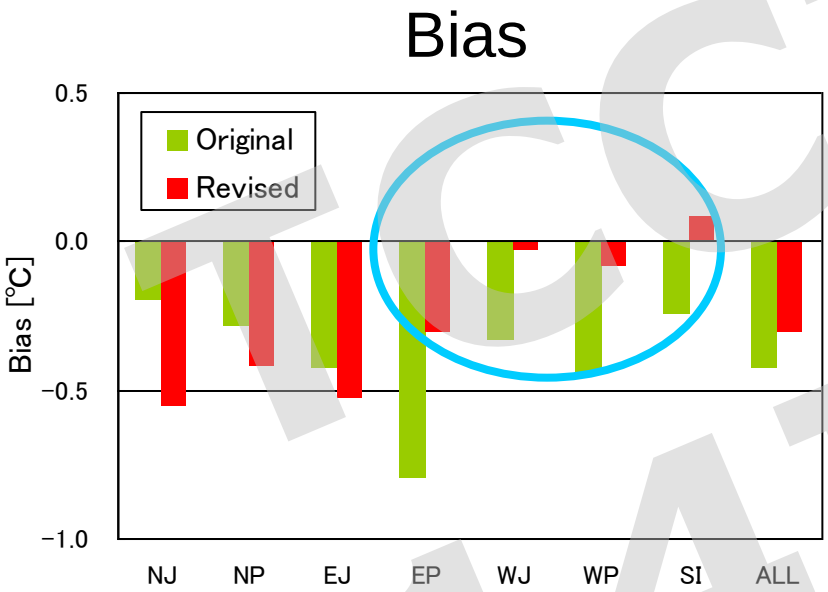


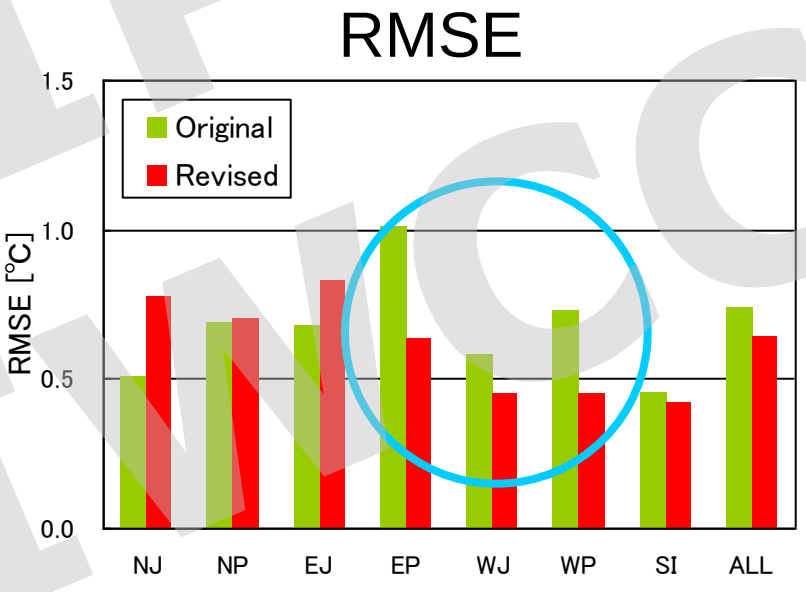
7 regions



- Annual temperature in each region is well reproduced by NHRCM05.
- Difference in temperature between the two models seems to be small.

Errors in annual mean temperature for each regions

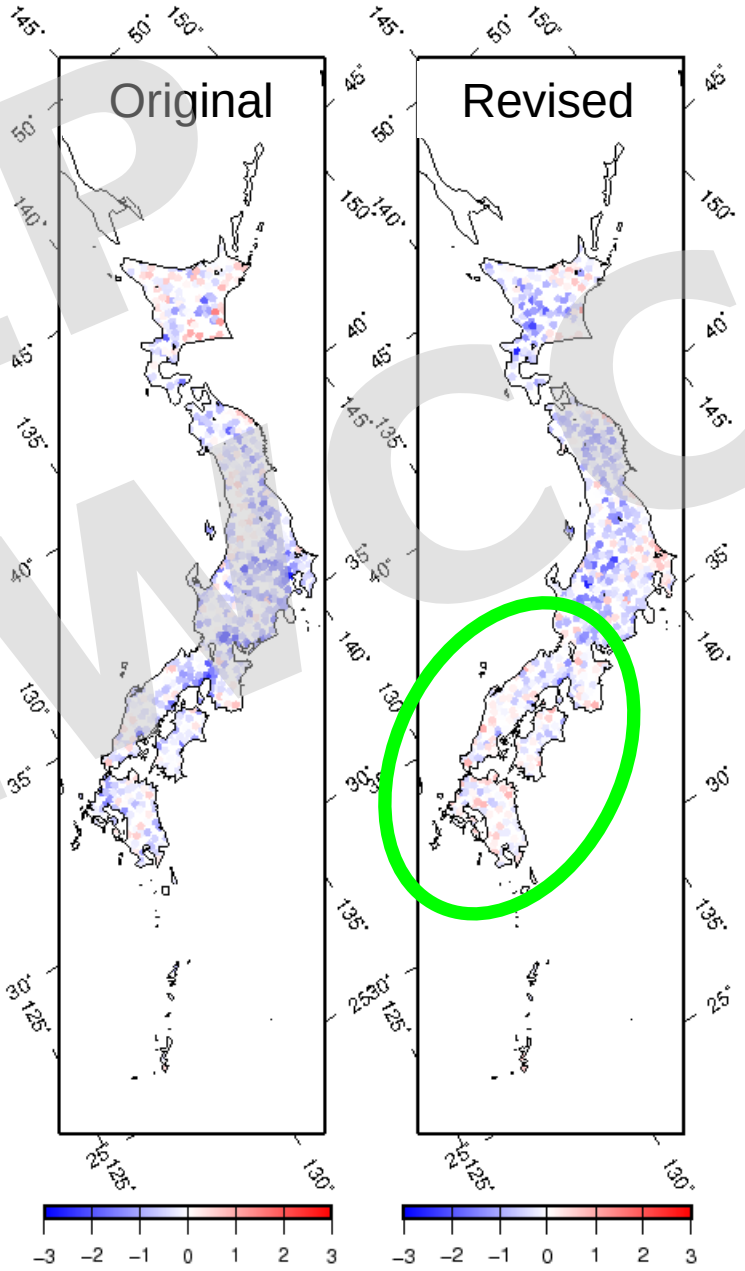




- Difference in errors between the two model results is not small in some regions.
  - In western and southern regions, bias and RMSE obtained from the revised model are smaller than those from the original model.

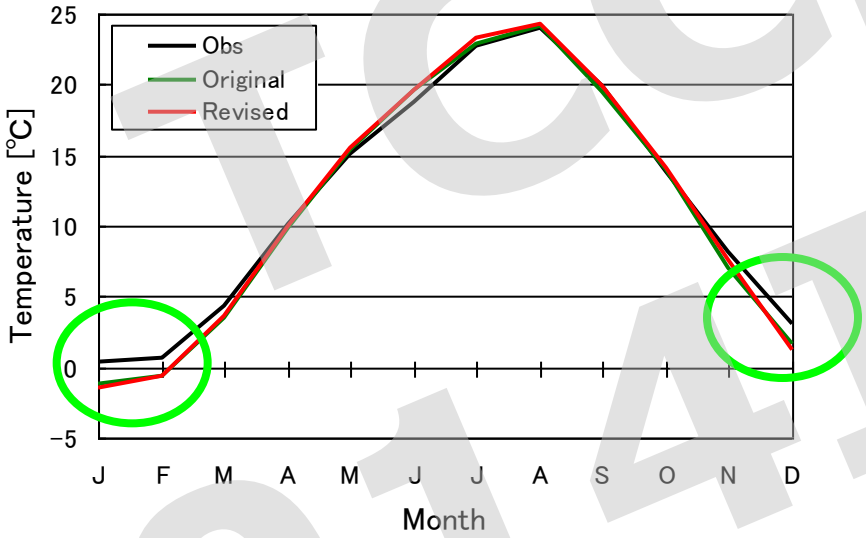
Horizontal distribution of bias in annual mean temperature

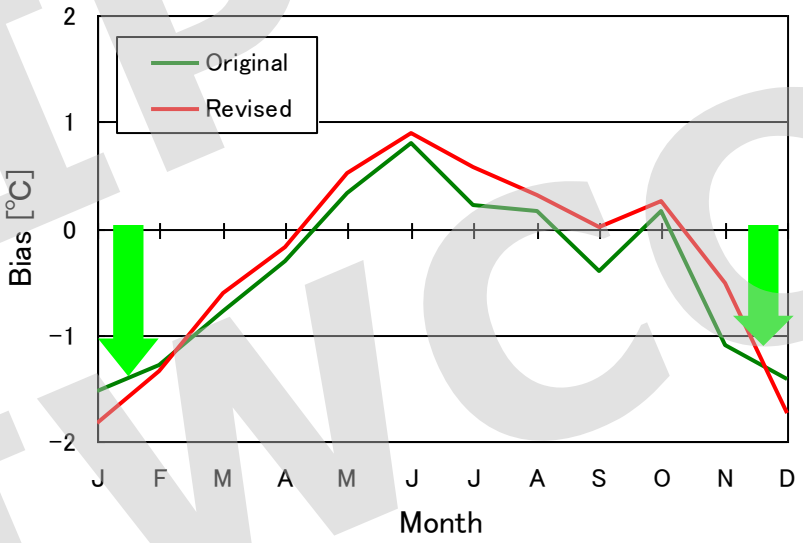
- Values over western and southern areas in the revised-model result are relatively small compared with those in the original-model result.

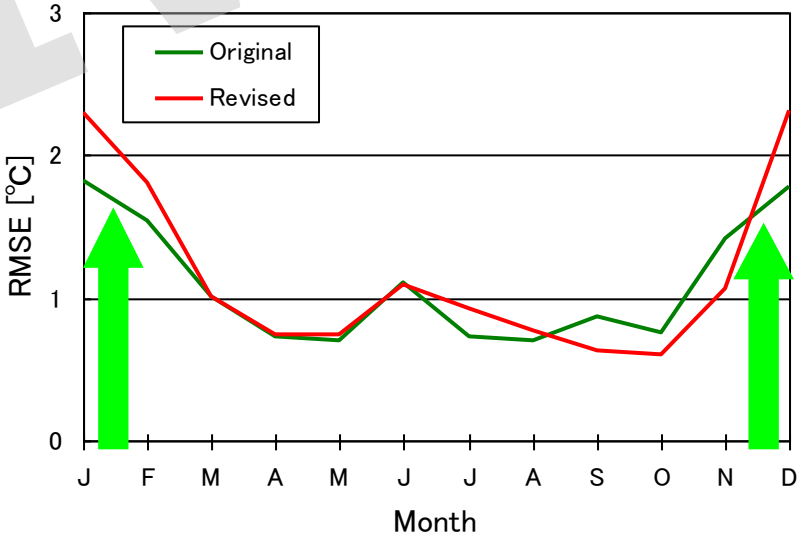


Time series of monthly-mean temperature

Observation
Original 5km-mesh NHRCM
Revised 5km-mesh NHRCM



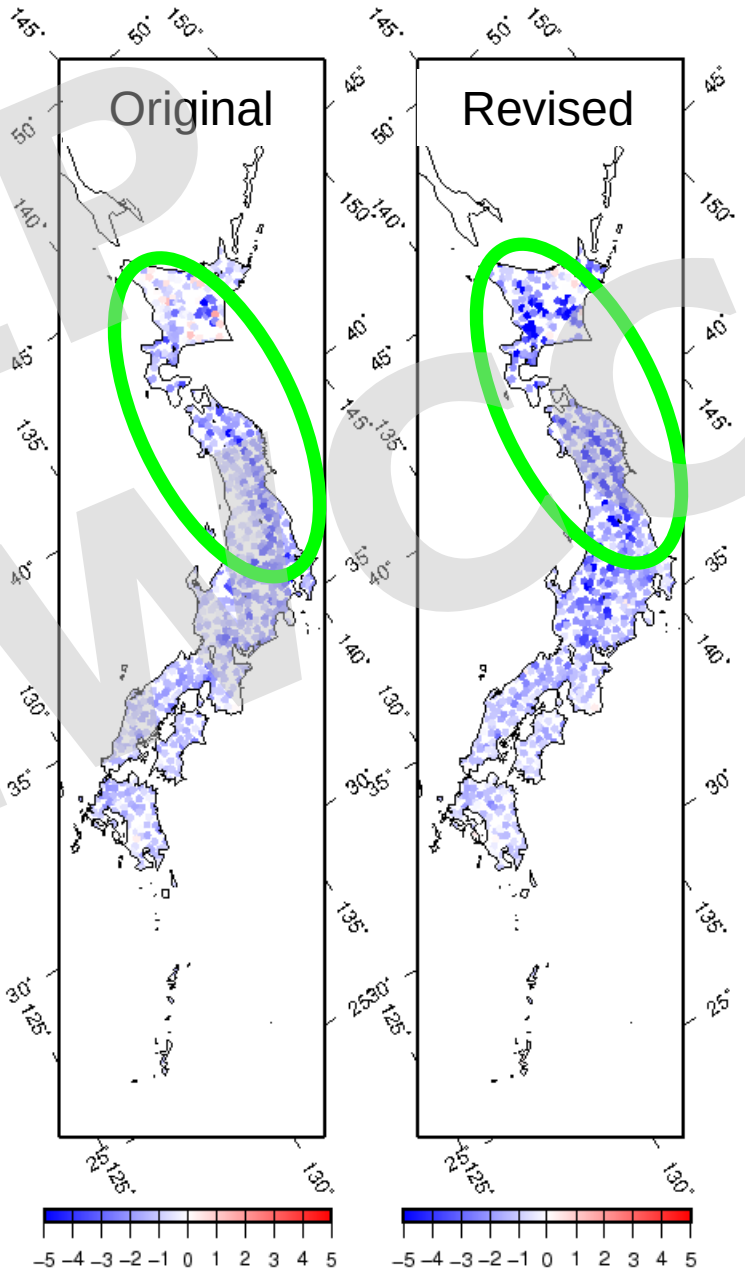




- There are some errors, in particular, in winter.
  - December, January, and February

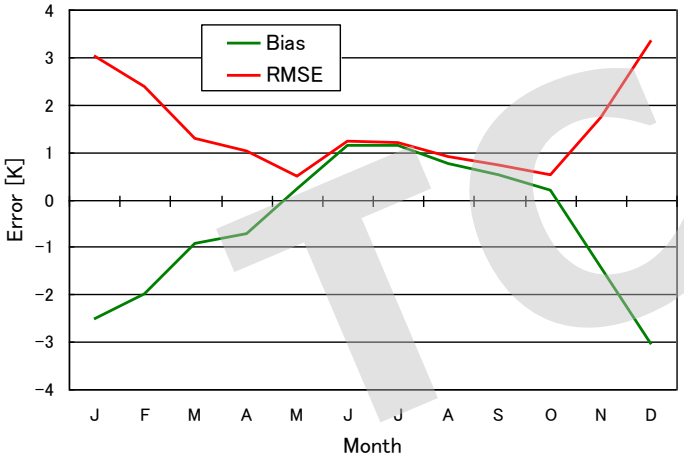
Horizontal distribution of bias in monthly-mean temperature in January

- Biases over northern regions are relatively large for both the original and revised model results.

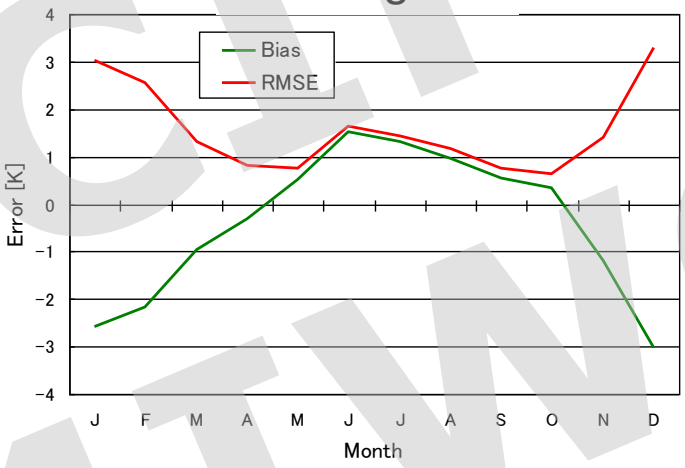


Errors over northern regions

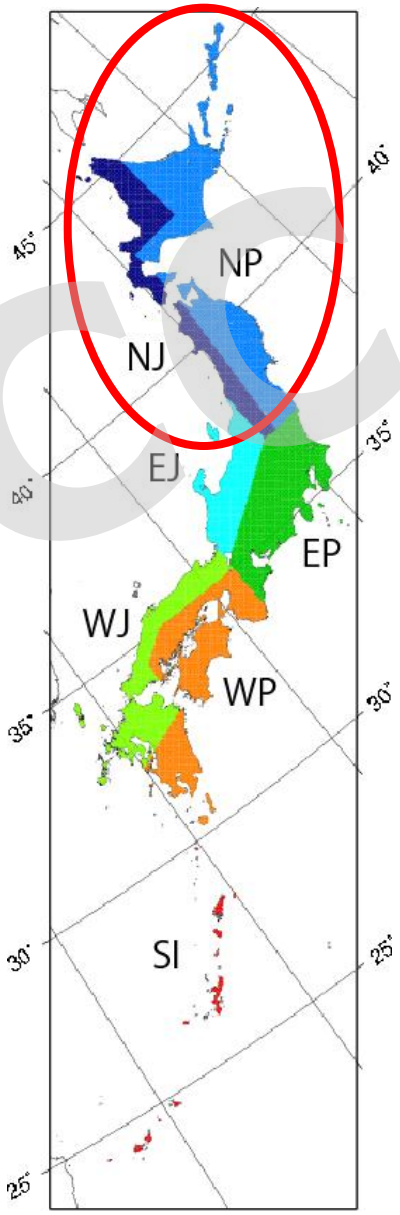
NJ region



NP region



7 regions

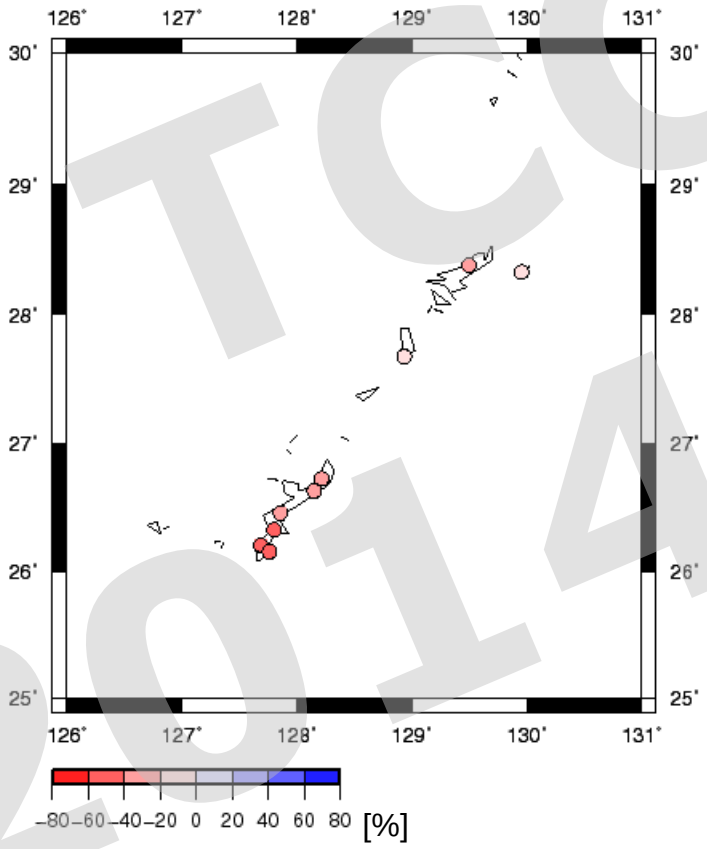


- In these northern regions, the magnitudes of errors (Bias and RMSE) are larger in winter.
- The reason for this is not sure so far, but snow cover seems to be a key factor.

Contents

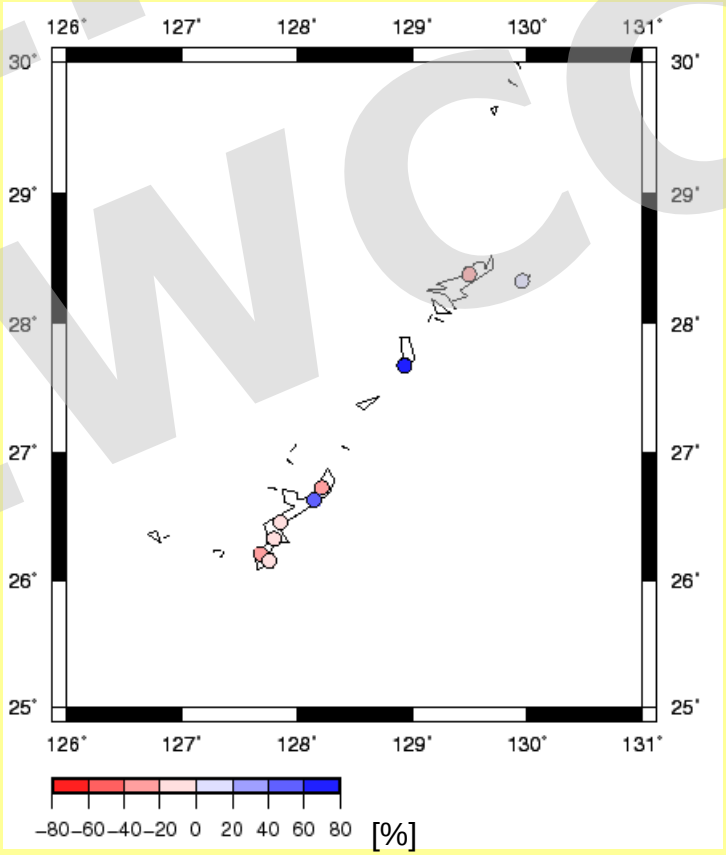
Bias in annual precipitation around Okinawa islands

Original 5km-mesh NHRCM



- Negative bias in precipitation

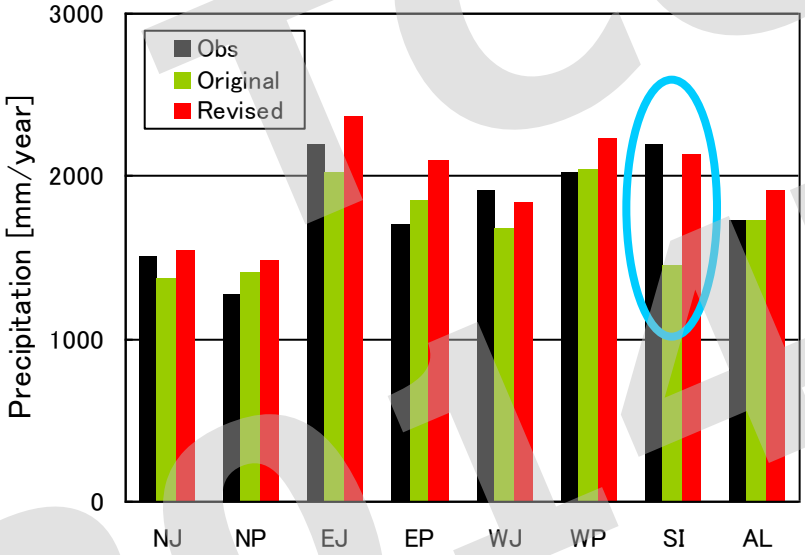
Revised 5km-mesh NHRCM



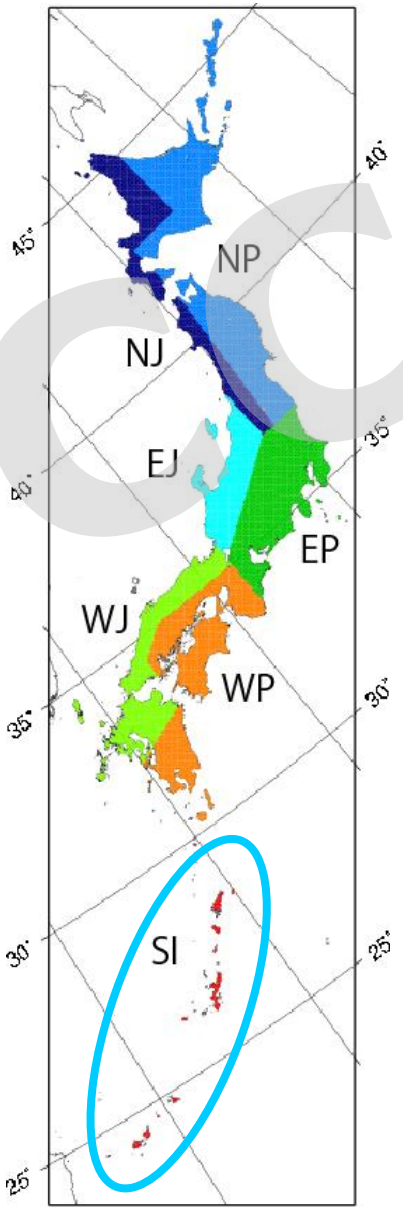
- Reduction in negative bias

Annual precipitation in each region

Observation
Original 5km-mesh NHRCM
Revised 5km-mesh NHRCM

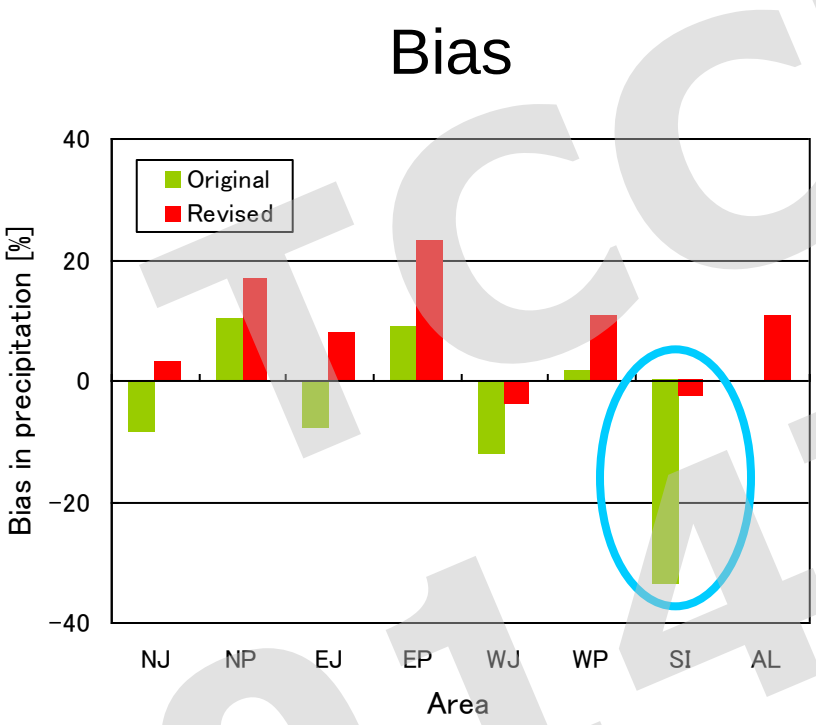


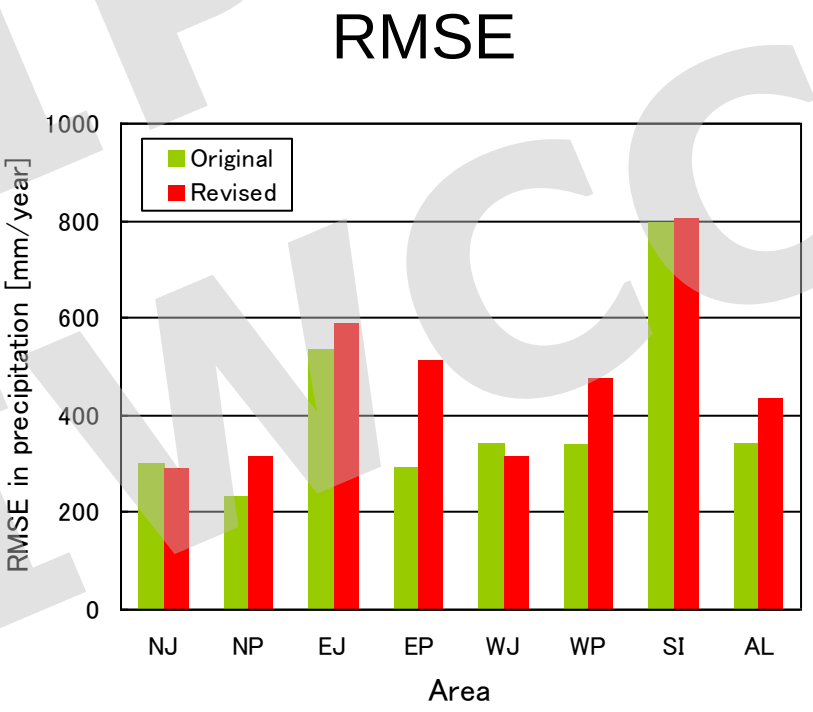
7 regions



- Precipitation in the southwestern island region is underestimated in the results with the original convection scheme.
- Simulated precipitation with the improved convection scheme approaches the observed precipitation.

Errors in annual precipitation for each region

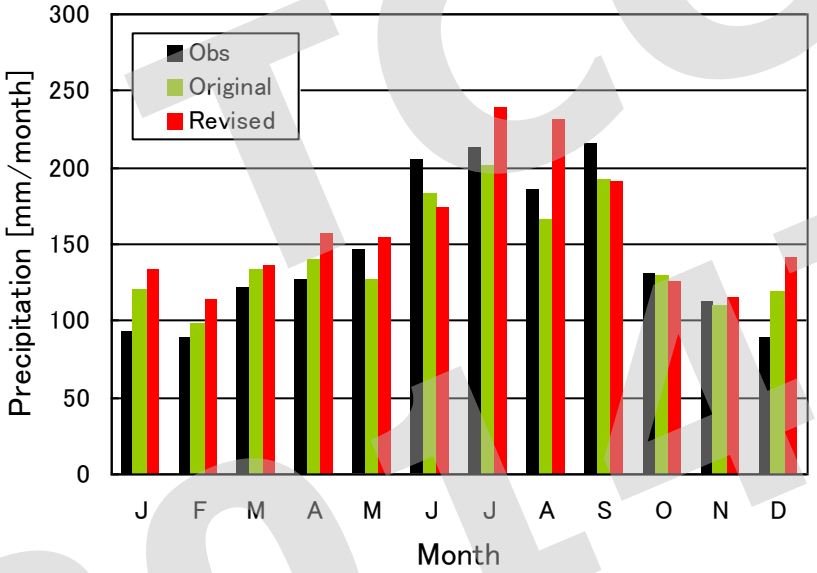


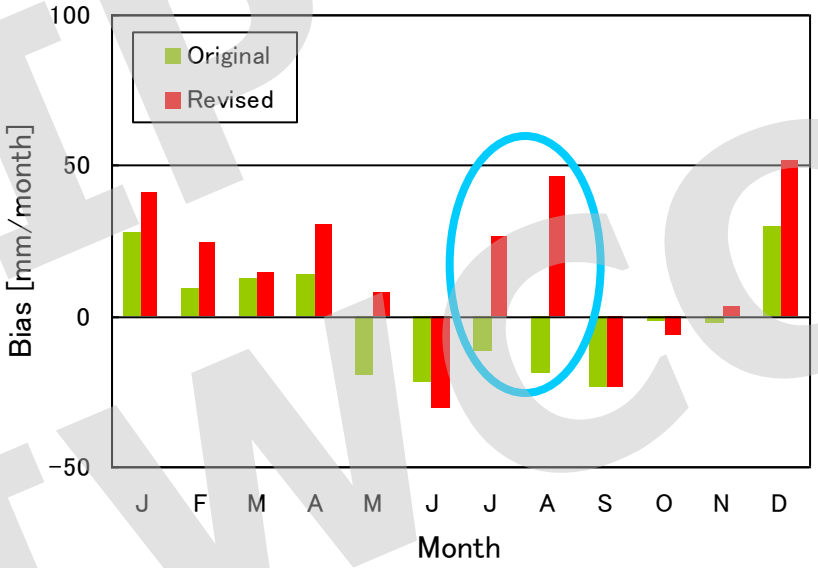


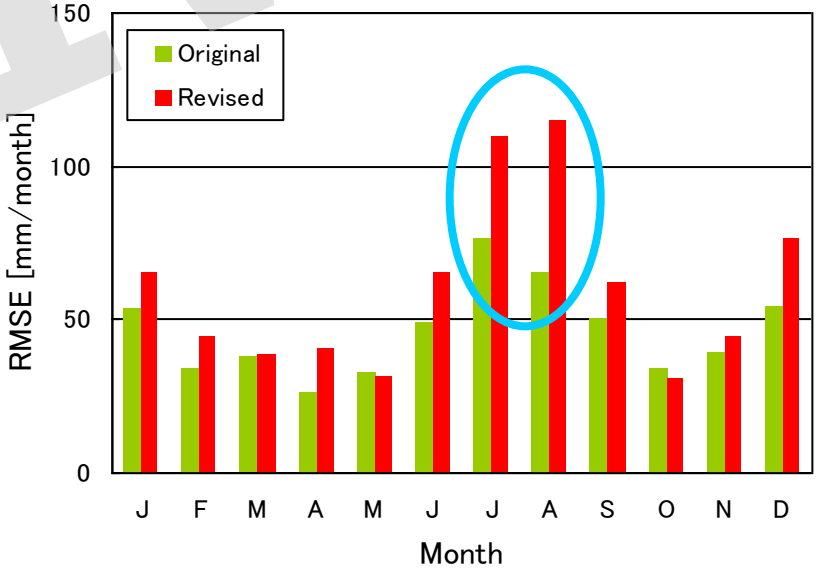
- The magnitude of bias in the southwestern island region is considerably reduced by using the improved convection scheme.

Time series of monthly precipitation

Observation
Original 5km-mesh NHRCM
Revised 5km-mesh NHRCM

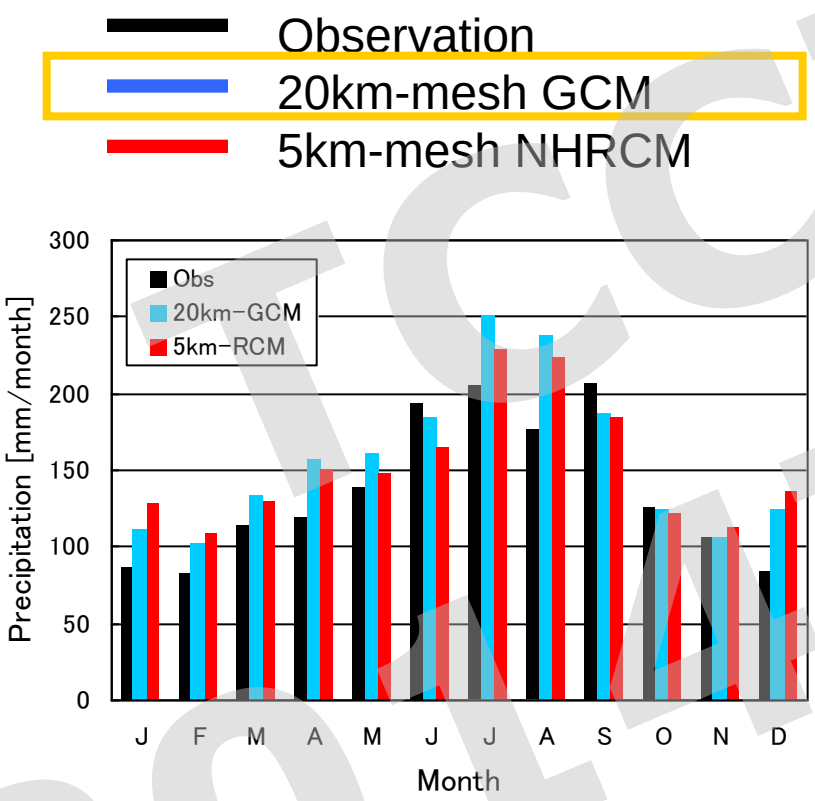


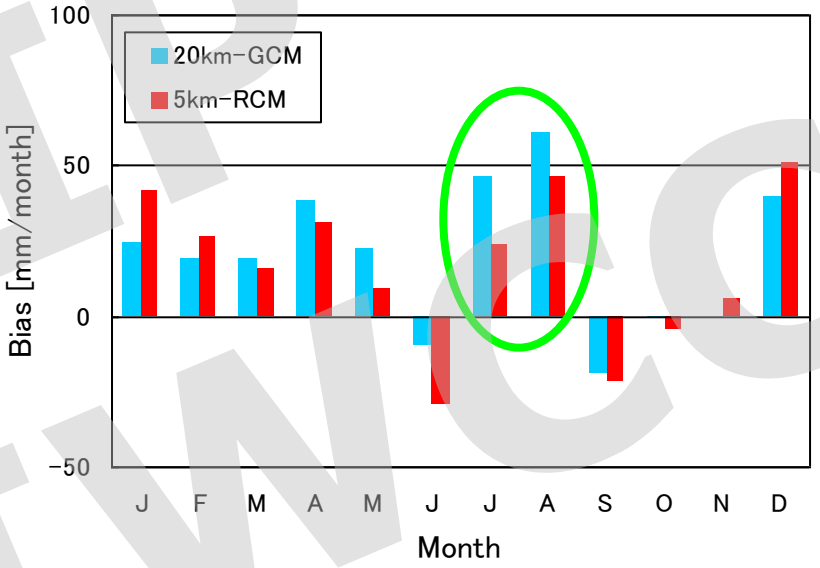


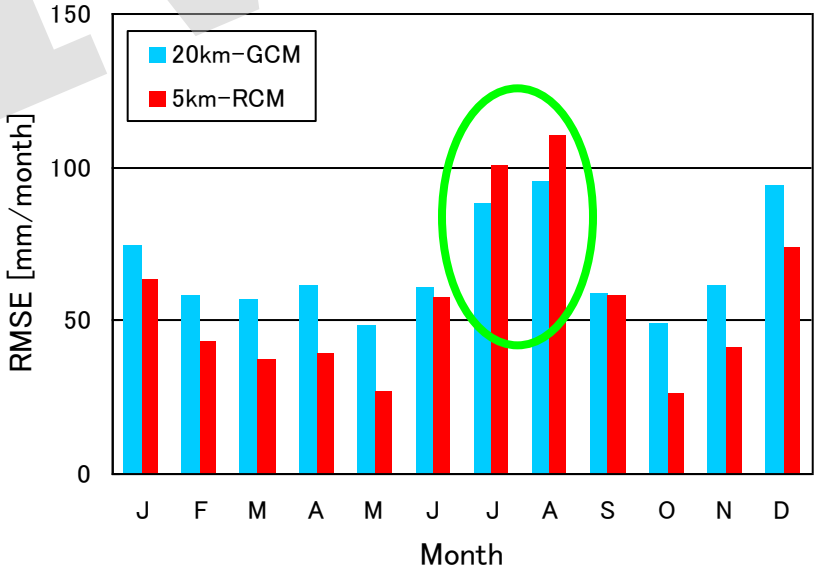


- Large errors in July and August

vs. driving model (GCM)







- Errors in July and August are also large in the GCM simulation.
  - The driving-model simulation greatly affects the RCM simulation.

4. Summary

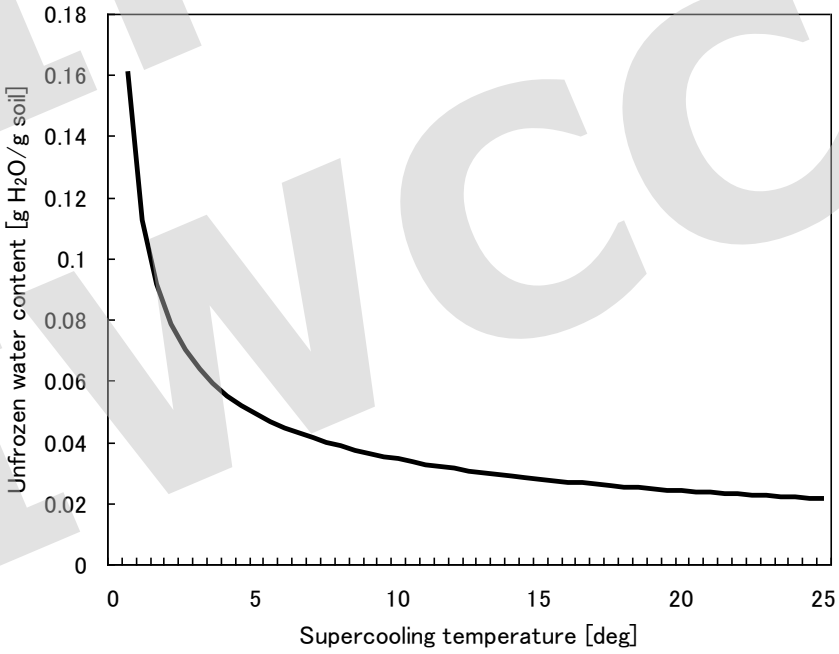
- Evaluation of the present climate reproduced by 5 km-mesh NHRCM
- Surface air temperature
  - Elimination of excess in the number of data around zero degrees Celsius
  - Negative bias over northern regions in winter
- Precipitation
  - Reduction in negative bias over the region of southwestern islands
  - Positive bias in summer

Acknowledgments

- Collaborators:
  - Izuru Takayabu, Hidetaka Sasaki, Mizuki Hanafusa, Masaya Nosaka, Toshinori Aoyagi, Fumitake Shido, Mitsuru Oh'izumi, Teruyuki Kato, Sachie Kanada, Asuka Suzuki-Parker, Kenshi Hibino, Toshiharu Nagatomo
- This work was conducted under the framework of the Development of Basic Technology for Risk Information on Climate Change supported by the SOUSEI Program of the Ministry of Education, Culture, Sports, Science, and Technology of Japan.SOUSEI program

Unfrozen water under the ground by Mitsuo Oh'izumi

- Based on Anderson and Tice (1972), and Anderson et al. (1973)



$$\ln w = 0.2618 + 0.5519 \ln S - 1.449 S^{-0.264} \ln(-\theta)$$

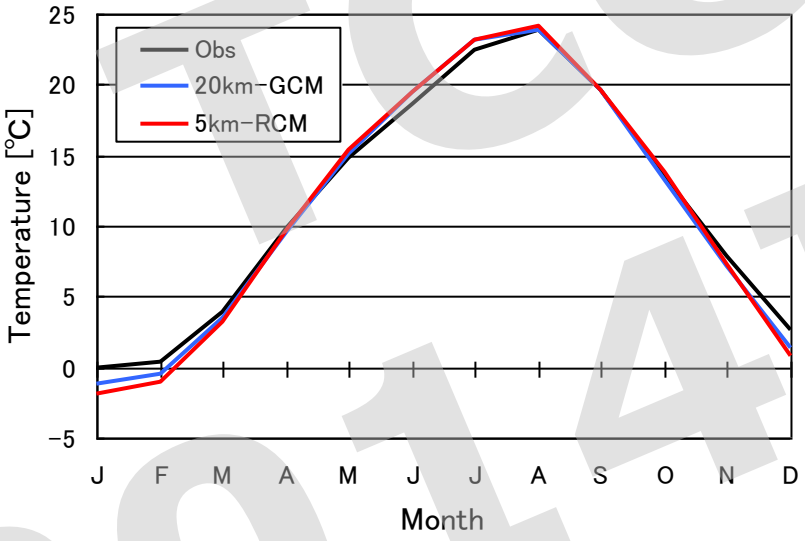
w: unfrozen water content (g H_2O/100g soil)
θ: temperature in degrees C
S: surface area of soil (assumed to be 50)

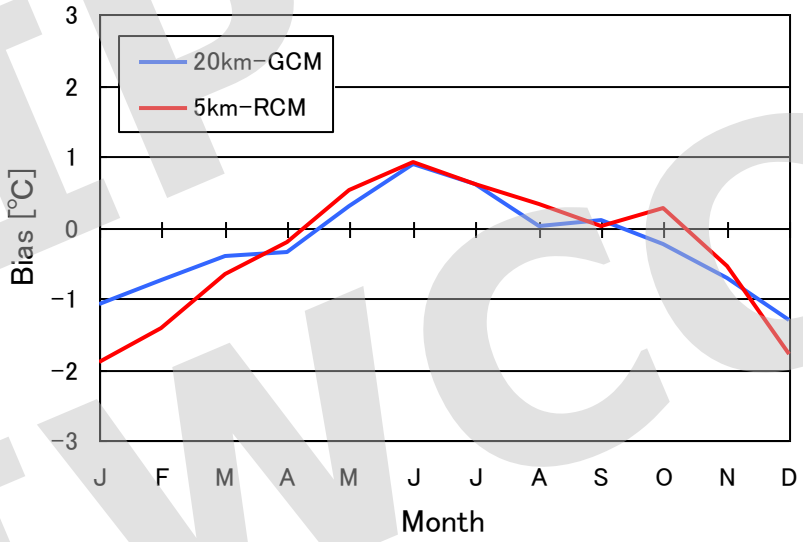
Improved Kain-Fritsch scheme around islands by Teruyuki Kato

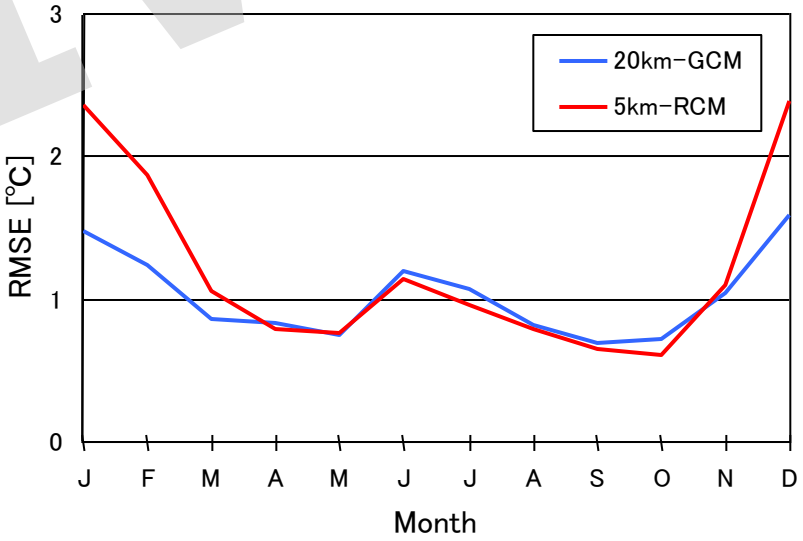
- For reducing negative bias in precipitation around an island
- Height for which an ascending air parcel originates depends on area of an island
  - Area of an island < 100 km^2 : without KF
  - Area is between 100 km^2 and 1000 km^2 :
    - adjust the height for which an ascending air parcel originates
  - Area > 1000 km^2 : same as before

vs. driving model (GCM)

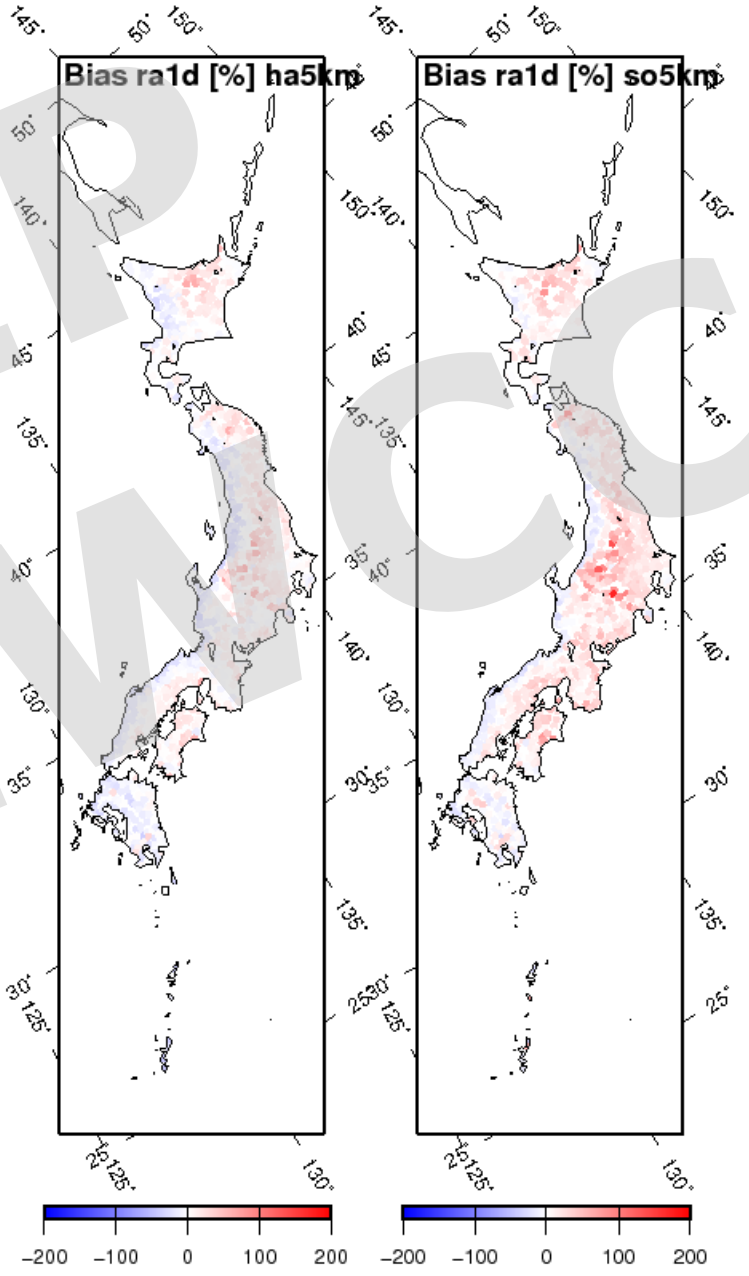
Observation
20km-mesh GCM
5km-mesh NHRCM



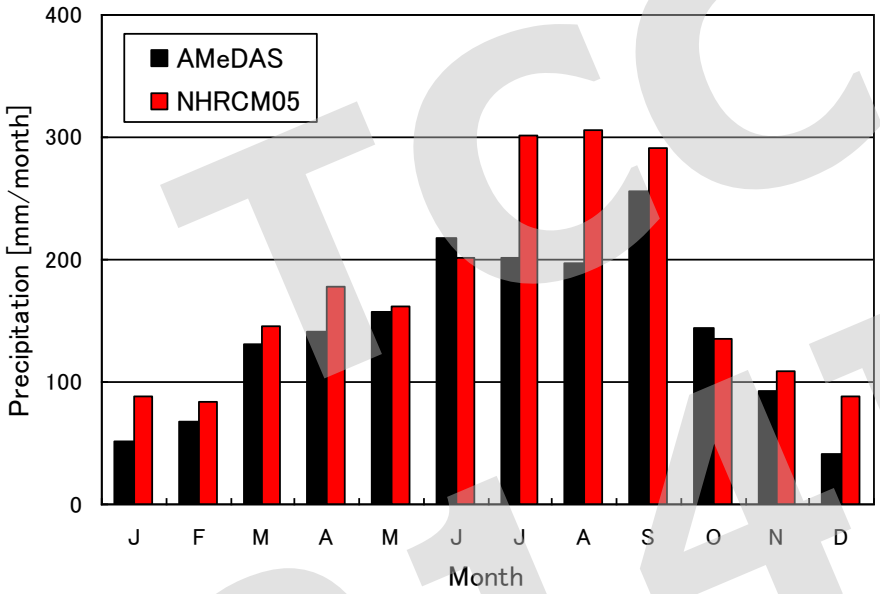


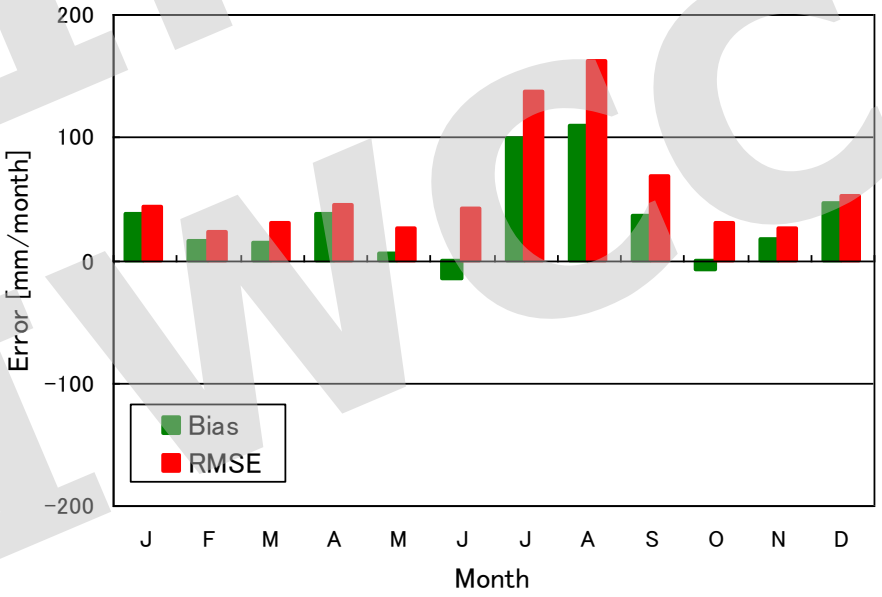


Horizontal distribution of bias in annual precipitation



Monthly precipitation in Pacific-side of Eastern-Japan region





- Precipitation in this region is overestimated in July and August for both global and regional model results.
  - These overestimations seem to be associated with the tracks of tropical cyclones, which depend on GCM itself and experimental design.

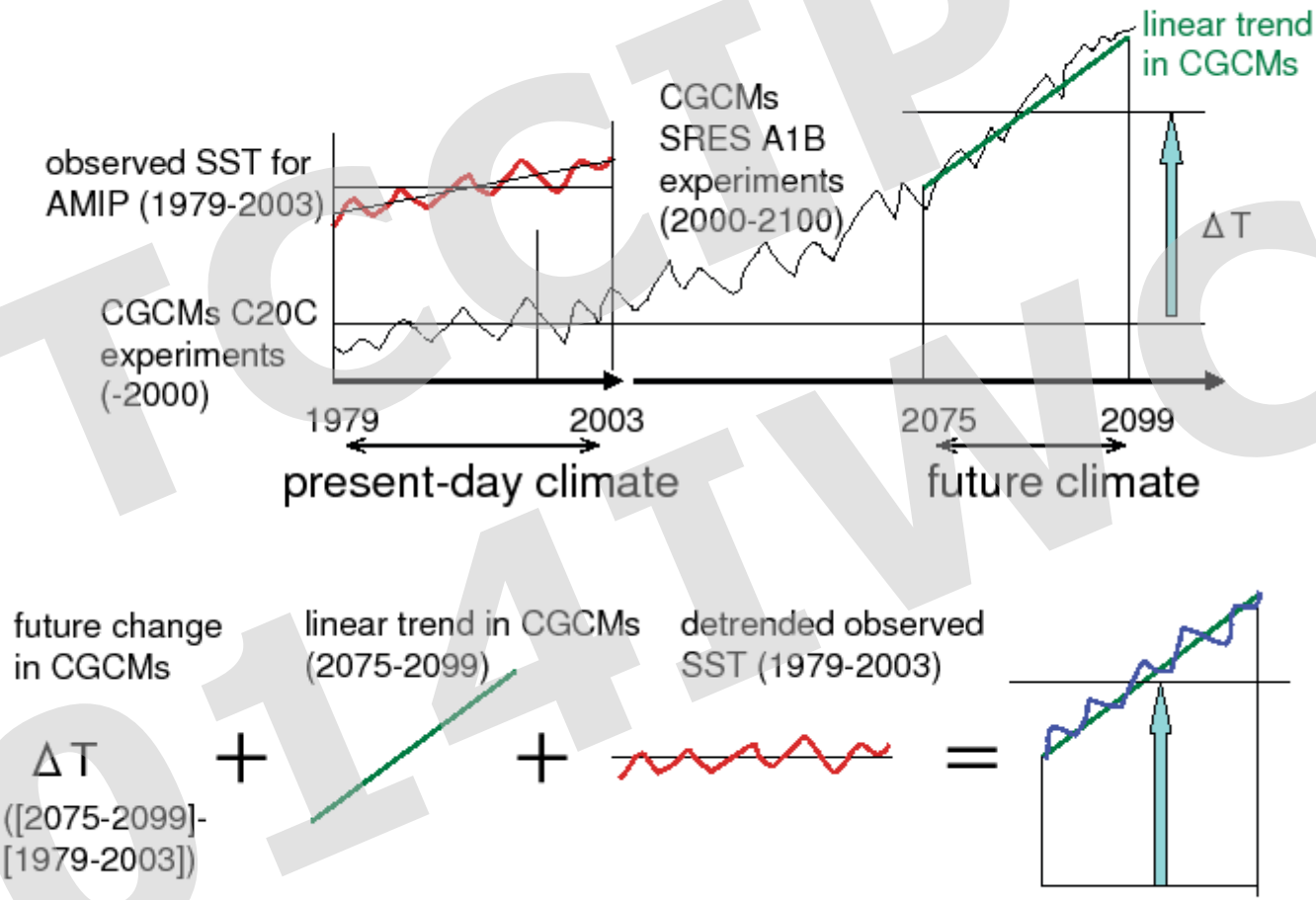
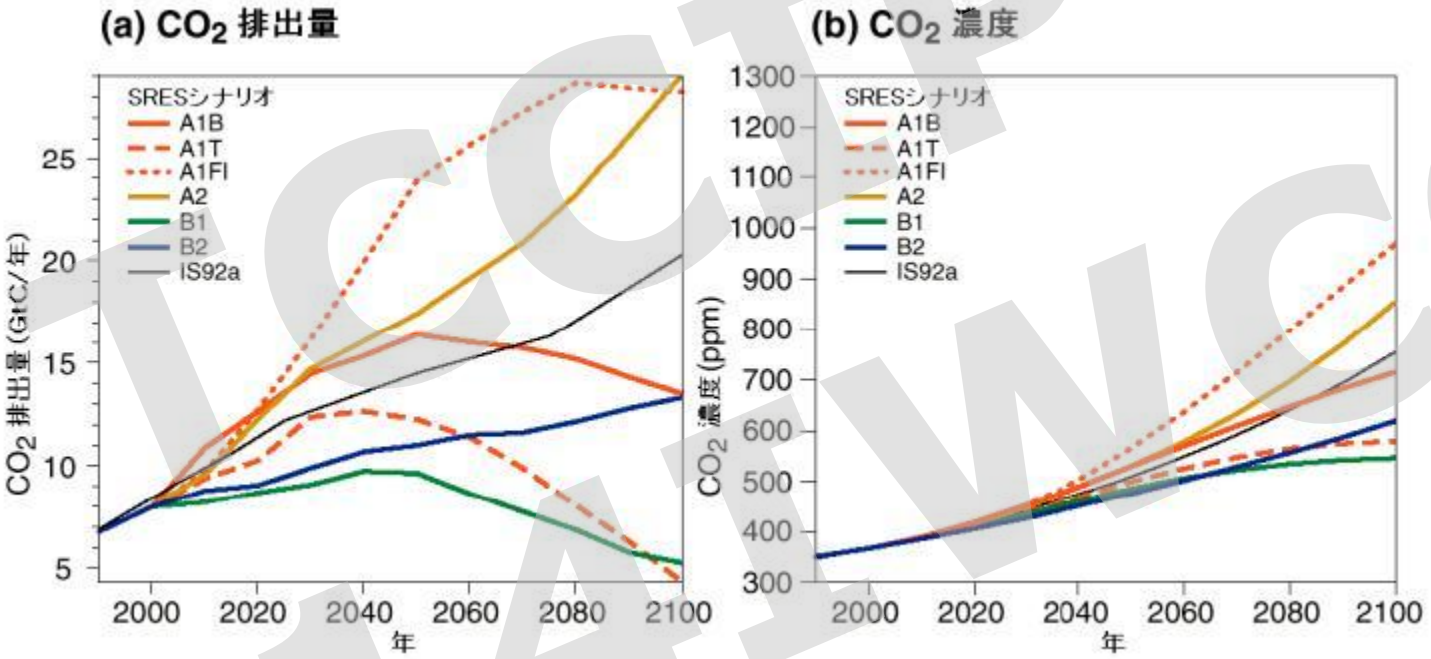


Fig. 1: The method used for estimating future SSTs.

Mizuta et al. (2008)

温室効果ガス排出シナリオ



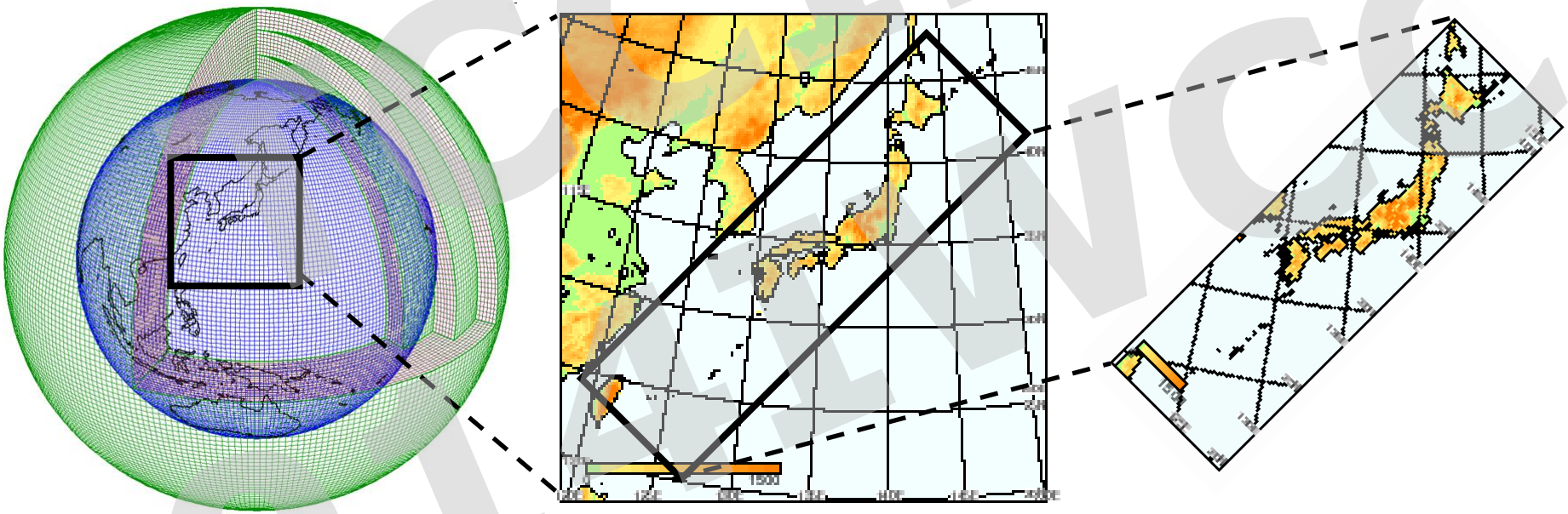
- A1: 高い経済成長、地域格差の縮小
  - A1B: バランスしたエネルギー源
  - A1T: 非化石エネルギー源
  - A1FI: 化石エネルギー源
- A2: 高い経済成長、地域の独自性
- B1: 持続可能な経済成長、地域格差の縮小
- B2: 持続可能な経済成長、地域の独自性

気象庁（2005）

The previous experimental design

JMA/MRI AGCM

RCM based on JMANHM (NHRCM)



20-km mesh

15-km mesh

5-km mesh

SST

Present: observed (monthly)
Future: change + trend + anomaly

Integration period: 20 years

Present climate: Aug 1980 – Jul 2000
Future climate: Aug 2076 – Jul 2096
(A1B scenario) (end of 21st century)