Challenges of convection-permitting regional climate simulations for future climate projection in Japan
- Program for Risk Information on Climate Change, SOUSEI program -

NCAR
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1. **Introduction of Japanese large project of climate projection: SOSEI program**

2. **Methodology of global and regional climate simulations in SOUSE program**

3. **Impact of high-resolution simulation on precipitation and snow depth in Japan**

4. **Summary**

- Since there are many mountain ranges in Japan, the local climate is so complicated.

- The urban areas are locally influenced by the heat island effects.

- The high resolution climate simulations are required to simulate the mesoscale heavy rainfall/snowfall, tropical cyclones, urban climate, and orographic effects in Japan.

JAPAN

I came from here.
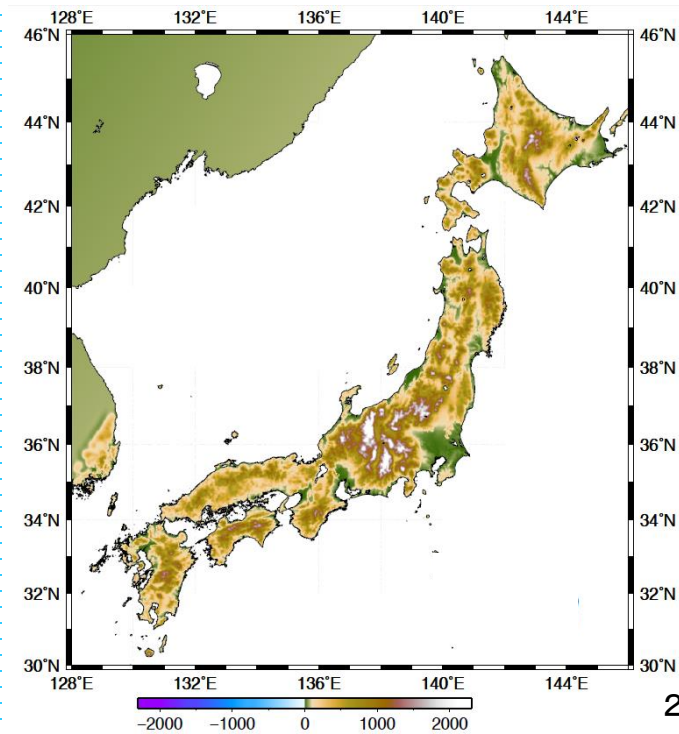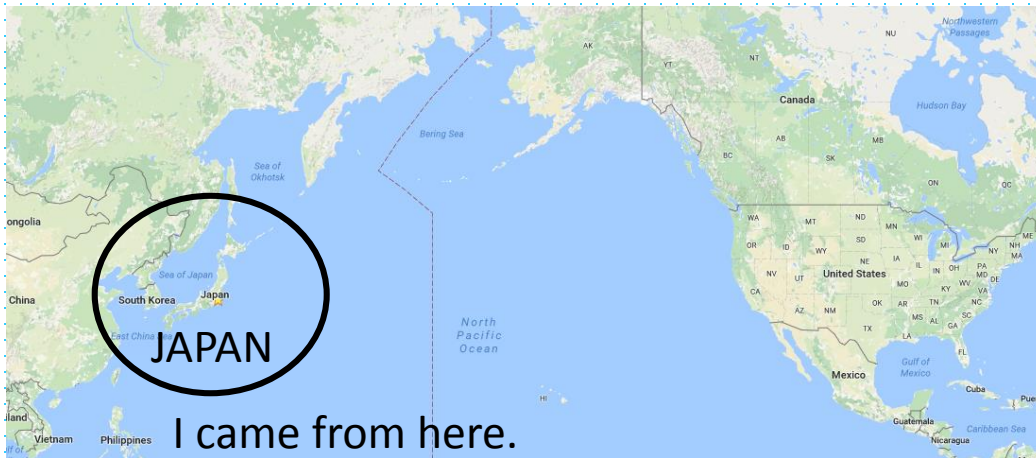
Japanese large scientific program, *Program for Risk Information on Climate Change,* called as **SOUSEI program**, conducts present and future climate simulations to generate basic information required for managing various risks resulting from climate change.

Program for Risk Information on Climate Change

SOUSEI

Program for Risk Information on Climate Change

Using the world-class supercomputers, such as Earth Simulator, we are pursuing research and development in which all themes are organically linked. Our research and development include prediction and diagnosis of imminent global climate change expected to occur within a few years or decades, research on greenhouse gas emission scenarios and associated long-term climate change projections, development of probabilistic climate change projection techniques, and development of technology for precise impact assessment, etc.

Four themes in SOUSEI program

http://www.jamstec.go.jp/sousei/eng/index.html

Theme C

Development of basic technology for risk information on climate change (= Downscaling)

Our team

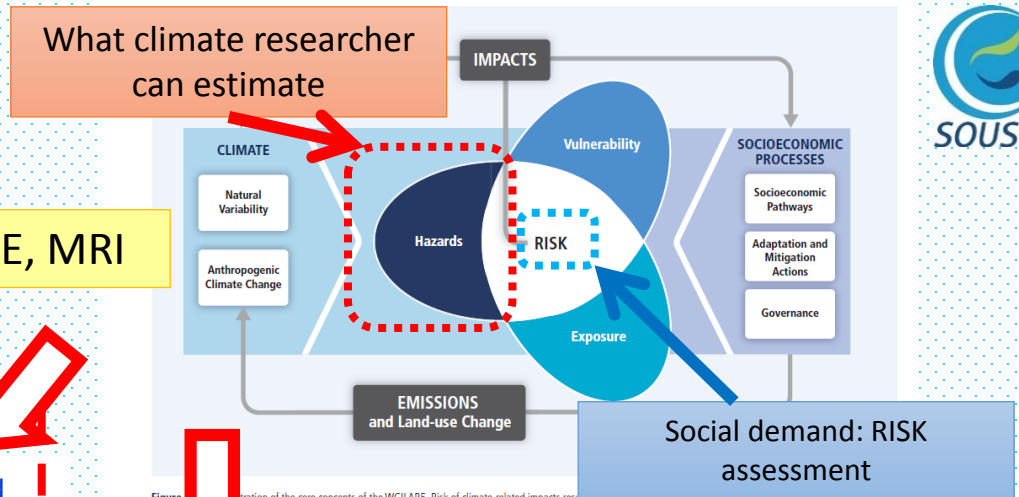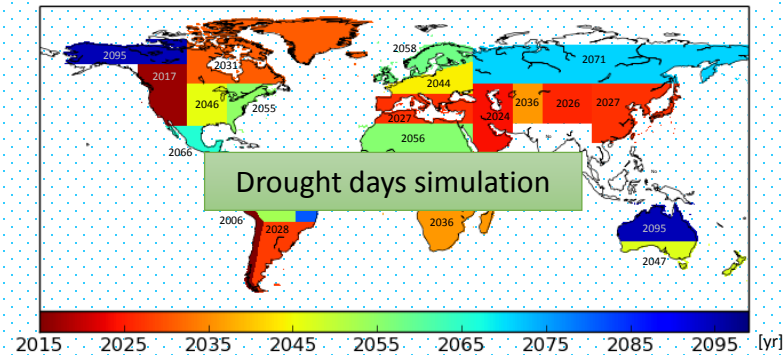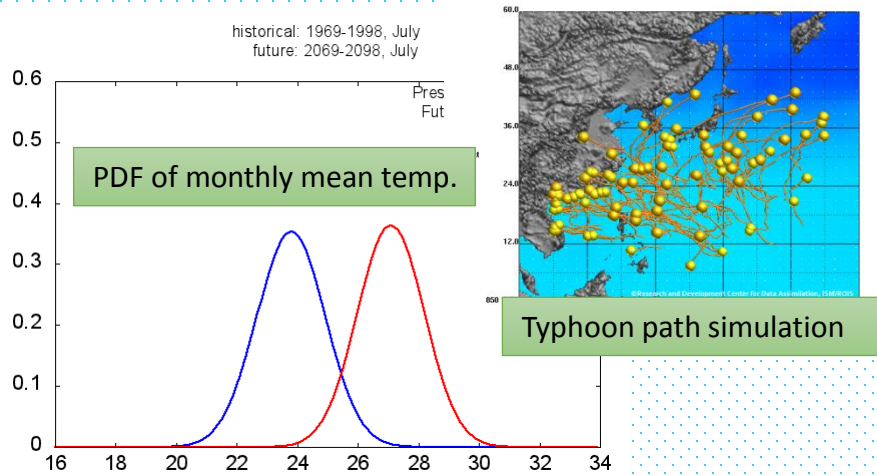| Theme A	Theme B	Theme C	Theme D
Prediction and diagnosis of imminent global climate change	**Climate change projection contributing to stabilization target setting**	**Development of basic techno-logy for risk information on climate change**	**Precise impact assessments on climate change**
■ Understanding mechanisms of climate variability and change ■ Development of an integrated prediction system for global climate studies	■ Long-term global change projection based on diverse scenarios ■ Obtaining scientific perceptions on large-scale variations and modifications of climate	■ Probabilistic climate prediction for risk assessment ■ Producing a standard climate scenario by using super high resolution models	■ Climate change impacts on natural hazards ■ Climate change impacts on water resources ■ Climate change impacts on ecosystem and biodiversity

Representative: Izuru Takayabu
Meteorological Research Institute

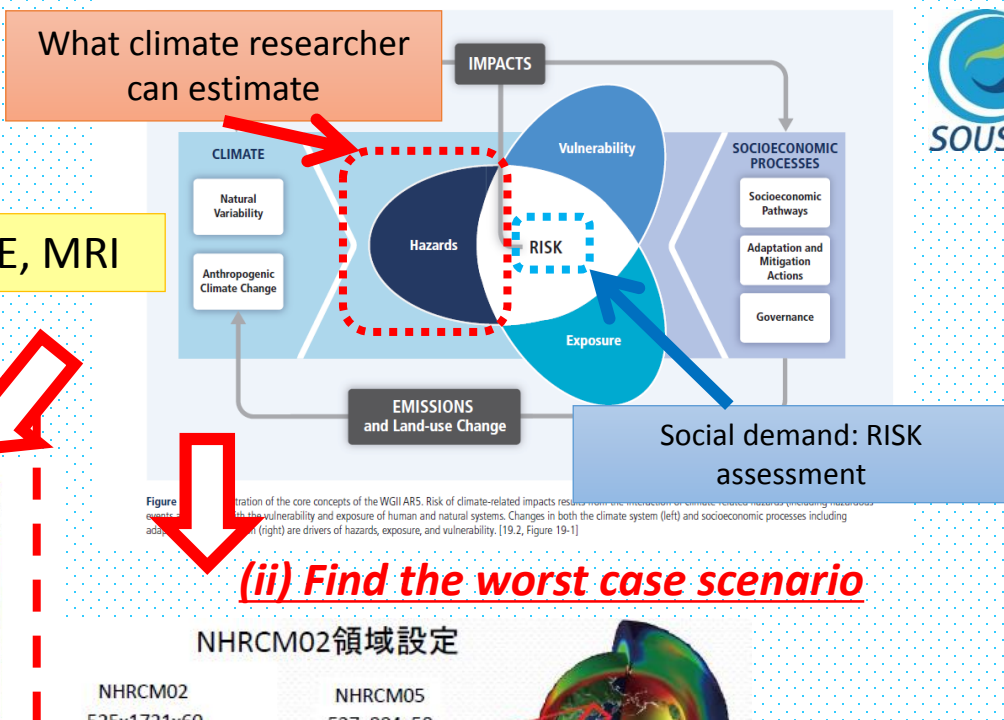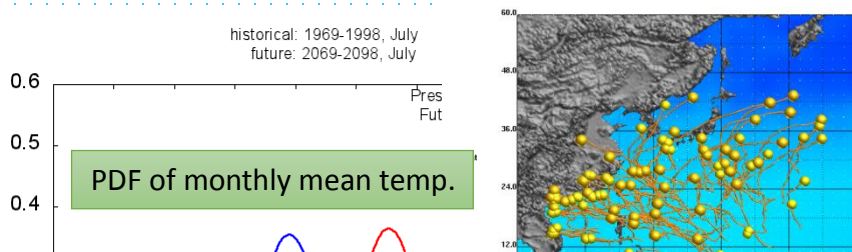3

Theme C: Development of basic technology for risk information on climate change

University of Tsukuba, NIED, ISM, AORI, ISEE, MRI

Representative: I. Takayabu @ MRI

SOUSEI

What climate researcher can estimate

IMPACTS

CLIMATE

Natural Variability

Hazards

RISK

Anthropogenic Climate Change

Exposure

Vulnerability

SOCIOECONOMIC PROCESSES

Socioeconomic Pathways

Adaptation and Mitigation Actions

Governance

EMISSIONS and Land-use Change

Social demand: RISK assessment

Figure ... tration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events ... th the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adap ... (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

(i) Estimate PDF of extreme events

historical: 1969-1998, July
future: 2069-2098, July

Pres
Fut

PDF of monthly mean temp.

Typhoon path simulation

Drought days simulation

2015 2025 2035 2045 2055 2065 2075 2085 2095 [yr]

(ii) Find the worst case scenario

NHRCM02領域設定

NHRCM02
525x1721x60

NHRCM05
527x804x50

20kmAGCM

Dynamical downscaling system to 2km grid model

0   500 1000 1500

Three dim. Super Typhoon structure

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Theme C: Development of basic technology for risk information on climate change

University of Tsukuba, NIED, ISM, AORI, ISEE, MRI

Representative: I. Takayabu @ MRI

(i) Estimate PDF of extreme events

What climate researcher can estimate

IMPACTS

CLIMATE
- Natural Variability
- Anthropogenic Climate Change

Hazards   RISK   Vulnerability   Exposure

SOCIOECONOMIC PROCESSES
- Socioeconomic Pathways
- Adaptation and Mitigation Actions
- Governance

EMISSIONS and Land-use Change

Social demand: RISK assessment

Figure ... illustration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events ...) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation ... (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

historical: 1969-1998, July
future: 2069-2098, July

0.6
0.5
0.4

Pres
Fut

PDF of monthly mean temp.

(ii) Find the worst case scenario

NHRCM02領域設定

NHRCM02   NHRCM05
525x1721x60   537x804x50

- In this presentation, I will introduce the approach of present and future climate simulation using high-resolution global and regional climate models.

- Then, I will show the biases of precipitation in Japan and impacts of high-resolution experiments on precipitation and snow depth in Japan.
  (Unfortunately, the future projections with 2km grid spacing is now calculating.)

20km MRI−AGCM[1] and 2km/5km NHRCM[2]

*MRI-AGCM:** **M**eteorological **R**esearch **I**nstitute **AGCM**
* **NHRCM:** **N**on-**H**ydrostatic **R**egional **C**limate **M**odel
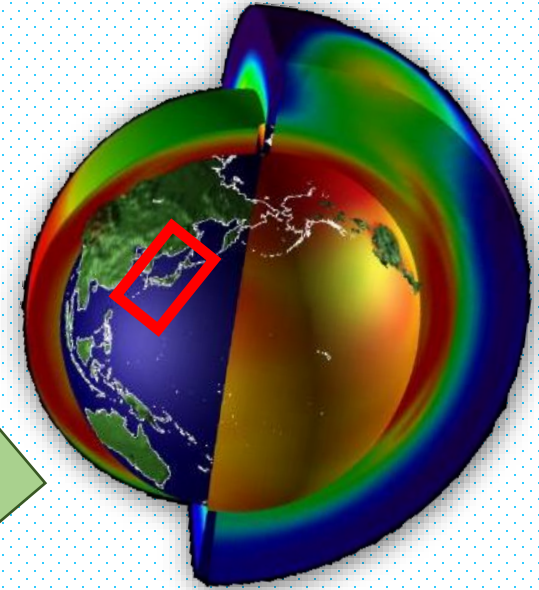
2km NHRCM
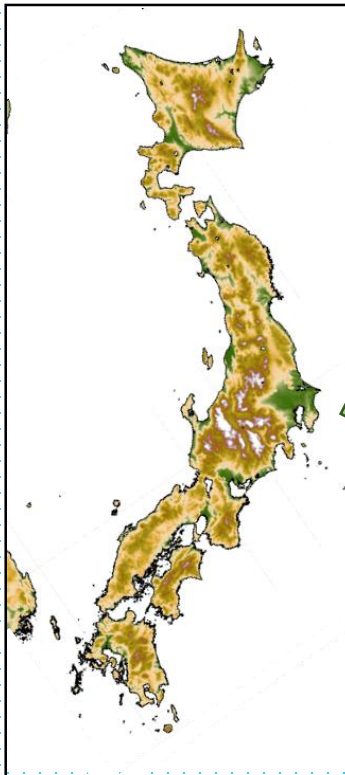
5km NHRCM
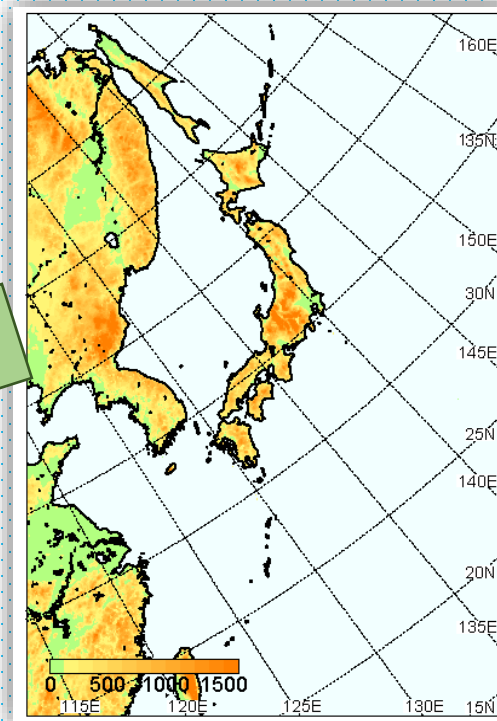
20km MRI-AGCM

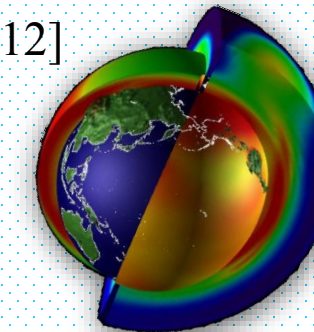High resolution AMIP-type present climate simulation and future climate projection. [Mizuta et al. 2012]

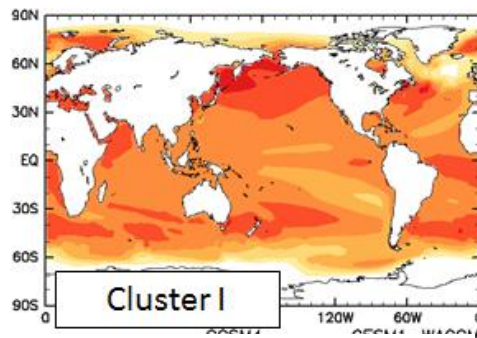# Past simulation and future projection by MRI-AGCM [Mizuta et al. 2012]

AMIP type time-slice simulations
Present climate: 1980-2000 (SST: HadISST)
Future climate: 2076-2096 (SST: RCP8.5)*

* Future climate simulations were performed using three SSTs anomaly in CMIP5 models under RCP8.5. To obtain three patterns of SST change, a cluster analysis was conducted.
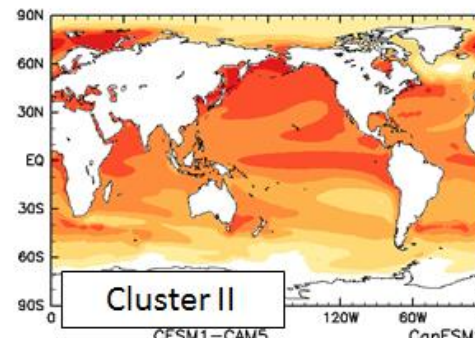
NCAR type   **HadGEM2 type** (including MRI-CGCM3)   **GFDL type**   **ensemble mean**
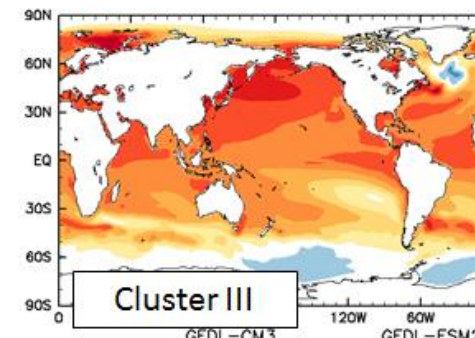
Model	Non-Hydrostatic Regional Climate Model (NHRCM) (A fully compressible and nonhydrostatic model) *[Sasaki et al. 2011]*	
Grid spacing	**5km**	**2km**
Grid number	527x804x50	525x1721x60
Microphysics	Bulk-type cloud microphysics *[Ikawa et al.,1994]*	
Convection	*Kain and Fritsch* (1993)	-
Radiation	Clear-sky [Yabu et al., 2005], Cloudy *[Kitagawa et al., 2000]*	
Boundary layer	Improved MYNN Level 3 [Nakanishi and Niino, 2004]	
Land surface	Improved MRI/JMA SiB *[Hirai and Ohizumi, 2004]*	
Integration	20 years [Jul. 20 – Aug. 31 (following year) in each year]	
Urban	-	Square Prism Urban Canopy (SPUC) *[Aoyagi and Seino, 2011]*

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Difference of temperature between 2006 land use and 1976 land use
[lateral boundary condition: 2006]

summer

winter

EXP2006HR – EXP1976, JUL_AUG

EXP2006HR – EXP1976, JAN_FEB

Tokyo

Tokyo

differential [°C]

☐ 2.25 – 2.50	
☐ 2.00 – 2.25	
☐ 1.75 – 2.00	
☐ 1.50 – 1.75	
☐ 1.25 – 1.50	
☐ 1.00 – 1.25	
☐ 0.75 – 1.00	
☐ 0.50 – 0.75	
☐ 0.25 – 0.50	
☐ 0.00 – 0.25	

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
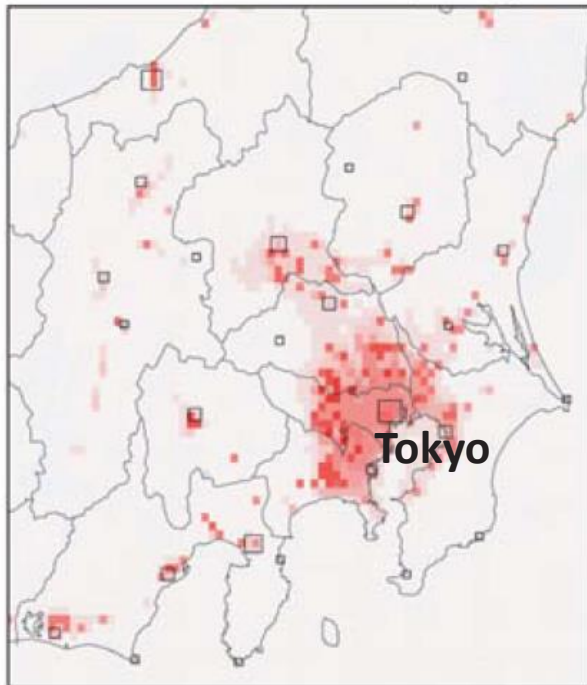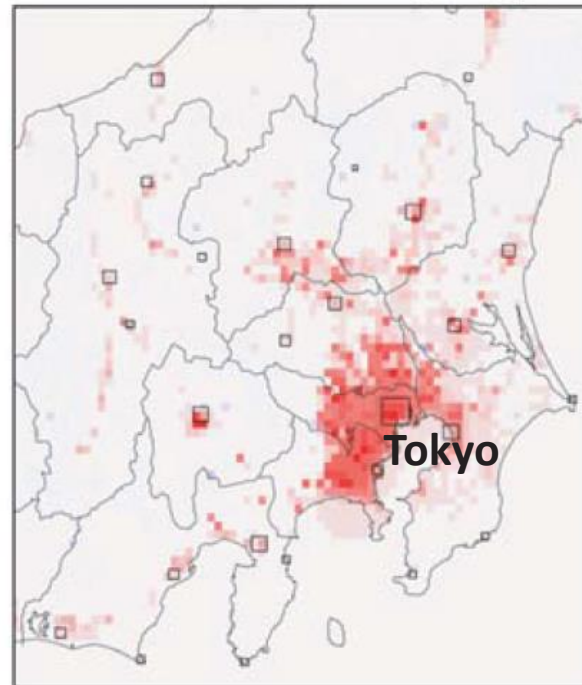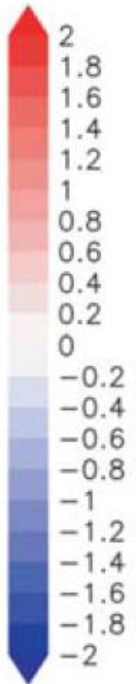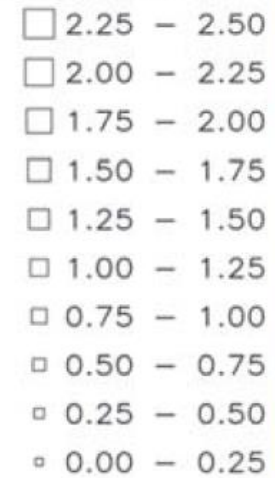
Higher temperature is simulated in both season around Tokyo Metropolitan area.
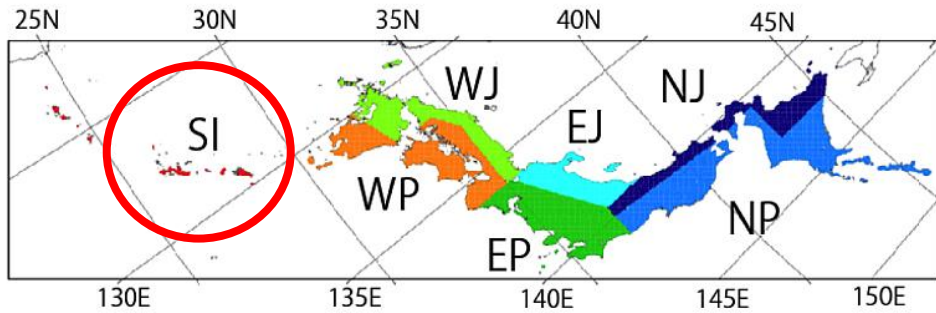
[Aoyagi and Seino, 2012]

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Biases of annual precipitation in each region

5km*: modified KF
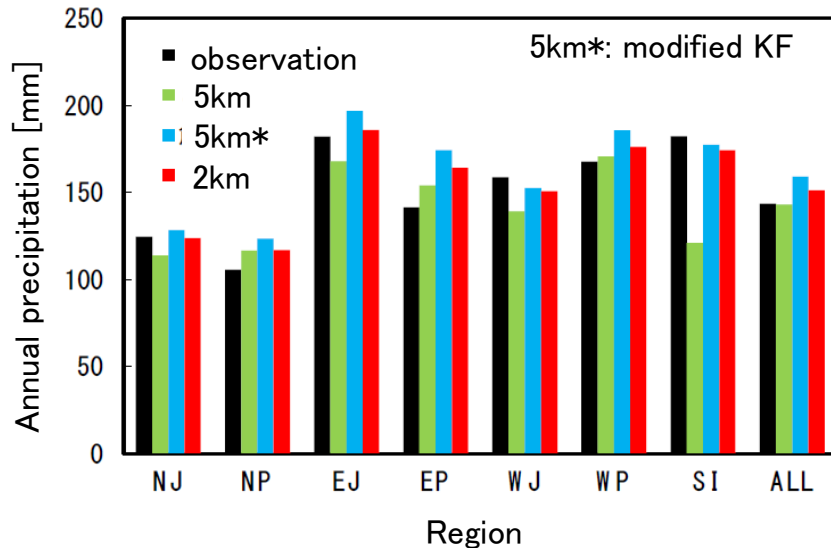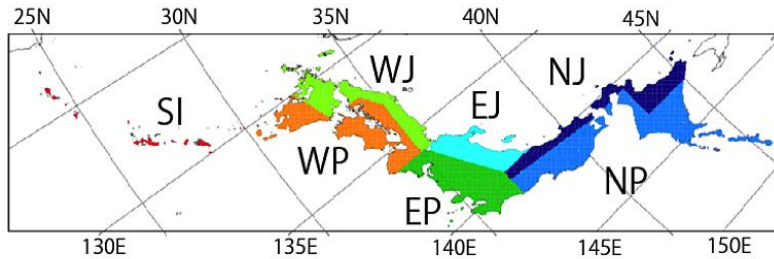
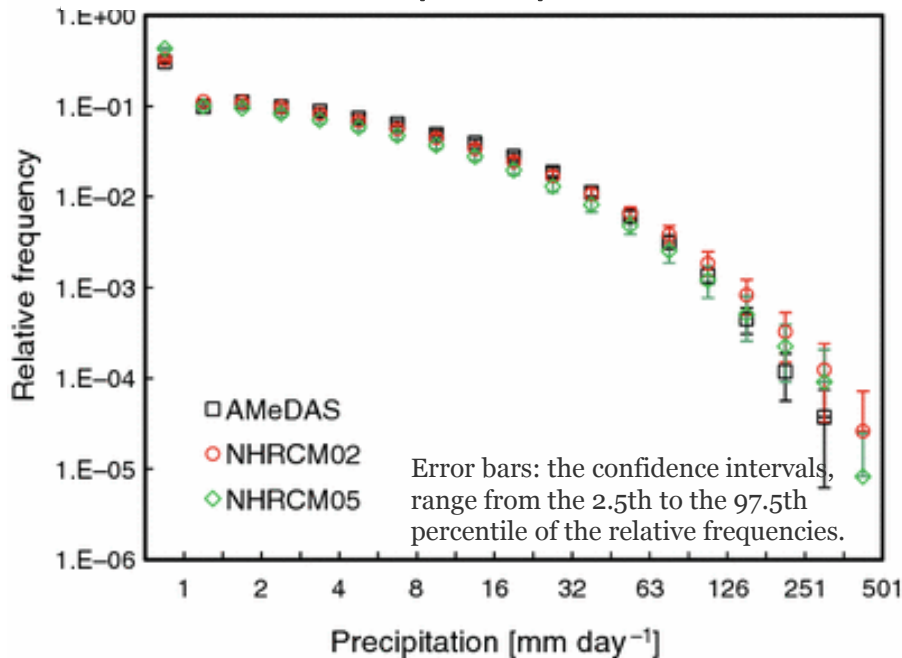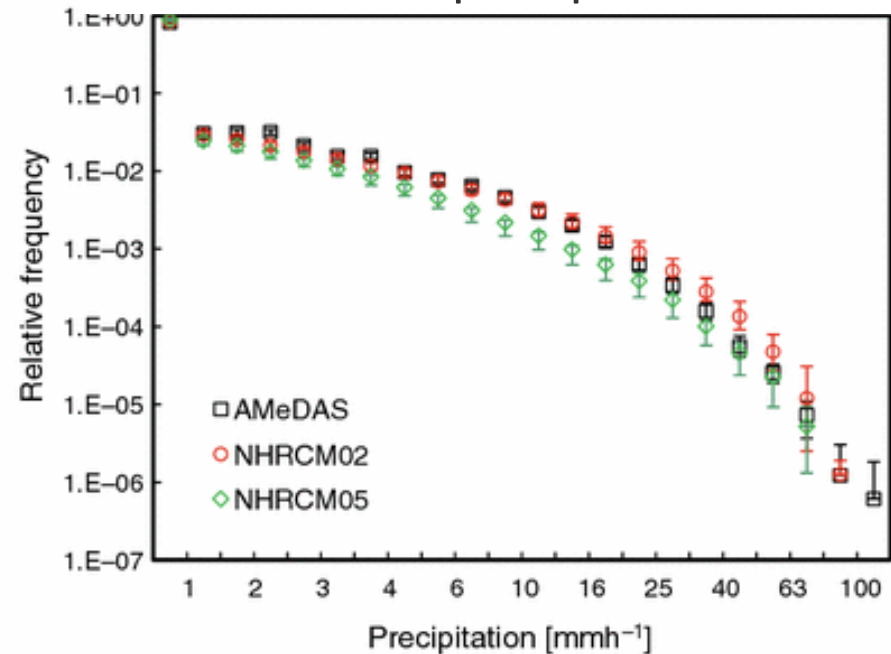Biases and RMSE of annual precipitation in 2km NHRCM are less than those in 5km NHRCM.
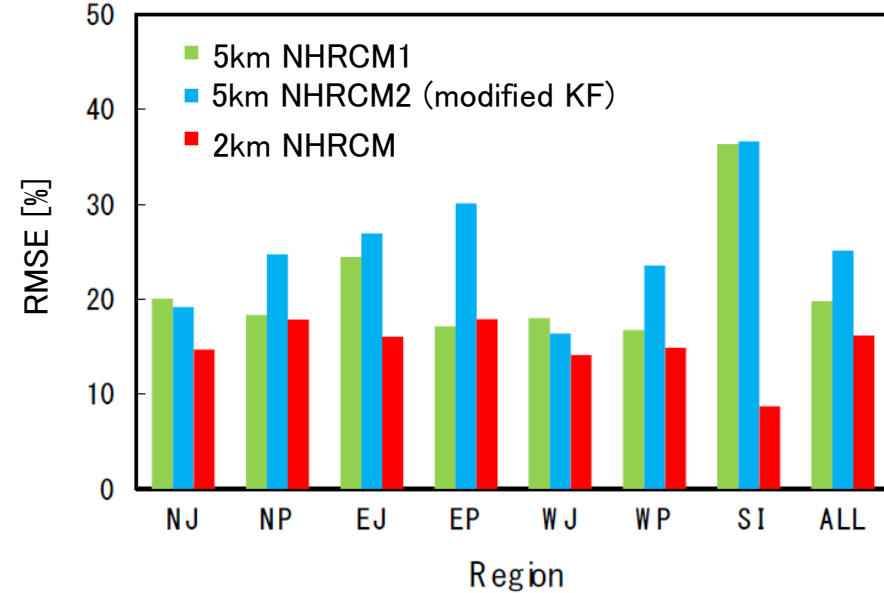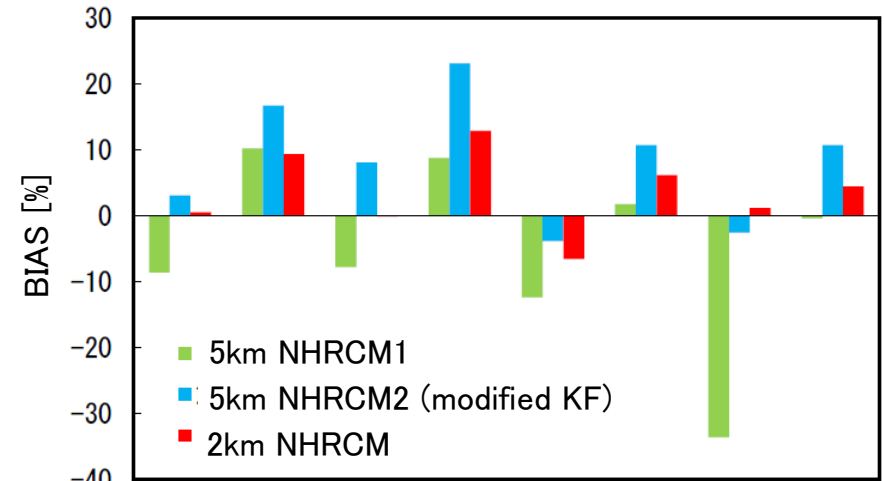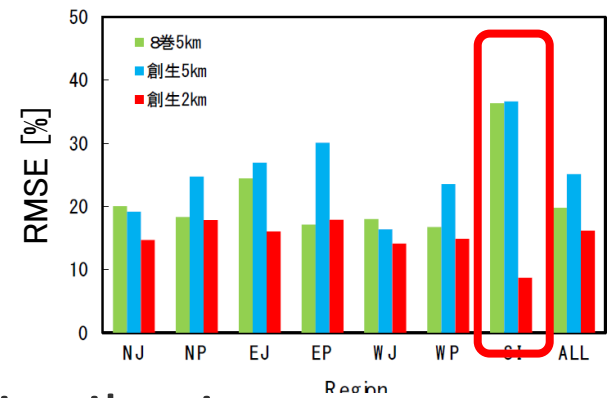
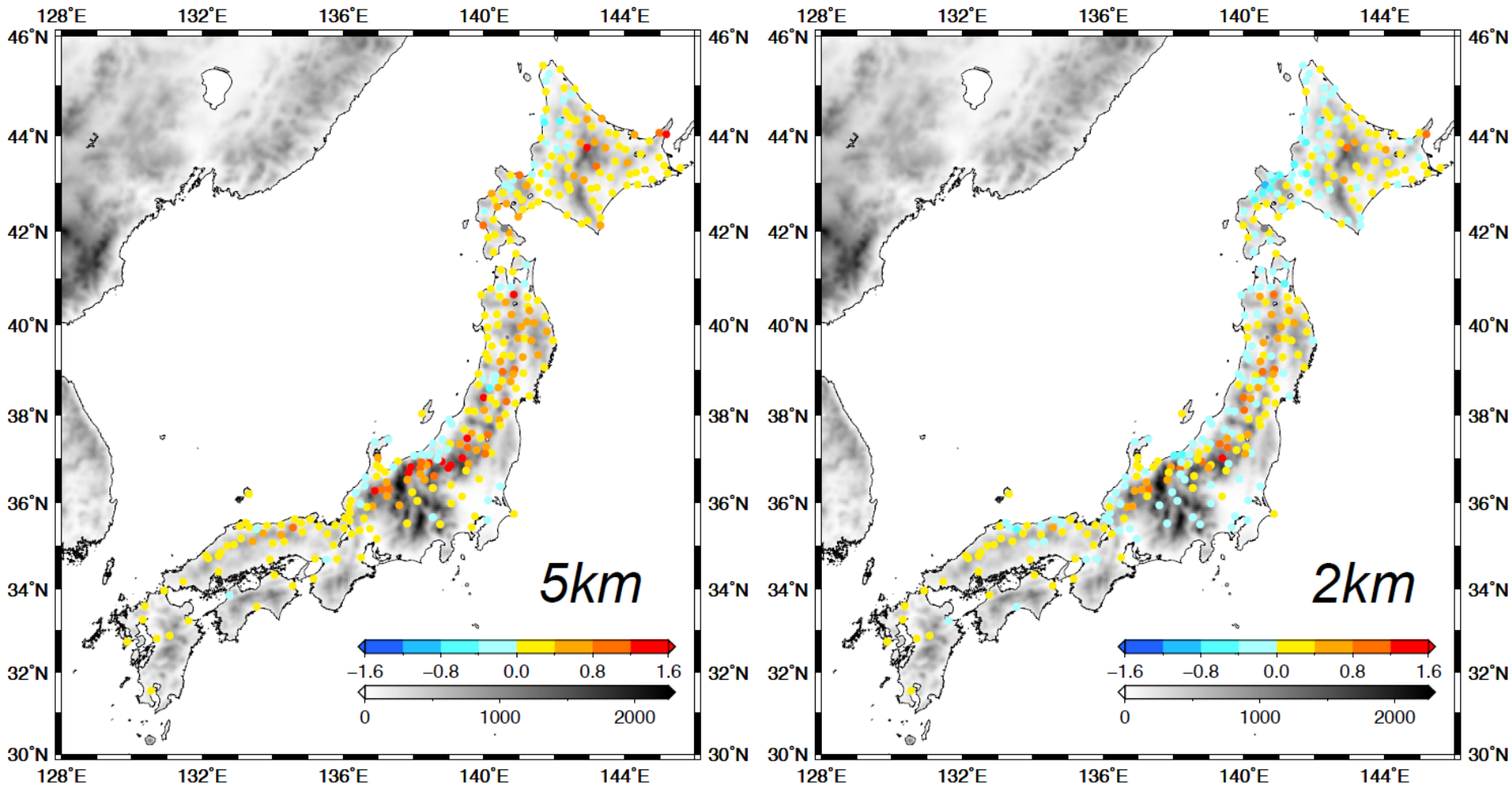Relative frequency distribution   Murata et al. (2015)

DAILY precipitation   HOURLY precipitation

Error bars: the confidence intervals, range from the 2.5th to the 97.5th percentile of the relative frequencies.

The relative frequency distribution of daily precipitation is well reproduced by 2km NHRCM than by 5km NHRCM when compared with the observed precipitation data except for higher intensities.
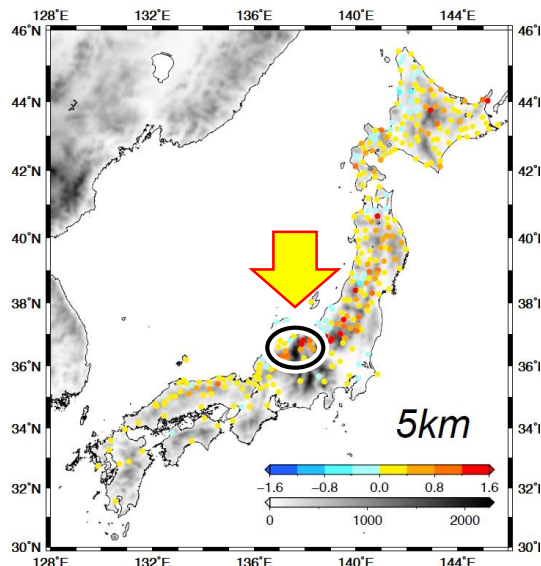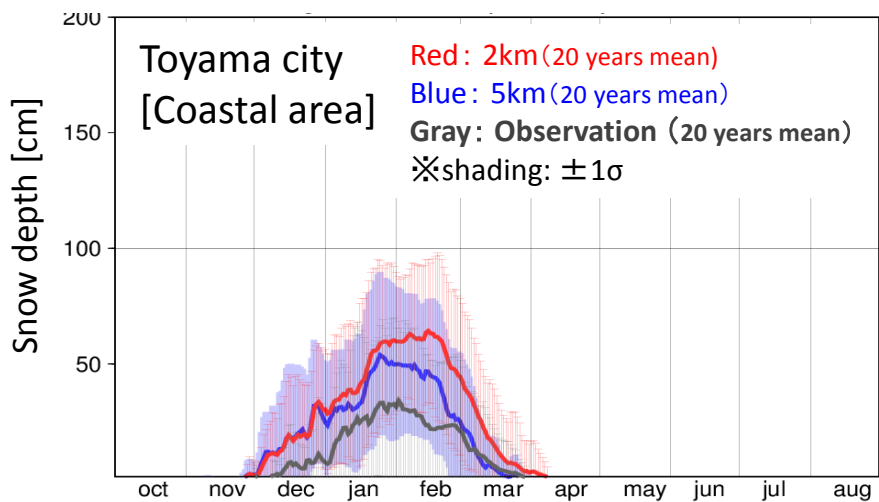
20 years mean maximum snow depth
[NHRCM] – [Observation]

Seasonal variation of snow depth

Toyama city [Coastal area]
Red: 2km (20 years mean)
Blue: 5km (20 years mean)
Gray: Observation (20 years mean)
※shading: ±1σ

5km

■ Bijyodaira site (977m)

Mountainous area (1,000m)
Red: 2km (20 years mean)
Blue: 5km (20 years mean)
Gray: Observation (2014/15)
※shading: ±1σ

■ Midagahara site (1,930m)

Mountainous area (2,000m)
Red solid: sousei−2km 20yrs
Blue solid: sousei−5km 20yrs
Grey: Obs. 2014/15 [Kaken]

Overestimation by 5km NHRCM

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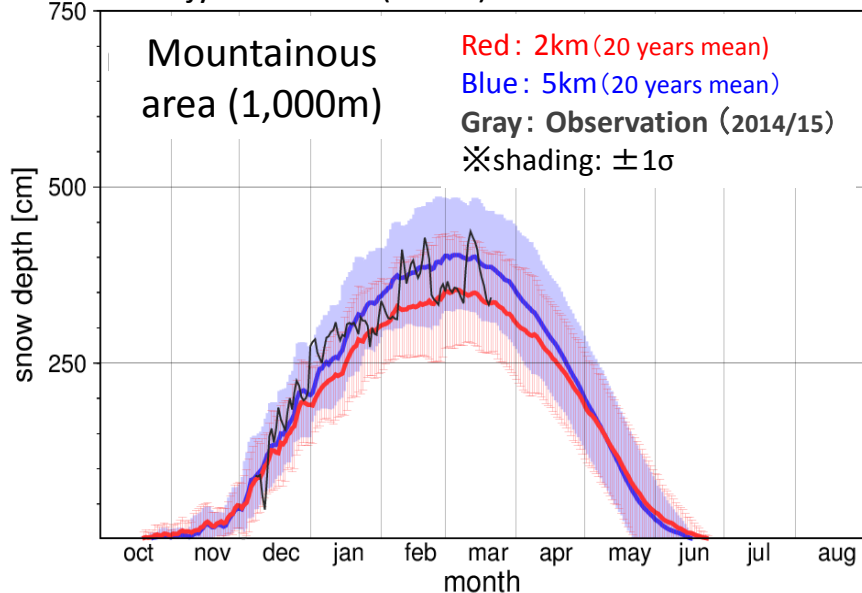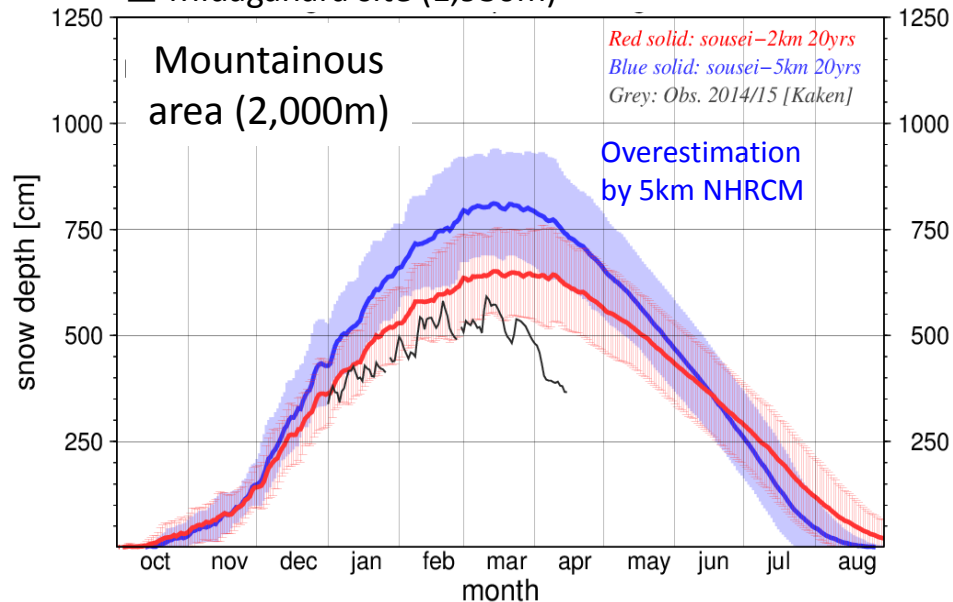
East Asian Winter Monsoon

From JMA web site

Warm SST → humid
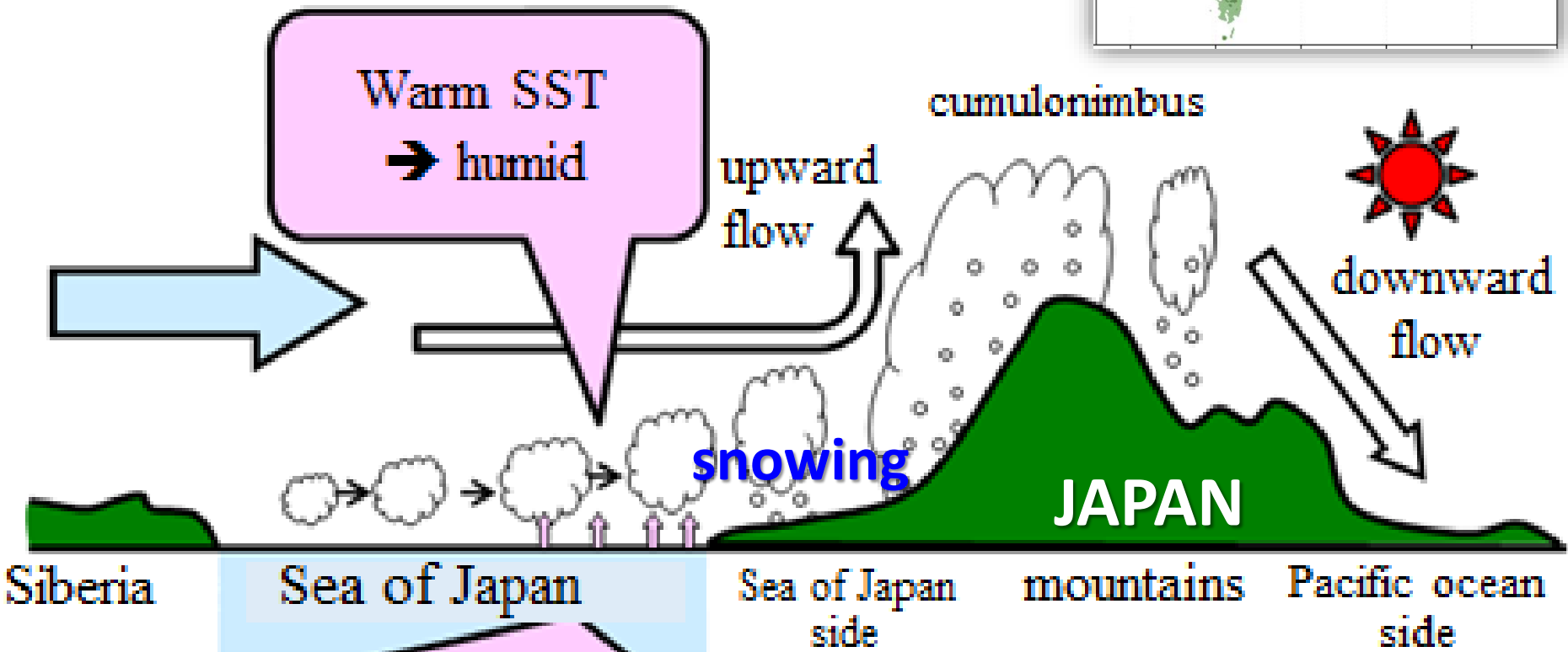
Colder air from Siberia and warmer SST result in more developed snow clouds and heavier snowfall

East Asian Winter Monsoon

Siberia
Sea of Japan
Japan

From JMA web site

Warm SST ➔ humid

upward flow

cumulonimbus

downward flow
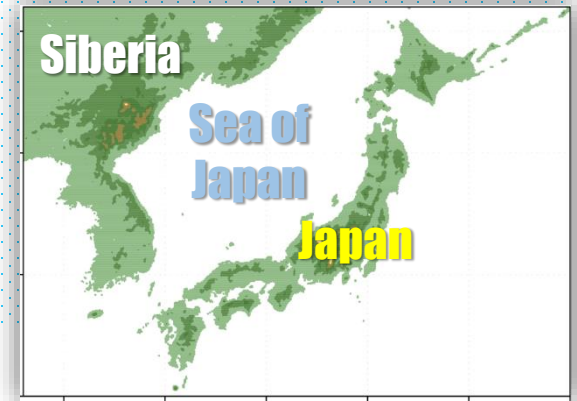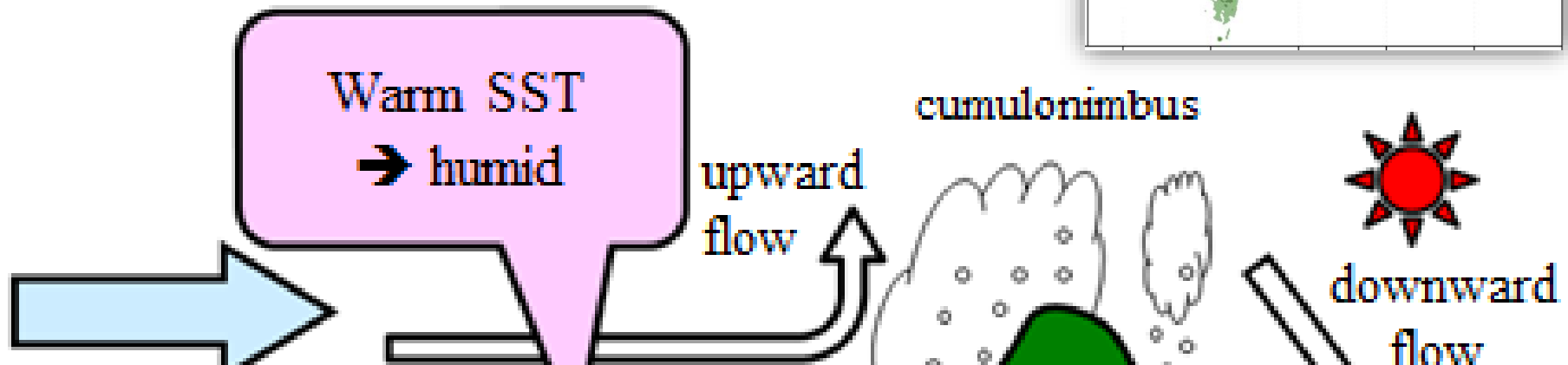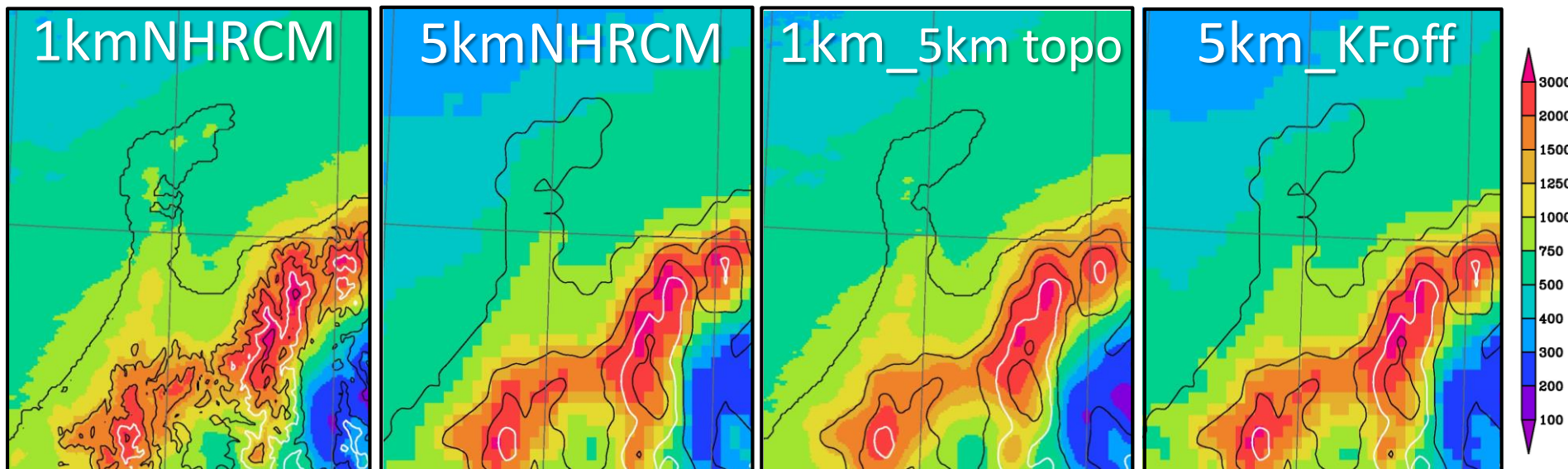
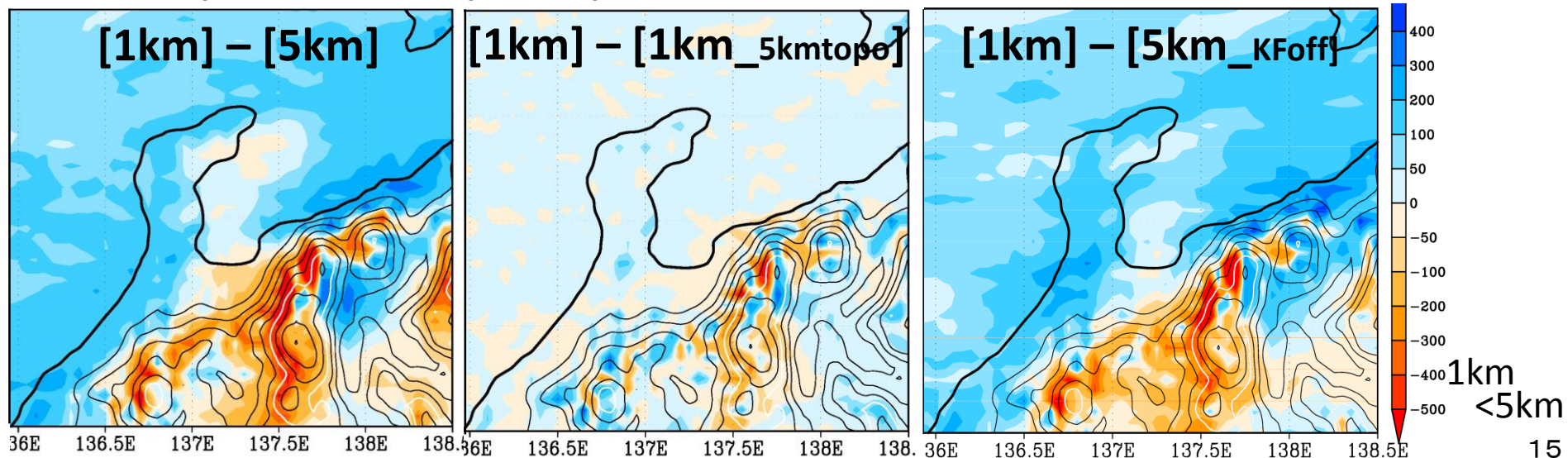- The major differences between 2km and 5km NHRCMs are
   ≫ Highly resolved topography
   ≫ With/without cumulus parameterization

➔ Sensitivity experiments on 2014/15 winter with 1km and 5km. Checking horizontal distribution of precipitation

Simulated snowfall in the mountainous areas

■ Winter total precipitation

■ Comparison of precipitation with 1kmNHRCM

■ SOUSEI program

- The SOUSEI program (theme C) performs present and future climate simulations using MRI-AGCM and NHRCM.

- The NHRCM with 2km grid-spacing are performed without cumulus parameterization and with urban canopy model (SPUC).

- The 2km NHRCM better simulated the precipitation and maximum snow depth in Japan rather than 5km NHRCM did.

■ Resolution dependency of snowfall and rainfall

- Annual maximum snow depth is overestimated by the NHRCM with 5km in the mountainous areas, which results from overestimation of winter precipitation.

- High-resolution experiments without KF scheme is important to accurately simulate Japanese snowfall.

Apr. 23, 2014 Yuki-no Ohtani

Thank you for your attention

This study was supported by the Program for Risk Information on Climate Change (SOUSEI)