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

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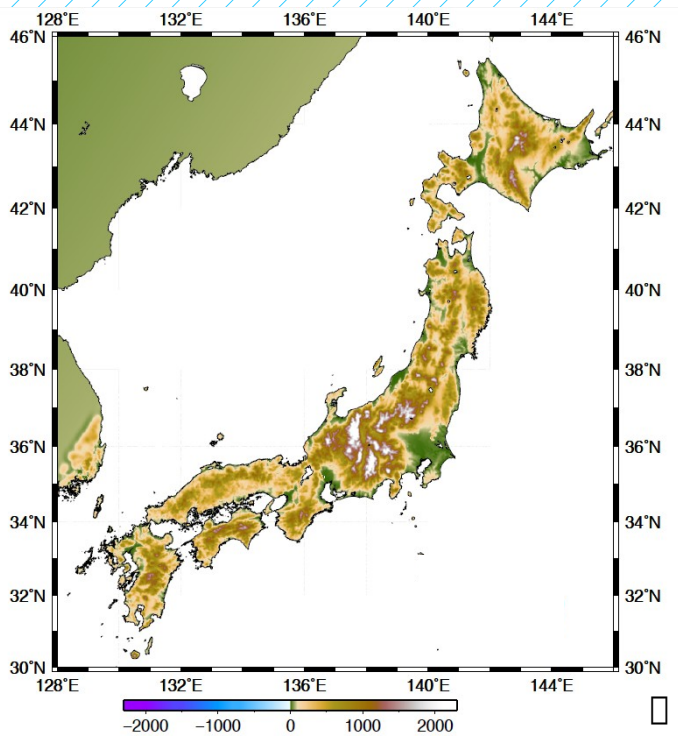
Introduction

- 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.



Introduction

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.

Four themes in SOUSEI program

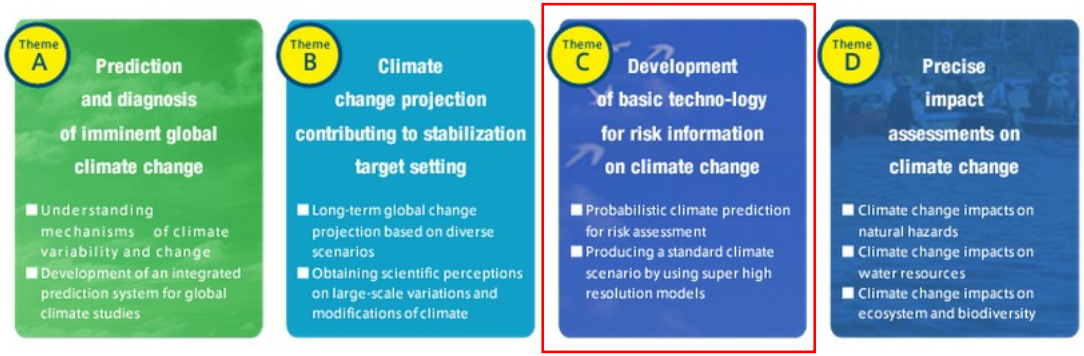
http://www.jamstec.go.jp/sousei/eng/index.html

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.

Theme C

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

Our team

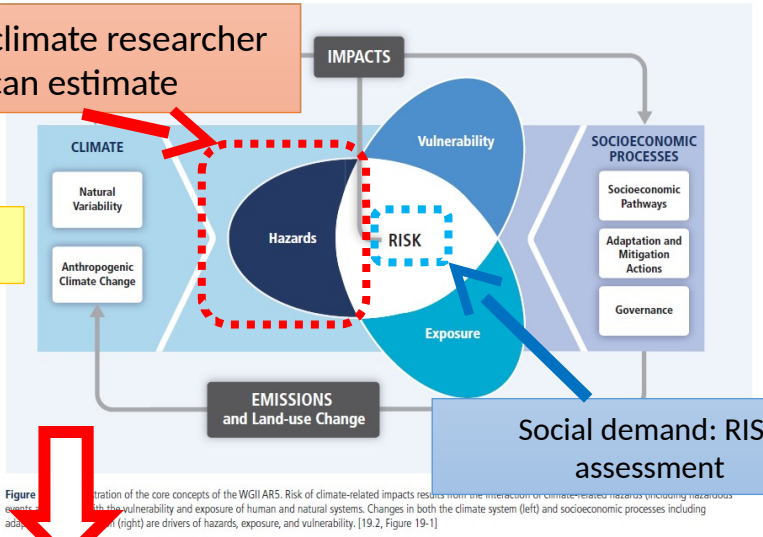


Theme C: Development of basic technology for risk information on climate change

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

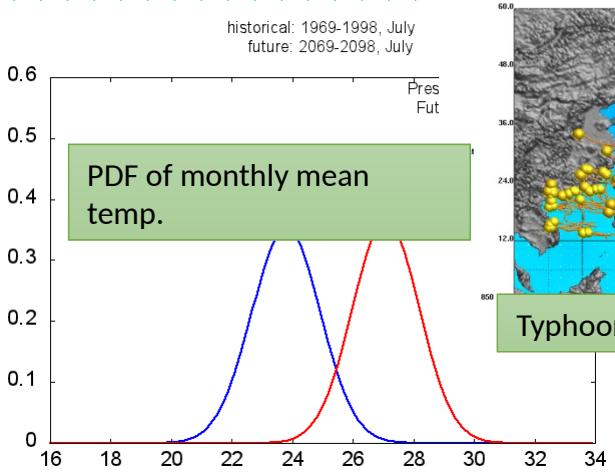
Representative: I. Takayabu @ MRI

What climate researcher can estimate

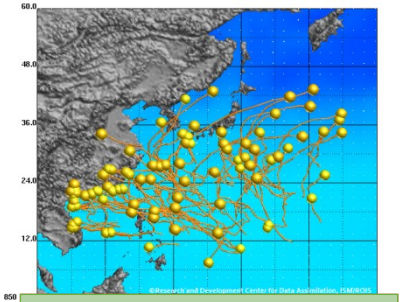


Social demand: RISK assessment

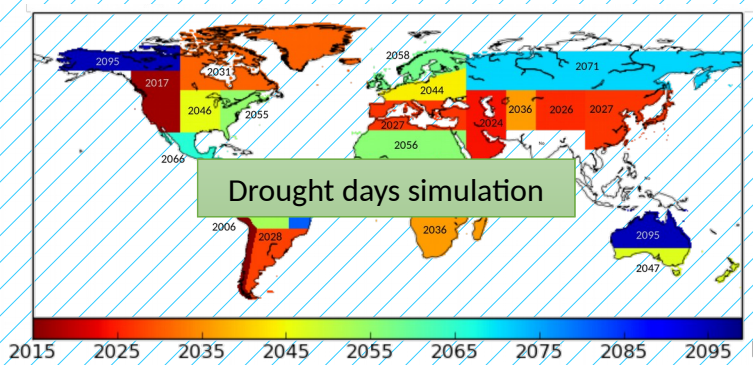
(i) Estimate PDF of extreme events



PDF of monthly mean temp.

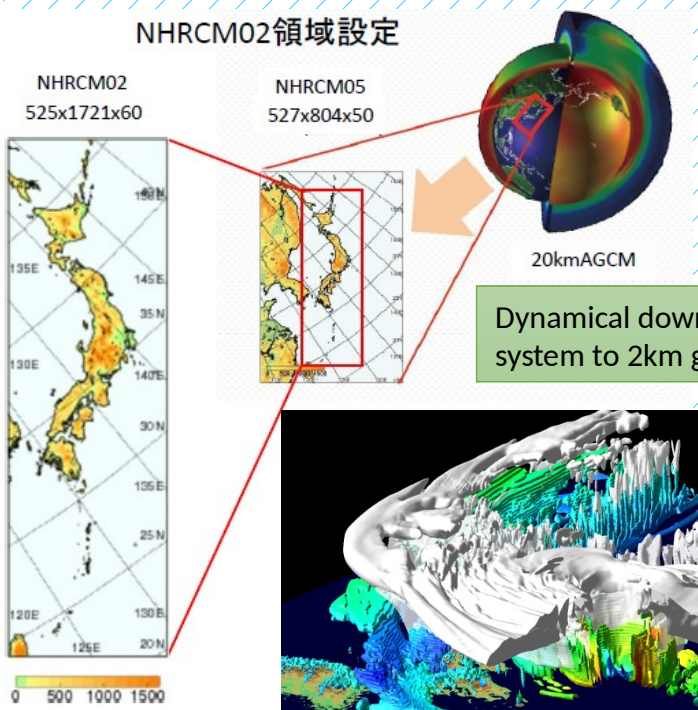


Typhoon path simulation



Drought days simulation

(ii) Find the worst case scenario



Dynamical downscaling system to 2km grid model

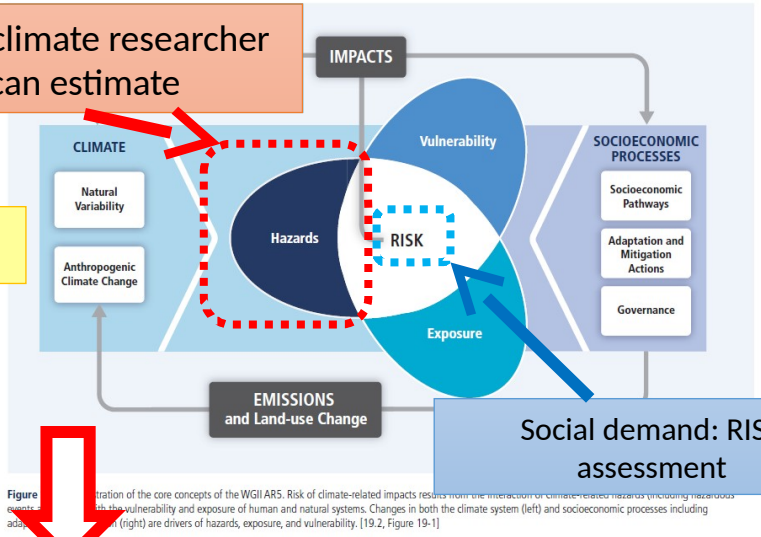
Three dim. Super Typhoon structure

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

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

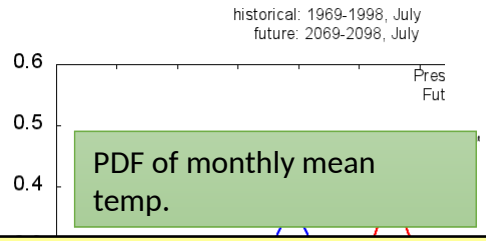
Representative: I. Takayabu @ MRI

What climate researcher can estimate

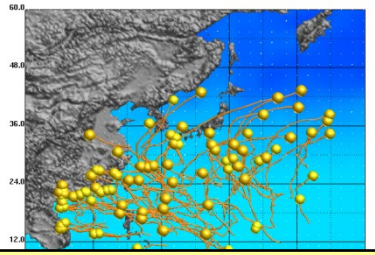


Social demand: RISK assessment

(i) Estimate PDF of extreme events



PDF of monthly mean temp.



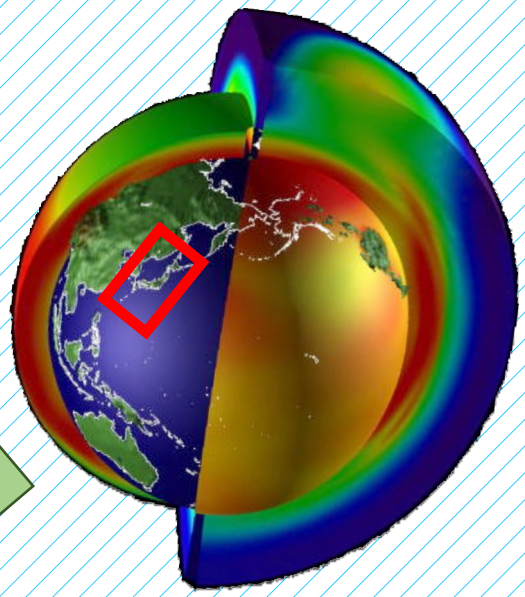
(ii) Find the worst case scenario

- 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.)

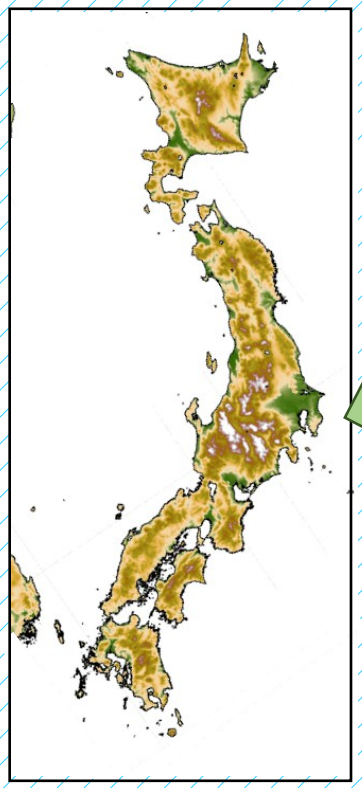
Methodology of Climate Experiment in SOUSEI theme C

20km MRI-AGCM*1 and 2km/5km NHRCM*2

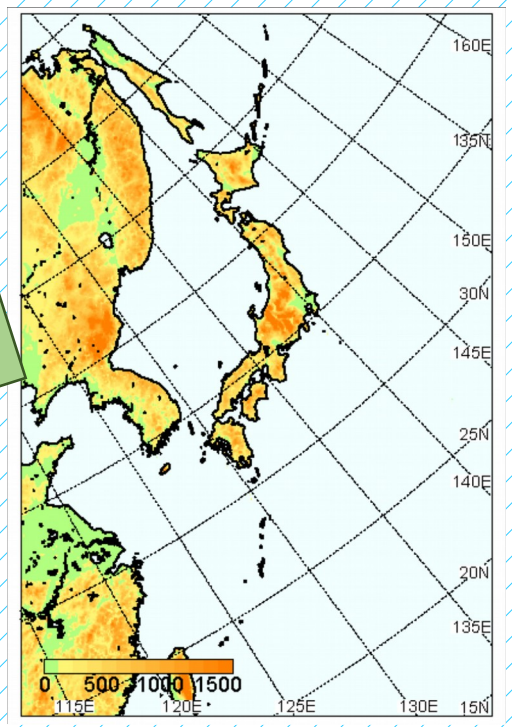
***MRI-AGCM: Meteorological Research Institute AGCM**
*** NHRCM: Non-Hydrostatic Regional Climate Model**



2km NHRCM



5km NHRCM

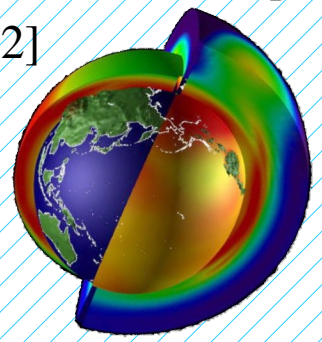


20km MRI-AGCM

High resolution AMIP-type present climate simulation and future climate projection.

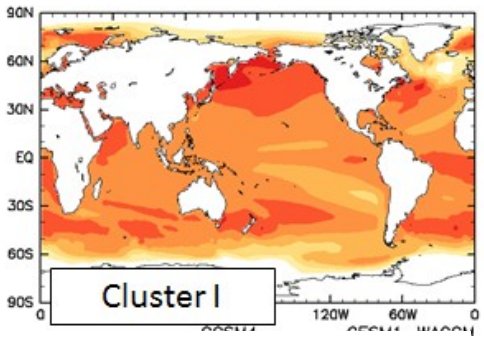
[Mizuta et al. 2012]

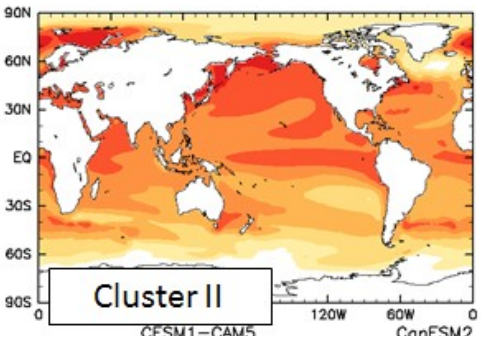
Past simulation and future projection by MRI-AGCM [Mizuta et al. 2012]

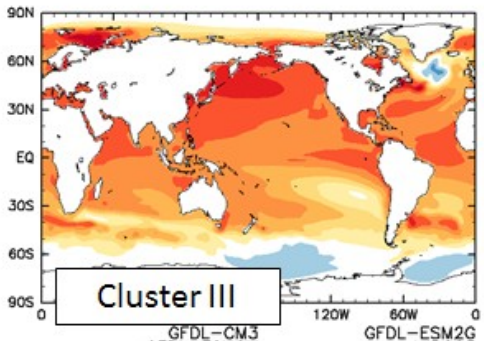


AMIP type time-slice simulations
- Present climate: 1980-2000 (SST: HadISST)
- Future climate: 2076-2096 (SST: RCP8.5)*

* 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.







(Nor

NCAR type

HadGEM2 type
(including MRI-CGCM3)

GFDL type

ensemble mean

Methodology of Climate Experiment in SOUSEI

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]

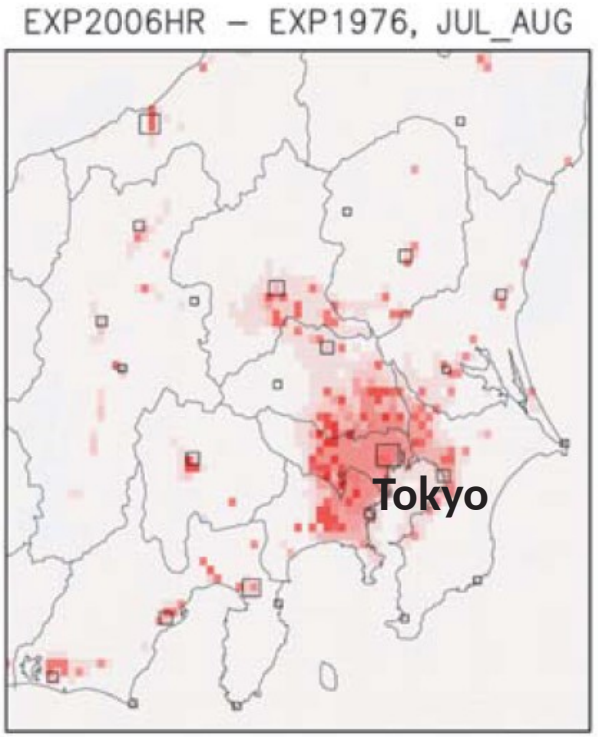
□

SPUC (Urban canopy model)

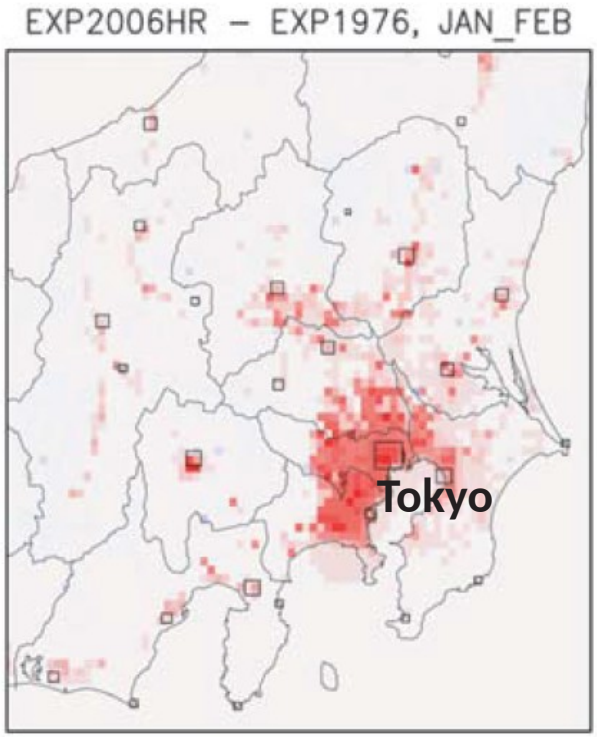
Difference of temperature between 2006 land use and 1976 land use

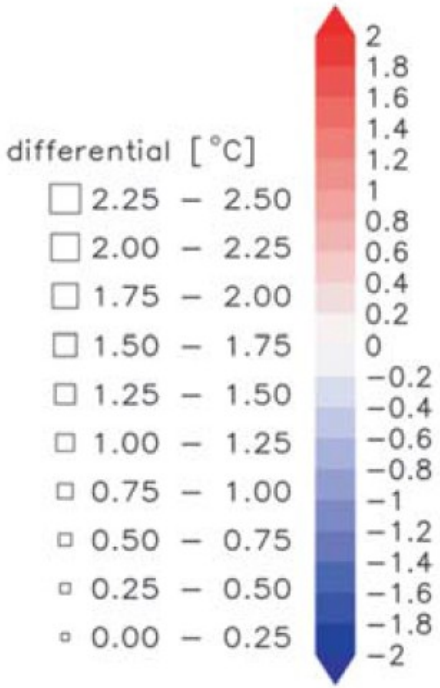
[lateral boundary condition: 2006]

summer



winter



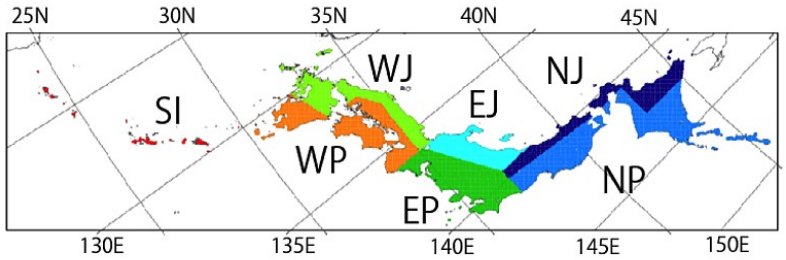


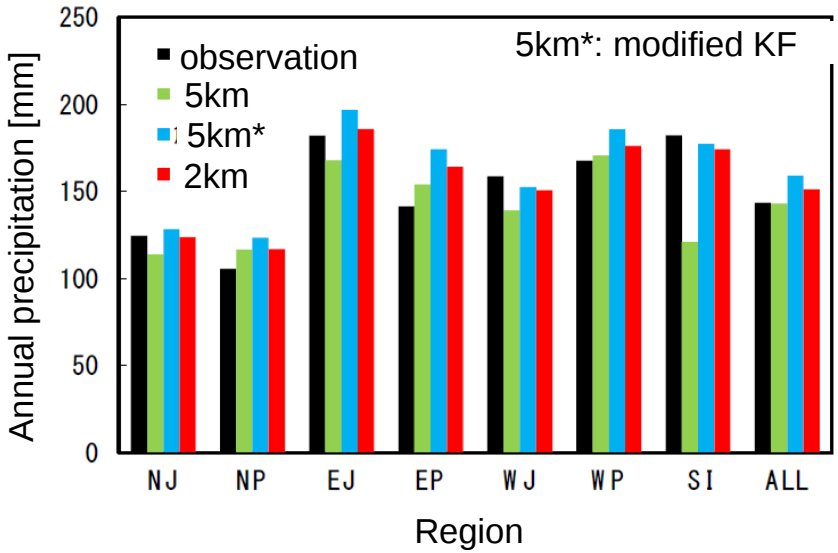
Higher temperature is simulated in both season around Tokyo Metropolitan area.

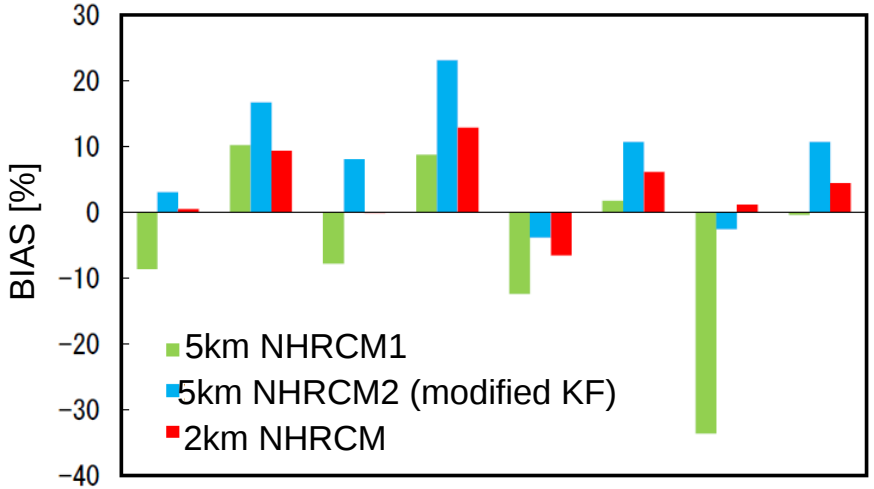
[Aoyagi and Seino, 2012]

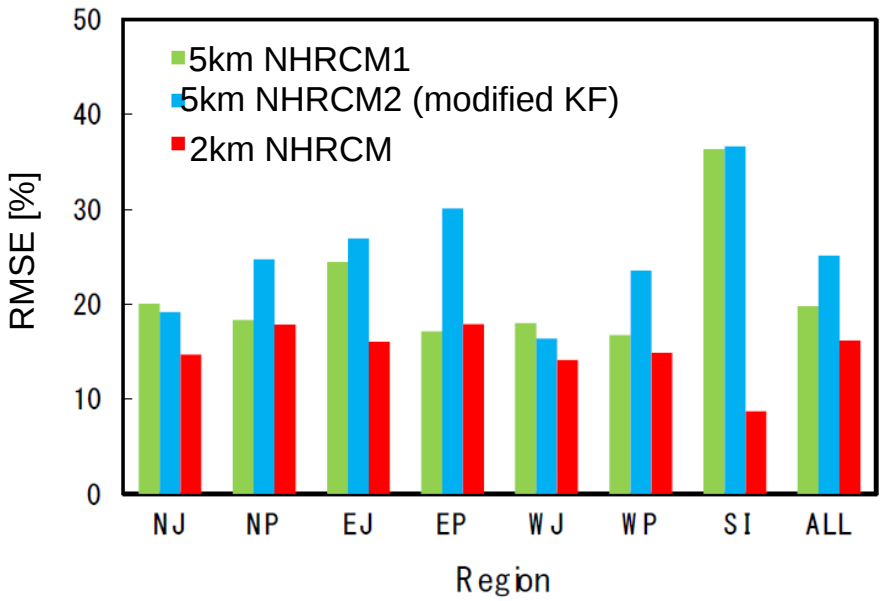
Precipitation biases

Biases of annual precipitation in each region

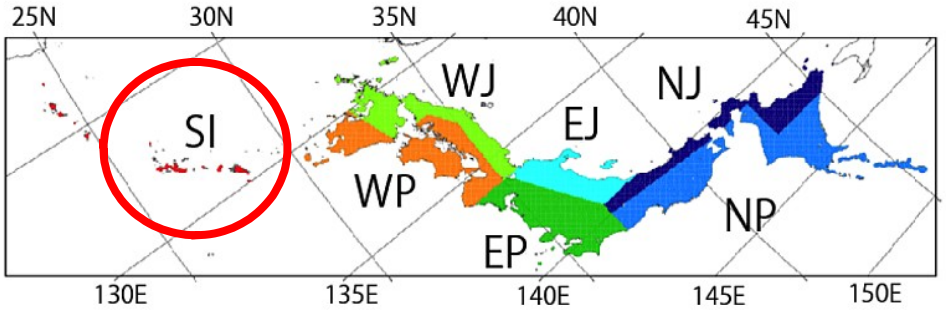


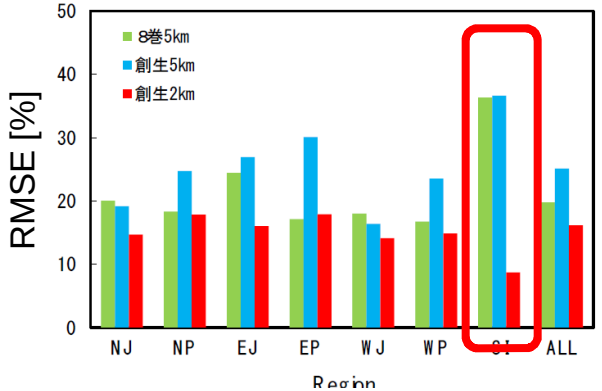






Biases and RMSE of annual precipitation in 2km NHRCM are less than those in 5km NHRCM.

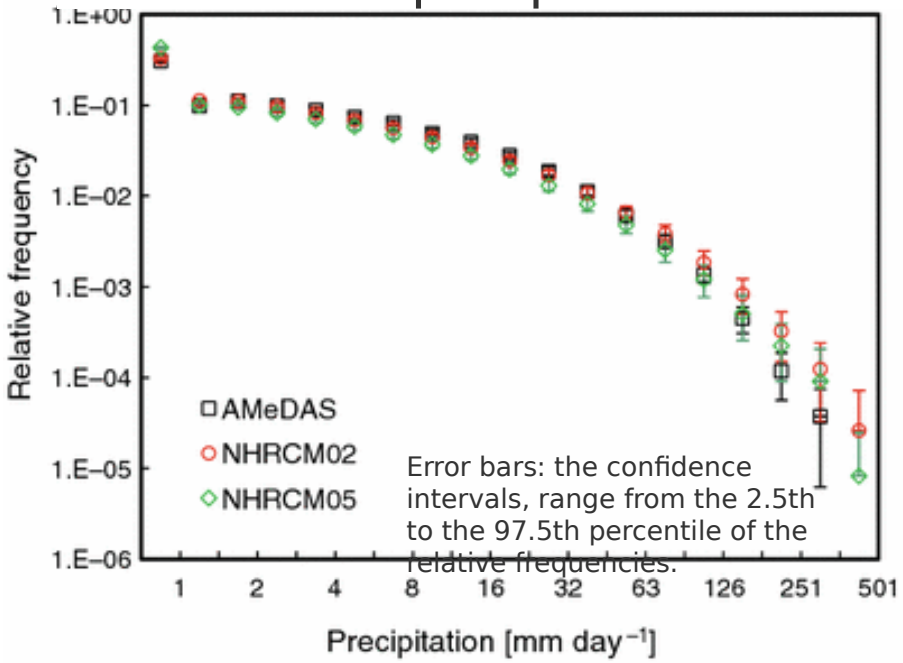




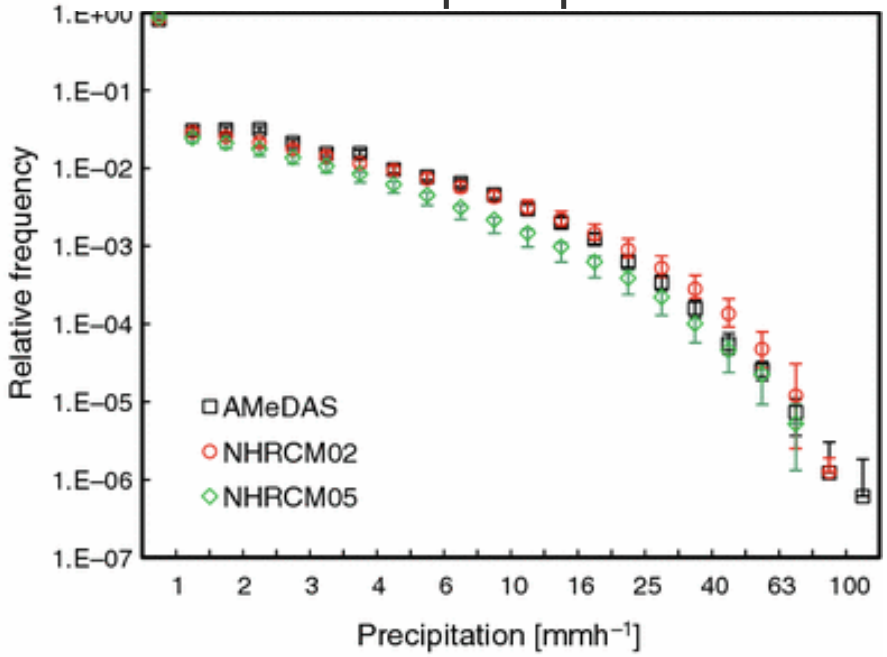
Relative frequency distribution

Murata et al. (2015)

DAILY precipitation



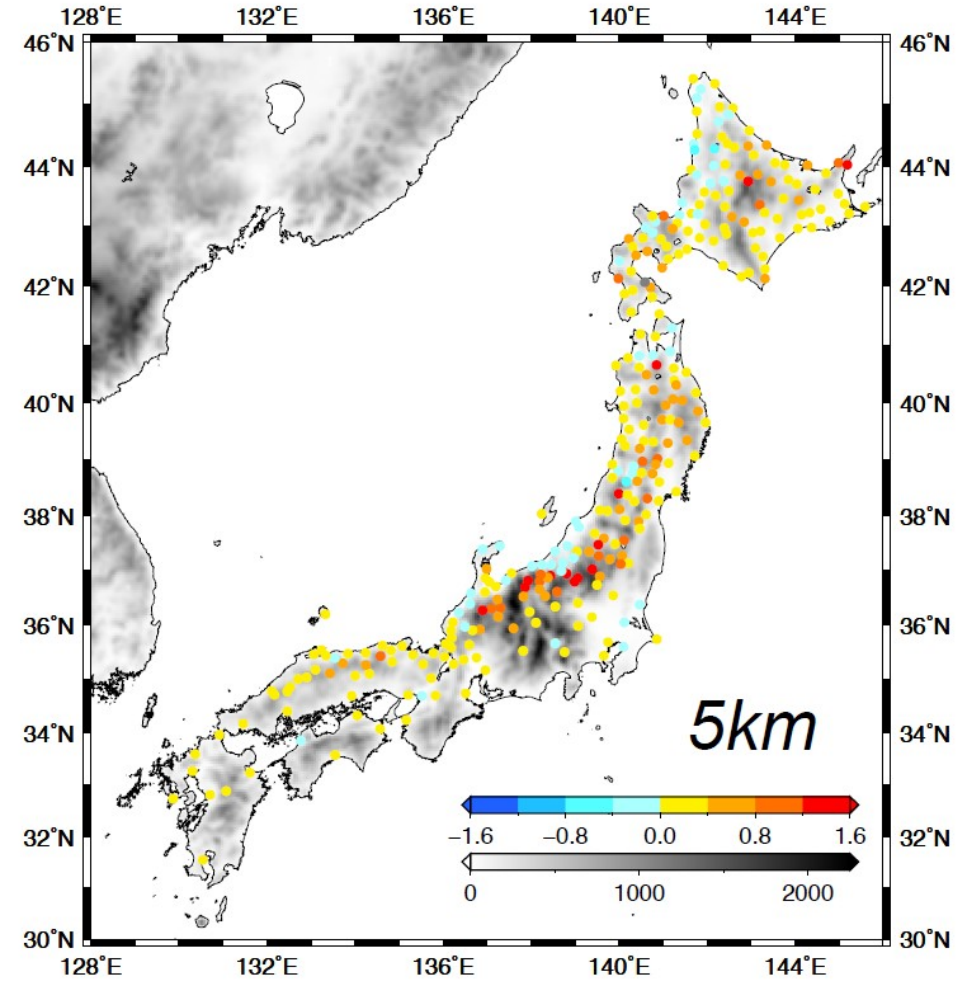
HOURLY precipitation

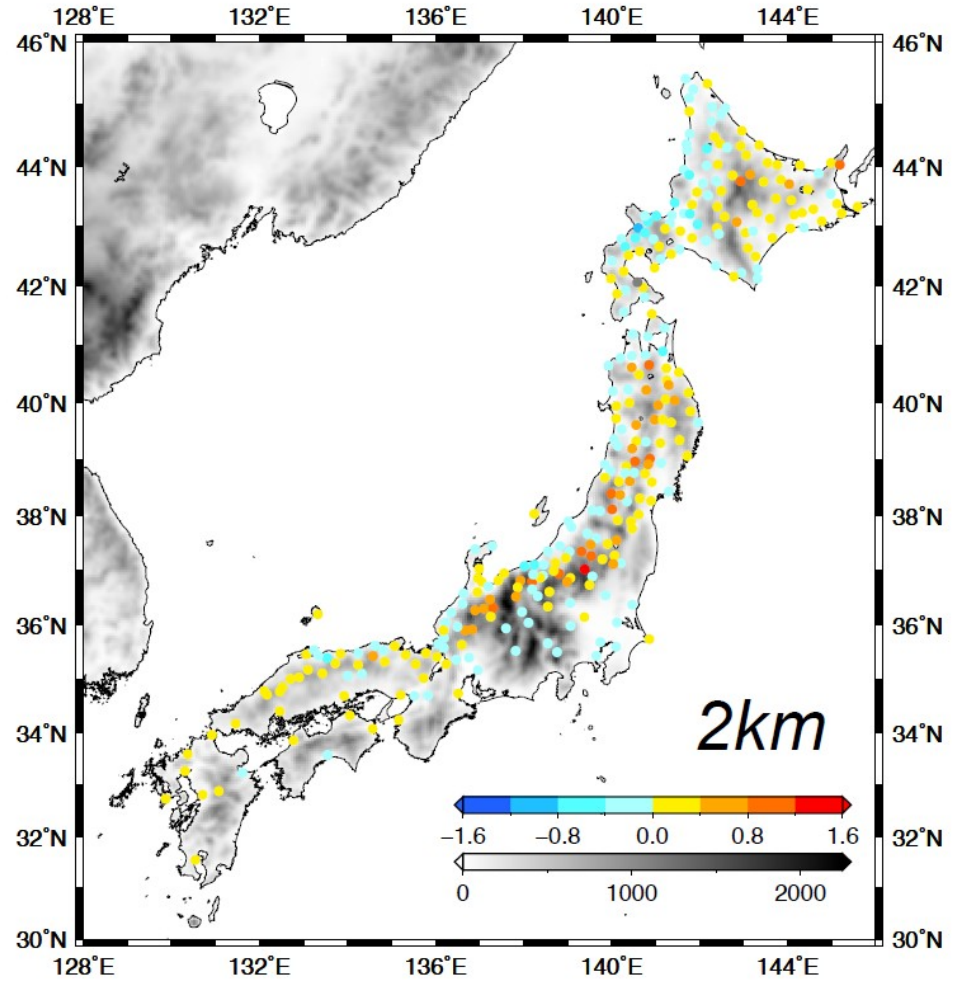


The relative frequency distribution of daily precipitation is well reproduced by 2km NHRCM than by 5km NHRCM when compared with the observed precipitation data except for higher intensities.

Simulated snowfall and snow depth

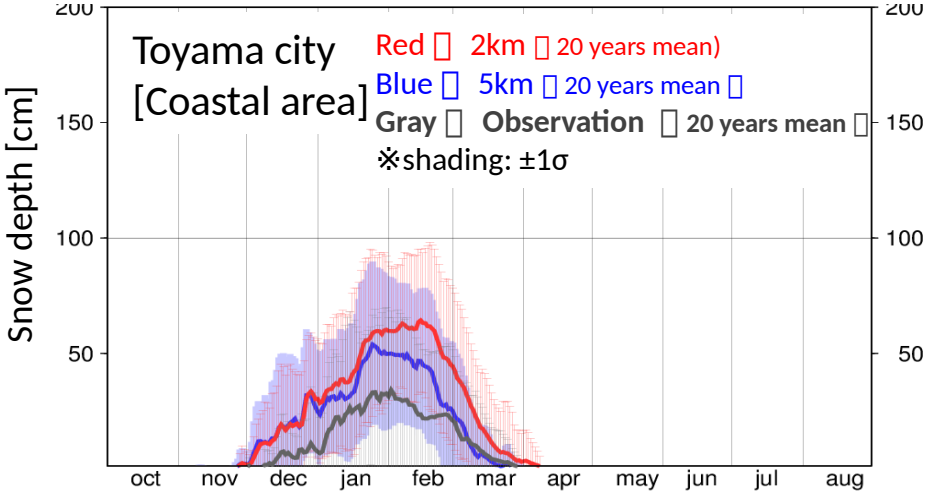
20 years mean maximum snow depth
[NHRCM] – [Observation]

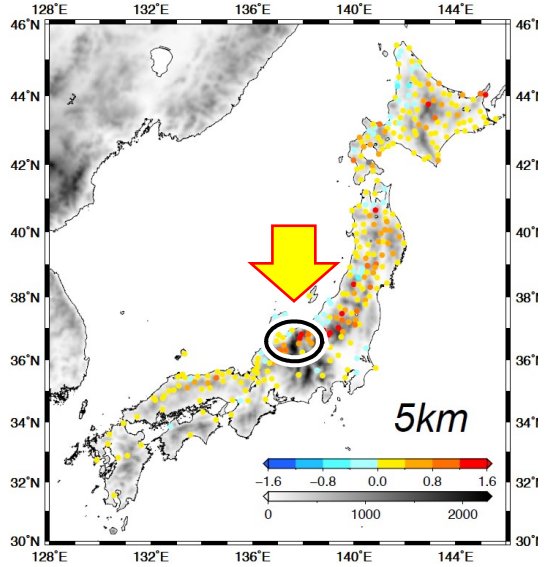




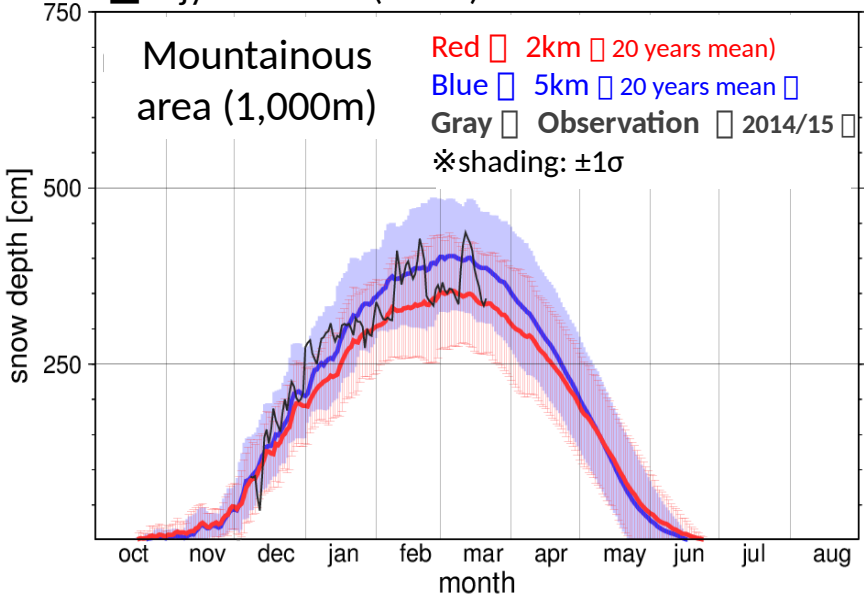
Simulated snowfall in the mountainous areas

Seasonal variation of snow depth

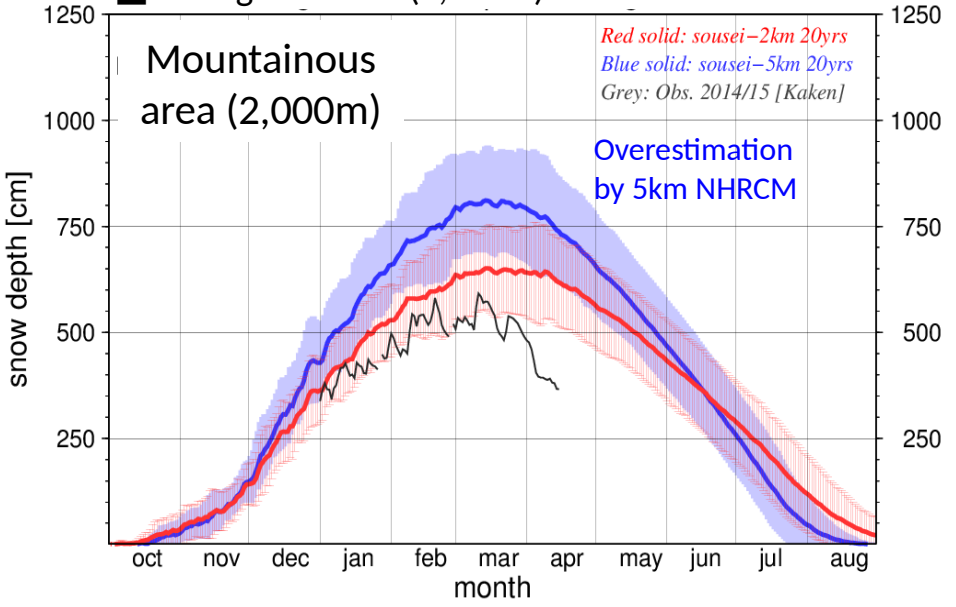




■ Bijyodaira site (977m)

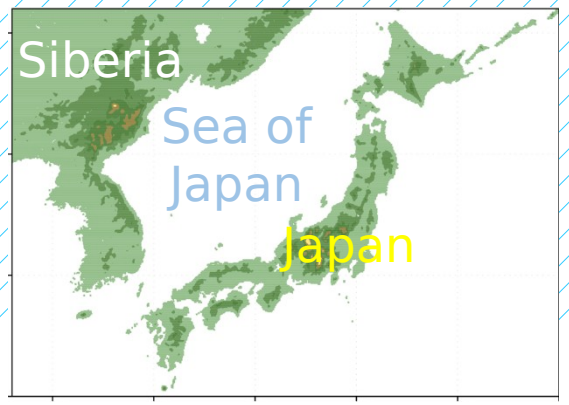


■ Midagahara site (1,930m)

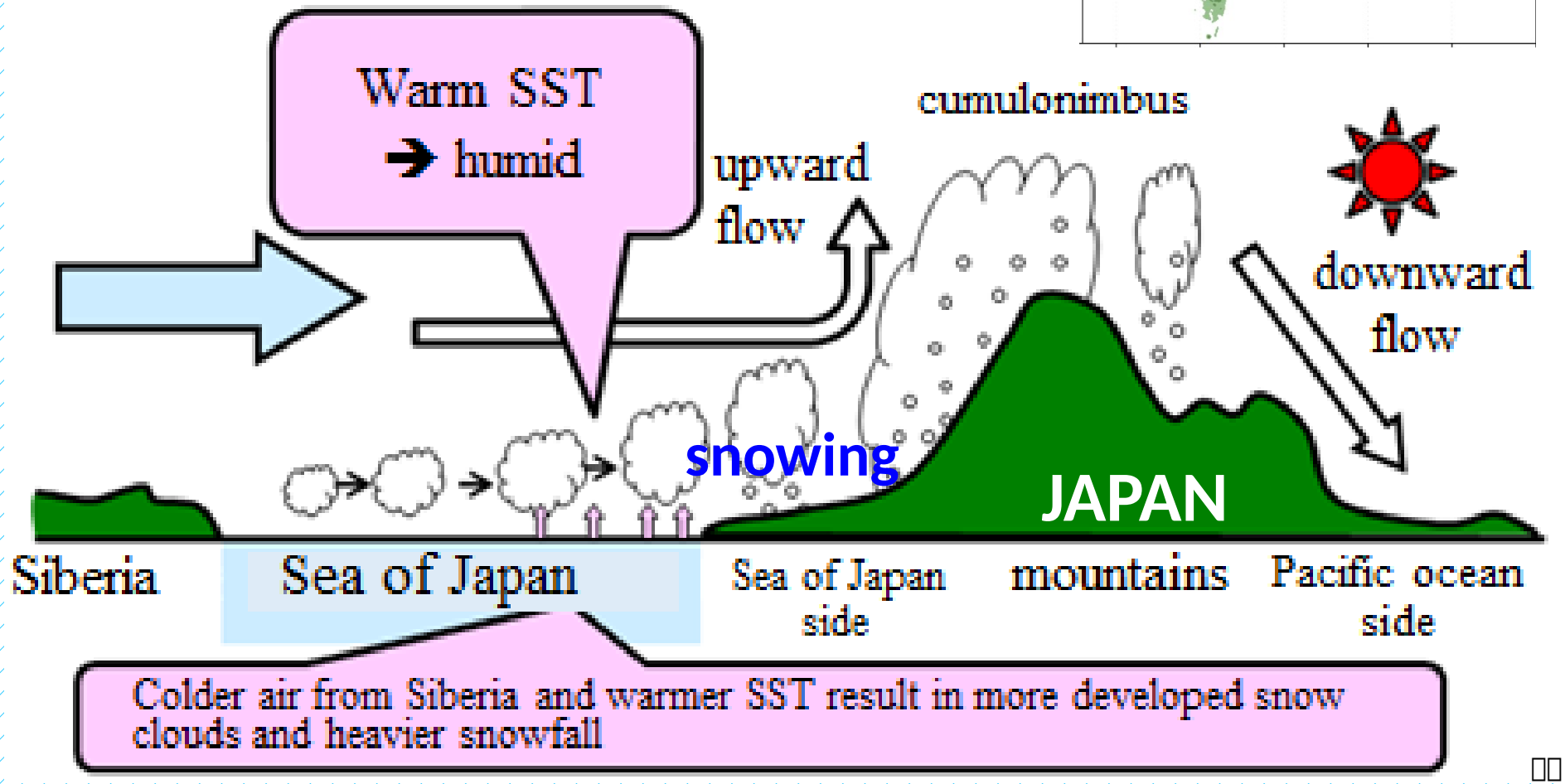


Simulated snowfall and snow depth

East Asian Winter Monsoon



From JMA web site



Simulated snowfall and snow depth

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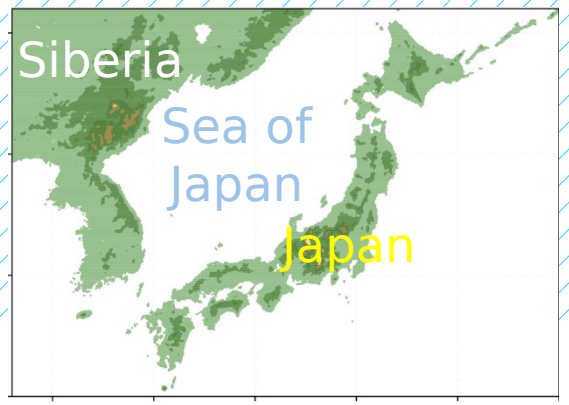

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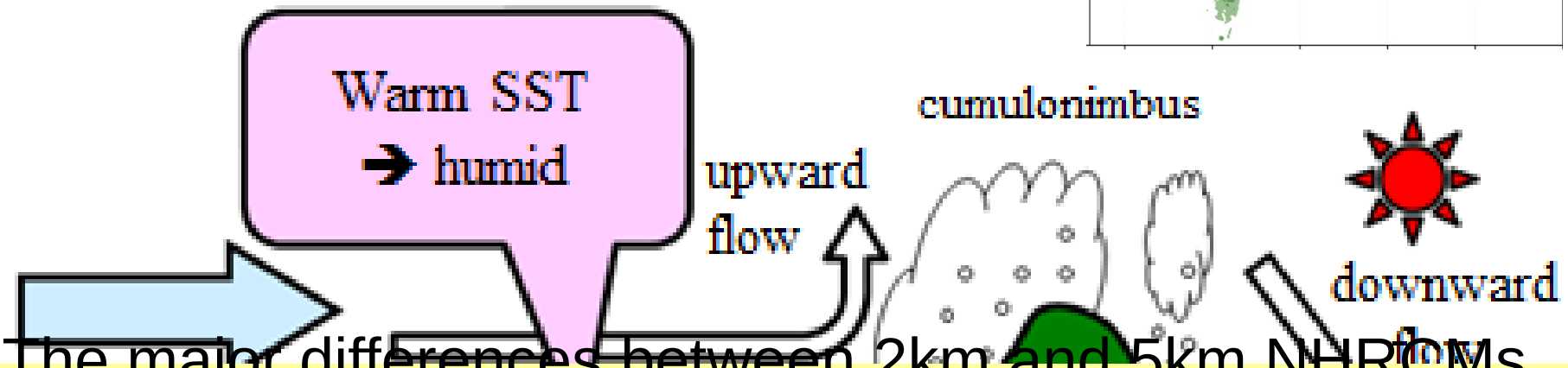


- The major differences between 2km and 5km NHRCMs are

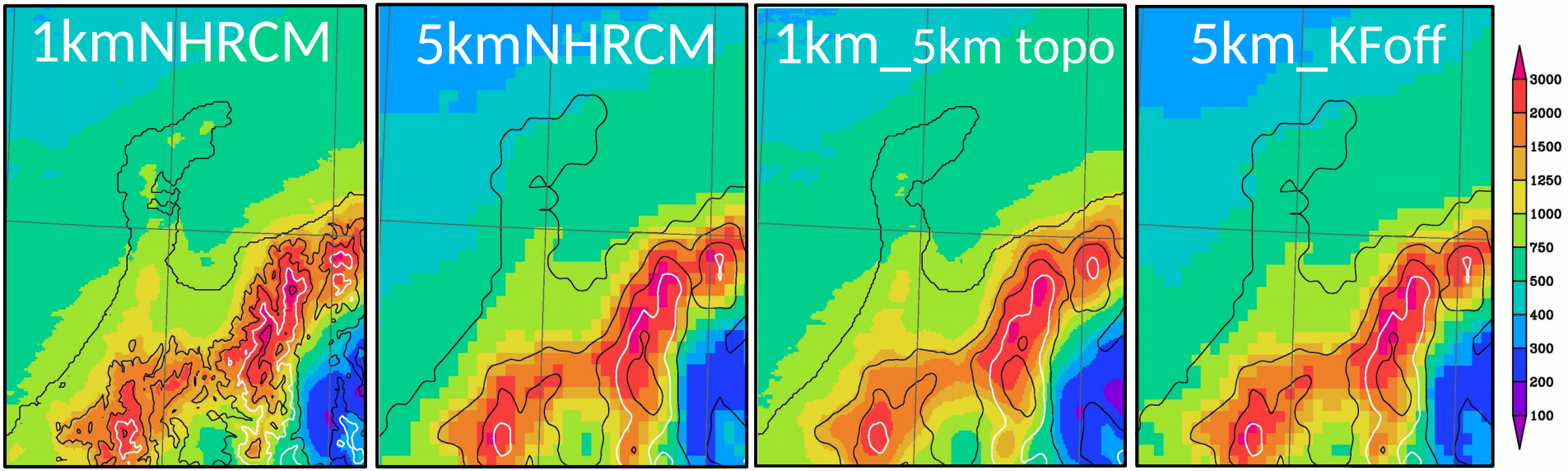
≫ Highly resolved topography

≫ With/without cumulus parameterization

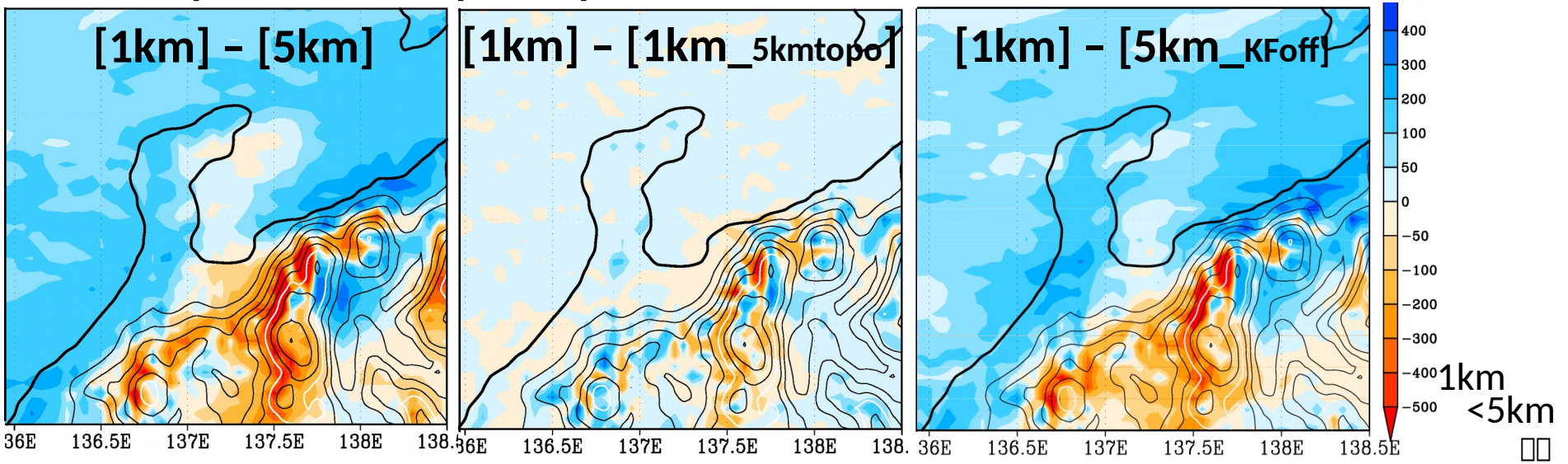
➔ Sensitivity experiments on 2014/15 winter with 1km and 5km. Checking horizontal distribution of precipitation

Simulated snowfall in the mountainous areas

Winter total precipitation



Comparison of precipitation with 1kmNHRCM



Summary

■ 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.

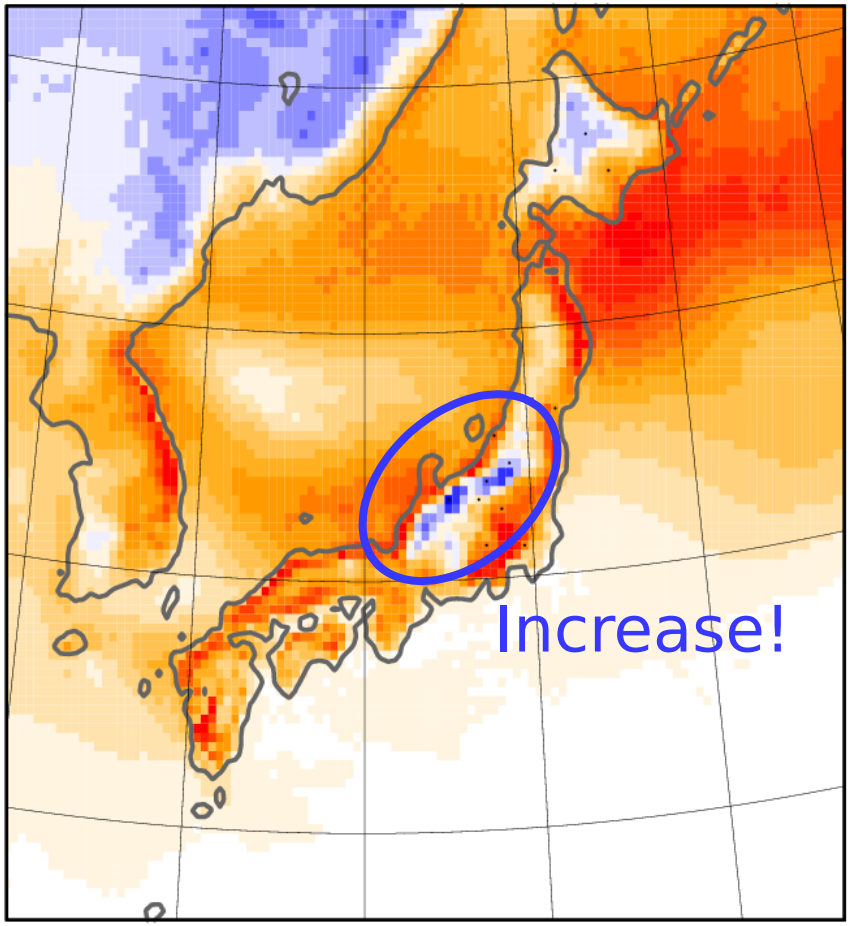
■ Resolution dependency of snowfall and rainfall

- 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

Future changes in extreme daily snowfall [d4PDF]

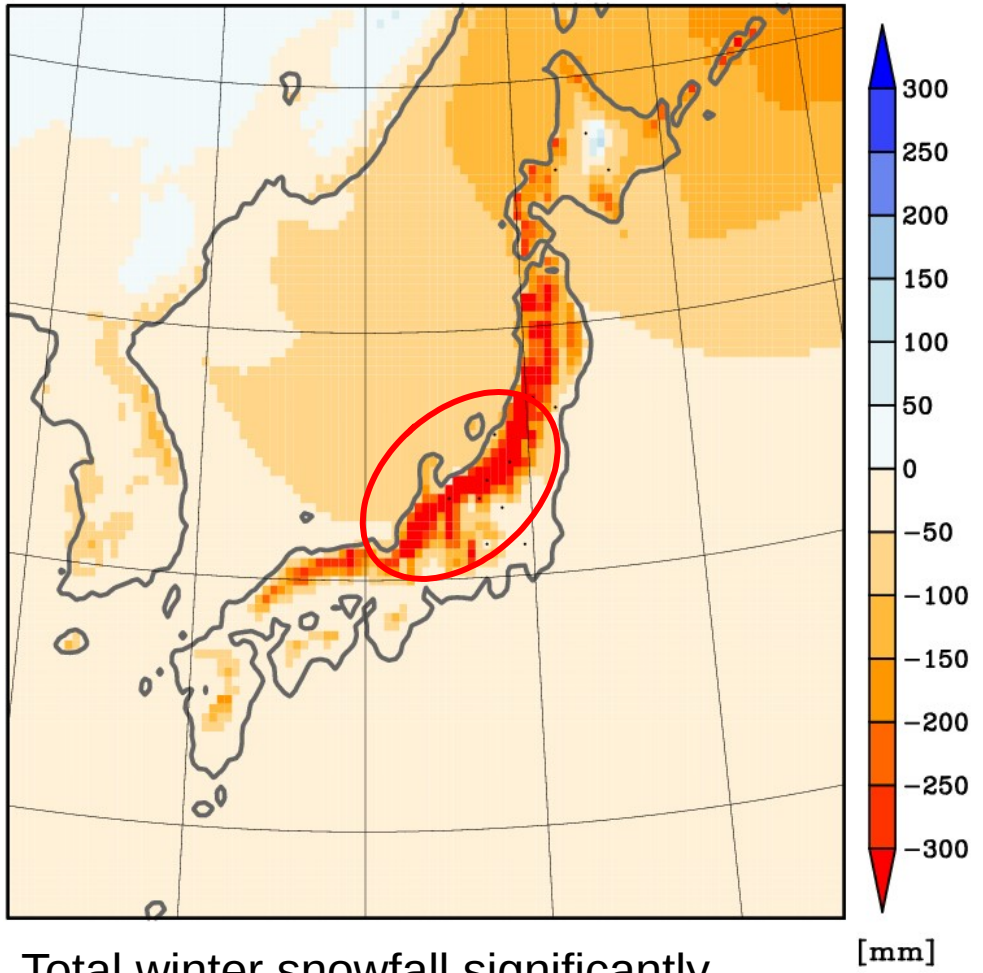
Kawase et al. (2016, Climatic Change)
doi:10.1007/s10584-016-1781-3

Heavy snowfall
(occurring every 10 years)



Remarkable increase in daily snowfall around Central Japan, Hokkaido, and eastern parts of Asian continent.

Total winter snowfall



Total winter snowfall significantly decrease in the most parts of Japan, especially Sea of Japan coast.

Thank you for your attention

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