Future changes in snowfall and snow cover at high Japanese mountain ranges

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Hiroaki Kawase

(Meteorological Research Institute, Japan Meteorological Agency, Japan)

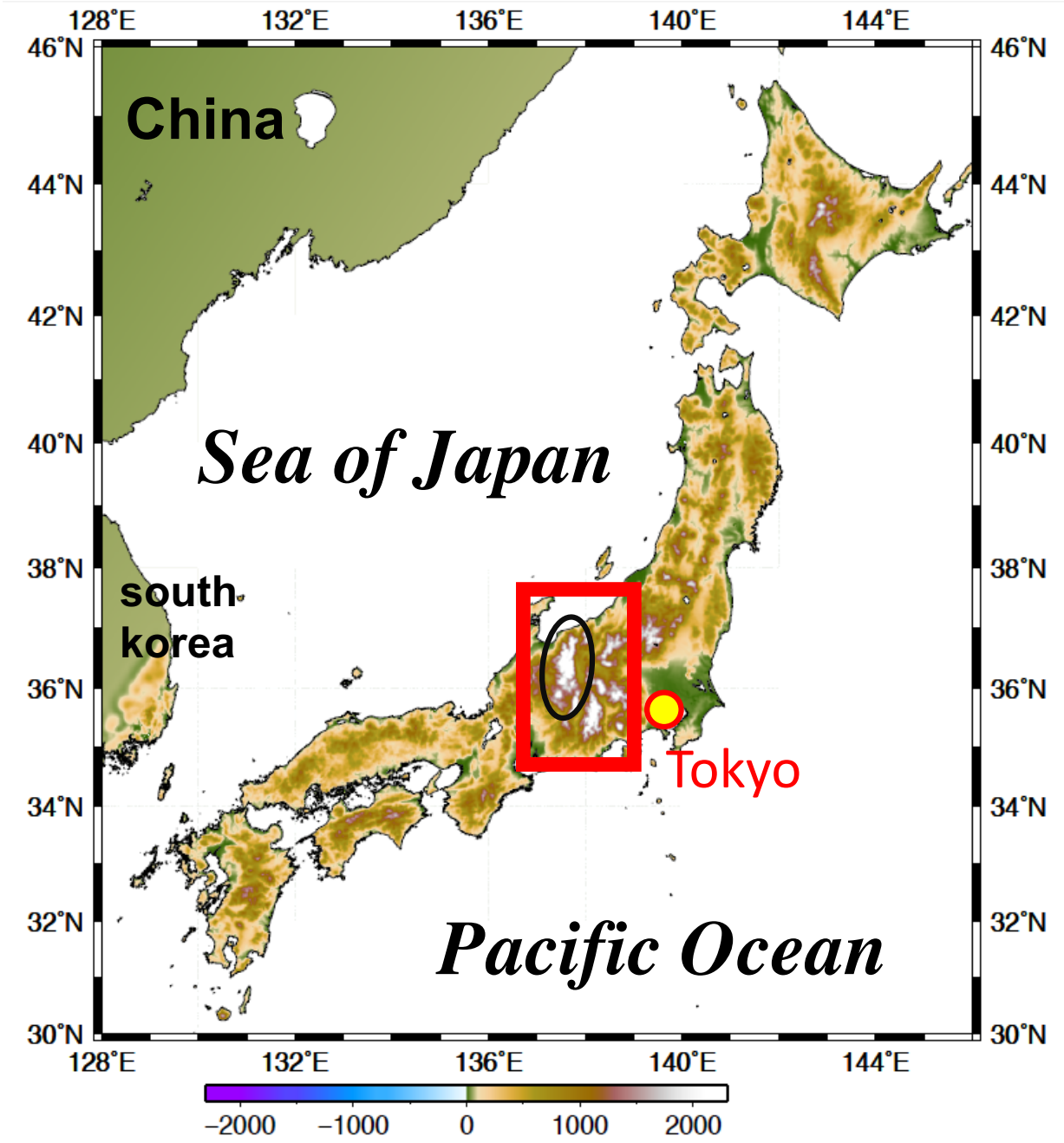
Takeshi Yamazaki, Takahiro Sasai, (Tohoku Univ.), Shiori Sugimoto, Mikiko Fujita (JAMSTEC), Akihiko Murata, Hidetaka Sasaki, Nasaya Nosaka (MRI)

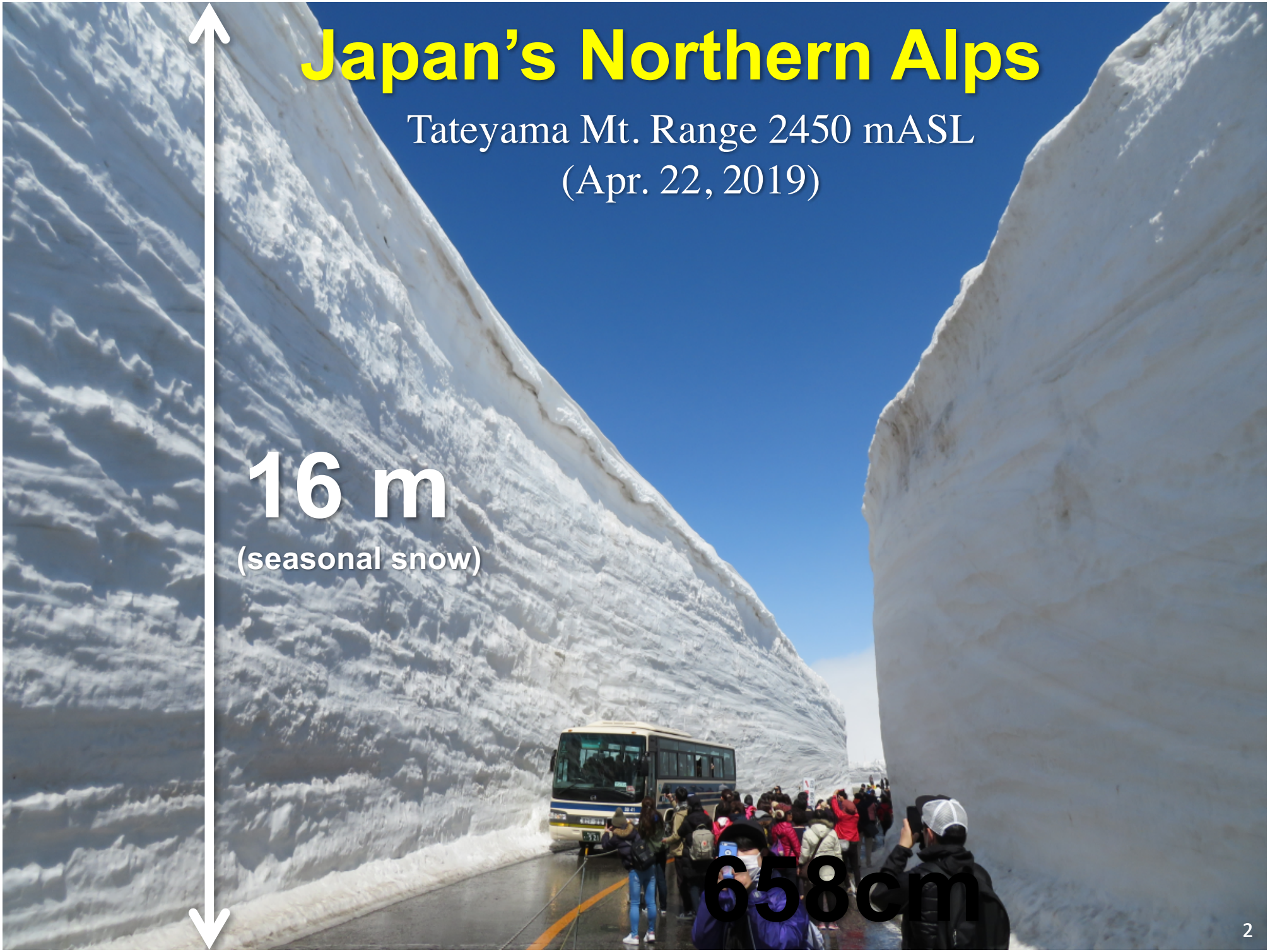
Introduction

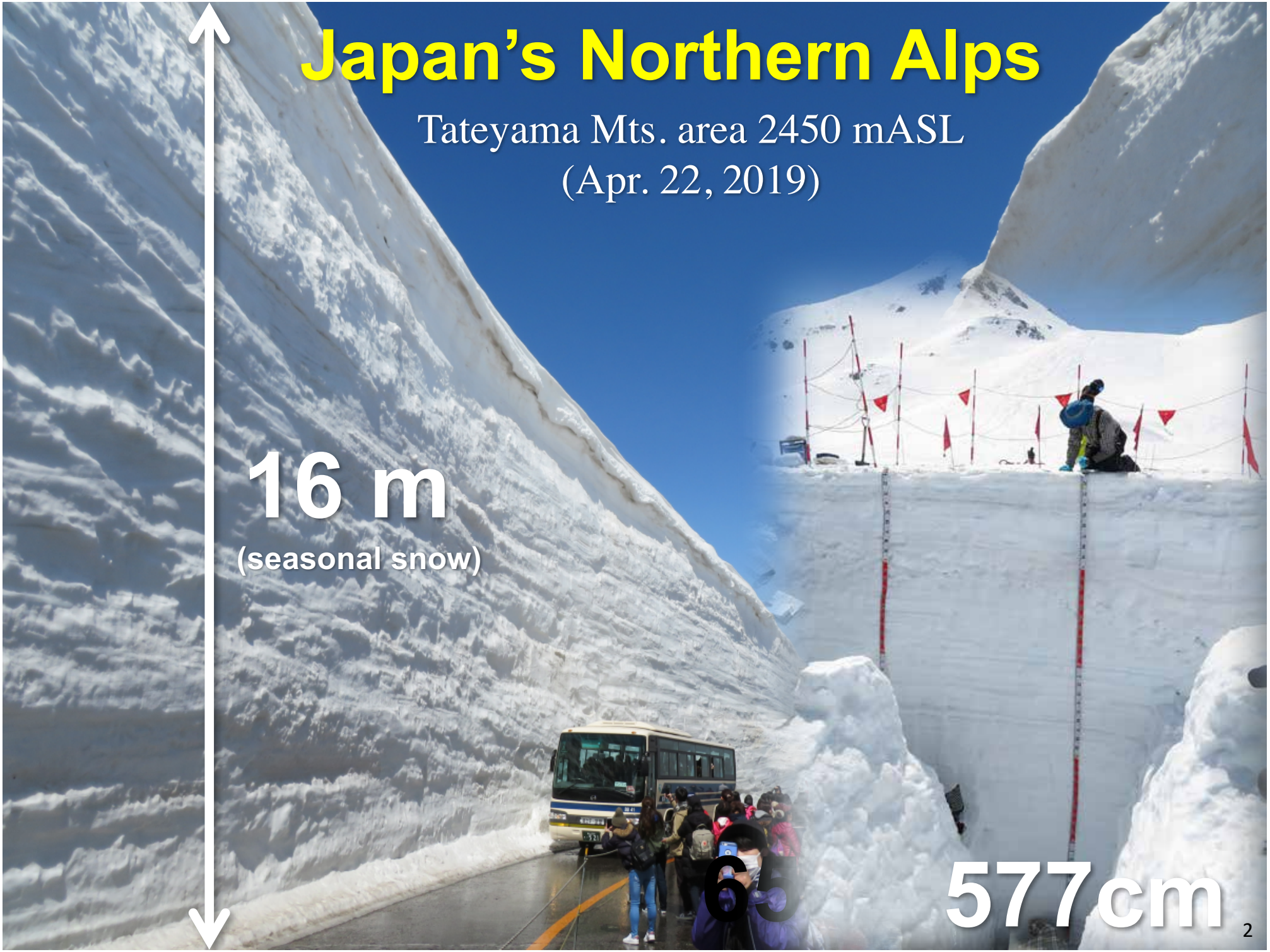
Japan has many mountains. About 75% of whole Japan is mountainous areas.

Mountain ranges in the central Japan are called as ***Japan's Alps***, which is named after European Alps.

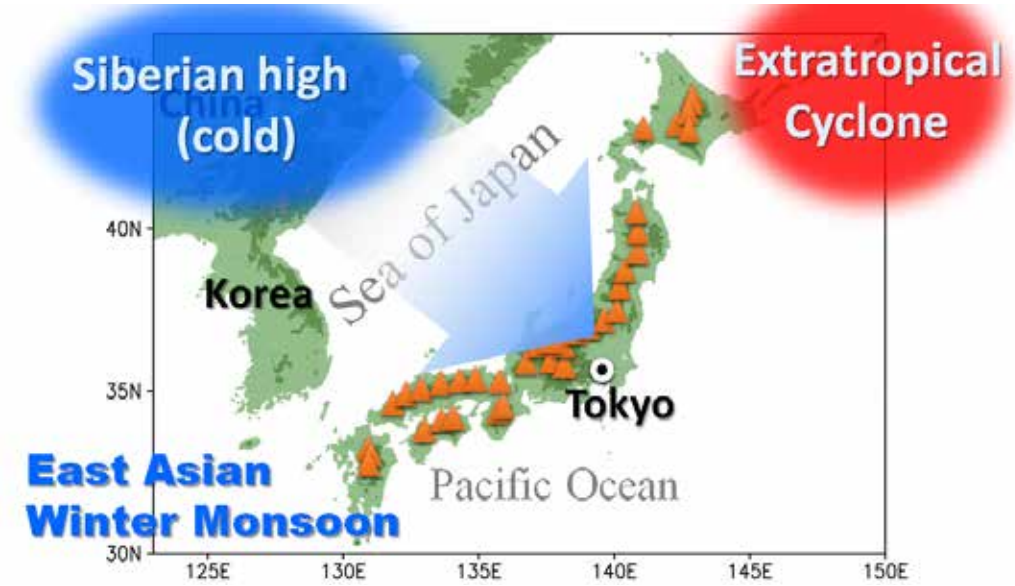
Japan's Northern Alps has enormous snow cover.

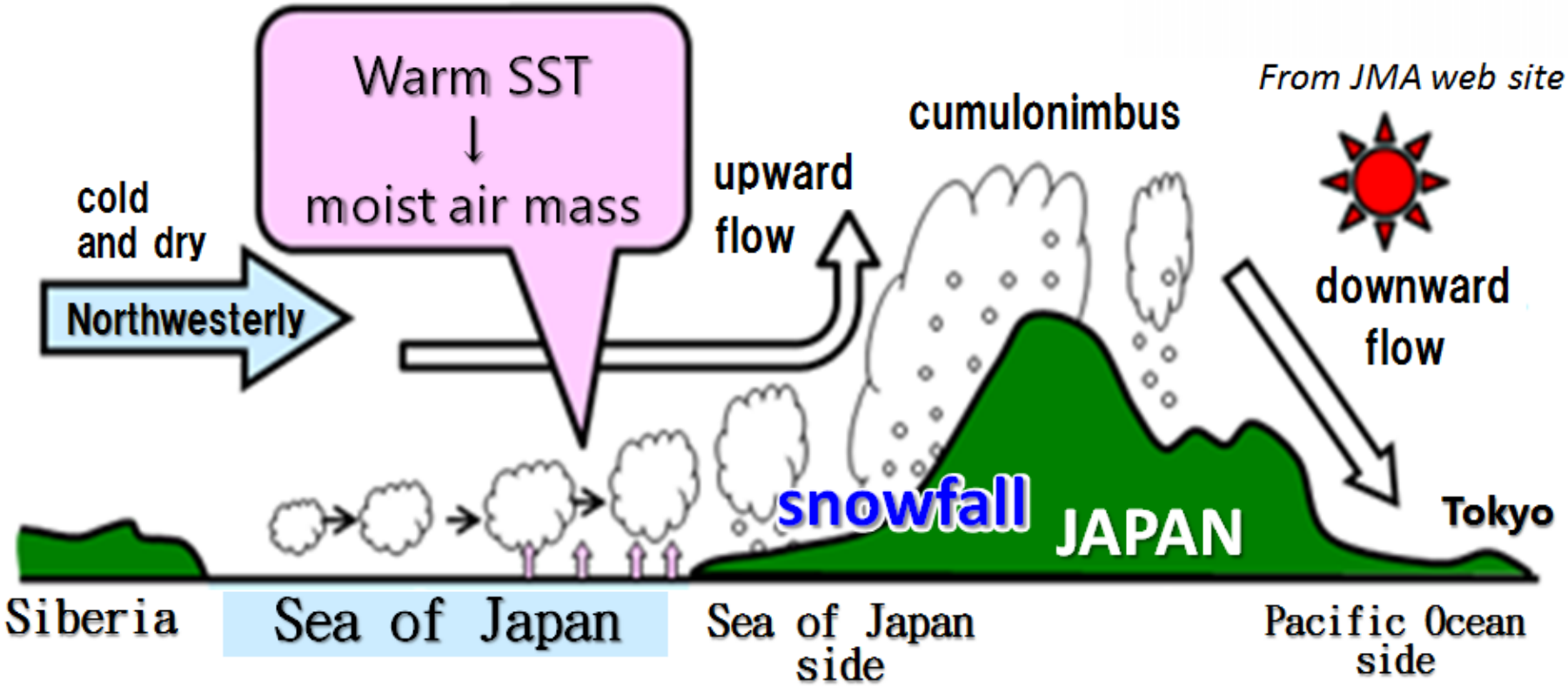



Japan's Northern Alps
Tateyama Mt. Range 2450 mASL
(Apr. 22, 2019)
16 m
(seasonal snow)
658cm


Japan's Northern Alps
Tateyama Mts. area 2450 mASL
(Apr. 22, 2019)
16 m
(seasonal snow)
65
577cm

Mechanism of heavy snowfall in Japan





- Similar to the **lake effect** in snowfall of the Great Lakes

Introduction

Impact of global warming on the Japanese snow

- East Asian Winter Monsoon will weaken due to global warming, resulting in a decrease in winter precipitation along the Sea of Japan side.

  [*Hu et al. 2000; Kimoto et al. 2005; Hori and Ueda 2006*]

- Weakening winter monsoon and temperature rise will reduce total snowfall in Japan, especially lower elevations.

  [*Hara et al.* 2008; *JMA** 2017; *Kawase et al.*, 2015]

- Over the Colorado Headwaters region, global warming enhanced snow melting at lower-elevations, while increased snowfall at higher elevations.

  [*Rasmussen et al.*, 2011; 2014]

- In Europe and the U.S., large reductions in extreme snowfalls are projected due to global warming, except for the coldest areas such as the European Alps and the Rocky Mountains

  [*de Vries et al. 2014; Lute et al. 2015*]

Introduction

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- Weakening winter monsoon and temperature rise will reduce total snowfall in Japan, especially lower elevations.

[*Hara et al.* 2008; *JMA** 2017; *Kawase et al.*, 2015]

Purpose

To evaluate the impact of global warming on winter snowfall and snow cover at high elevations of Japan's Alps using the regional climate model with 1 km grid spacing.

TOUGOU Integrated Research Program for Advancing Climate Models | SOUSEI | SI-CAT

d4PDF

(Database for Policy Decision making for Future climate change)

■ Global climate experiments（MRI-AGCM3）60km

○ Historical experiments (60yrs, 100 member) **6000 years**

SST: COBE-SST2 1951～2010 (with 100 initial perturbations)

○ Future experiments (60yrs, 90/54 member) **5400/3240 years**

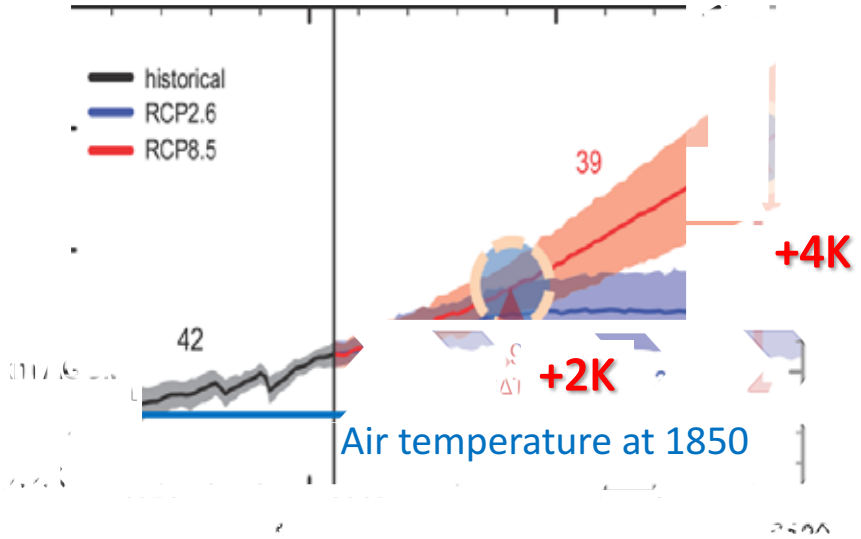
SST: Historical SST plus six SST anomalies of CMIP5 models between past and future climate assuming **2K/4K warming (RCP8.5)** relative to preindustrial period.

Downscaling

■ Regional climate experiments (NHRCM with 20km)

NHRCM is Nonhydrostatic Regional Climate Model developed by MRI, JAPAN.

Global mean surface air temperature



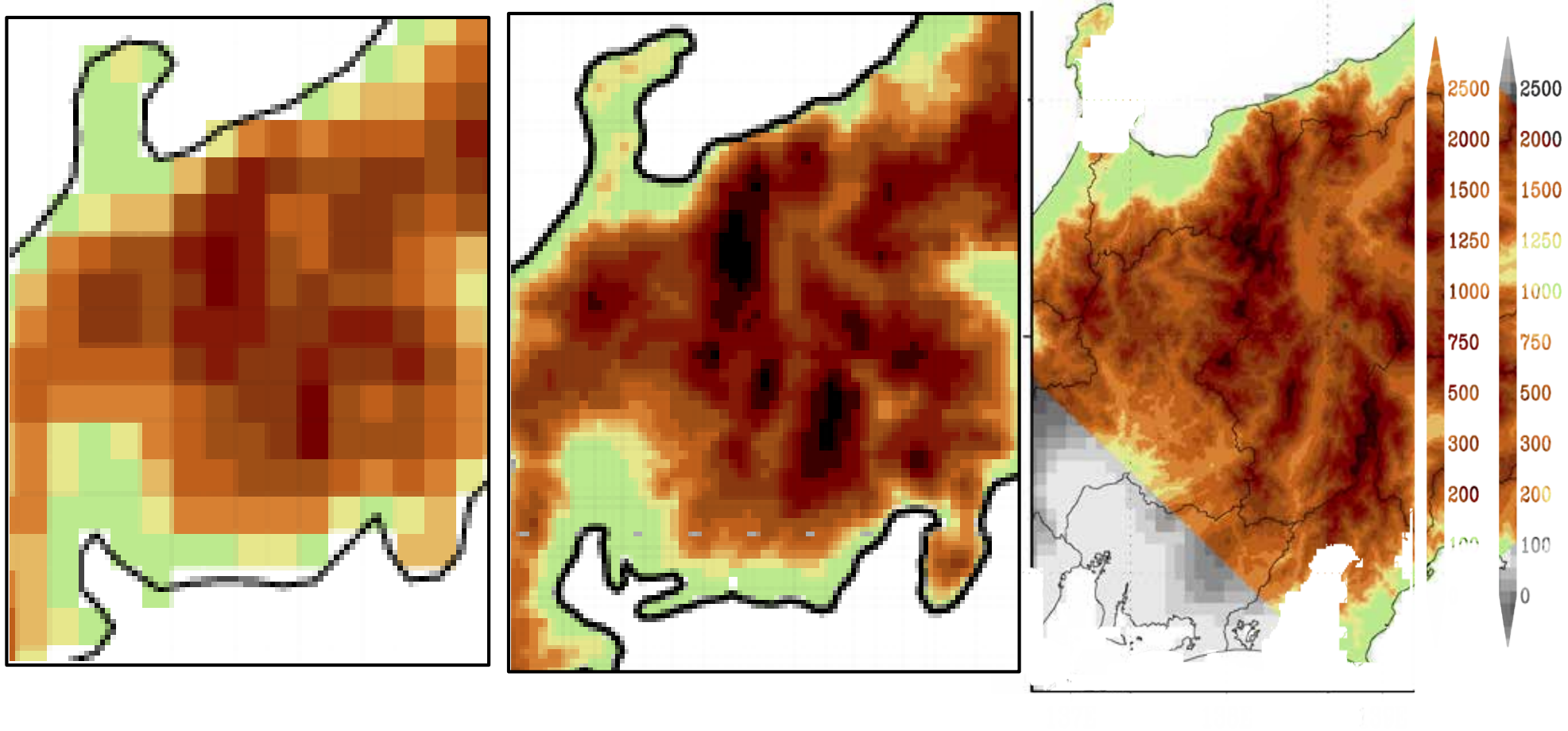
[Mizuta et al., 2017; Fujita et al. 2019]

Topography in RCMs

20km

5km

1km

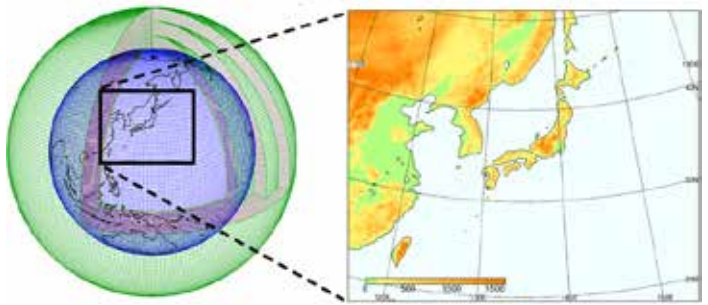


Realistic Japan's Alps

Additional downscaling and selection of years

SI-CAT

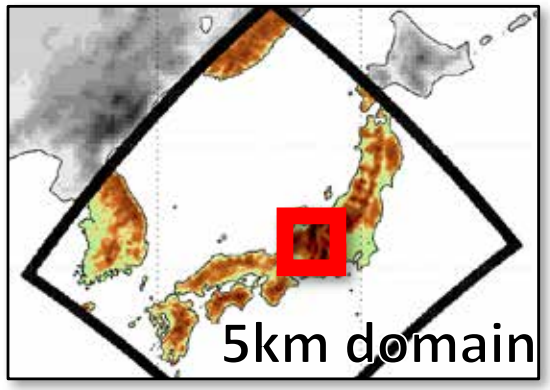
d4PDF ~3000yrs.



Dynamical downscaling

NHRCM with 5km ***~400yrs.***

* **Historical:** 372 years (31 years x 12)
* **2K warming:** 372 years (31 years x 12)
* **4K warming**: 372 years (31 yeas x 12)



Calculation of annual maximum snow cover at Japan's Alps above 1,000m in each climate

Selection and dynamical downscaling

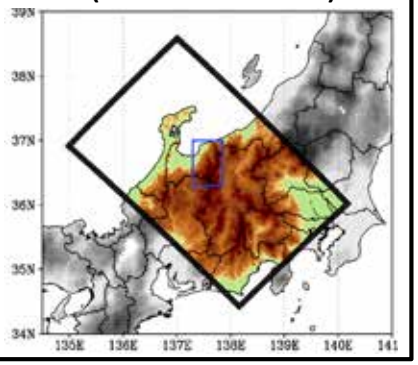
Top 5 years: **Heavy snow**-covered years

Median 5 years: **Medium snow**-covered years

Bottom 5 years: **Light snow**-covered years

(15 yrs. x 3 clim.) ➔ **Downscaling using 1km NHRCM**

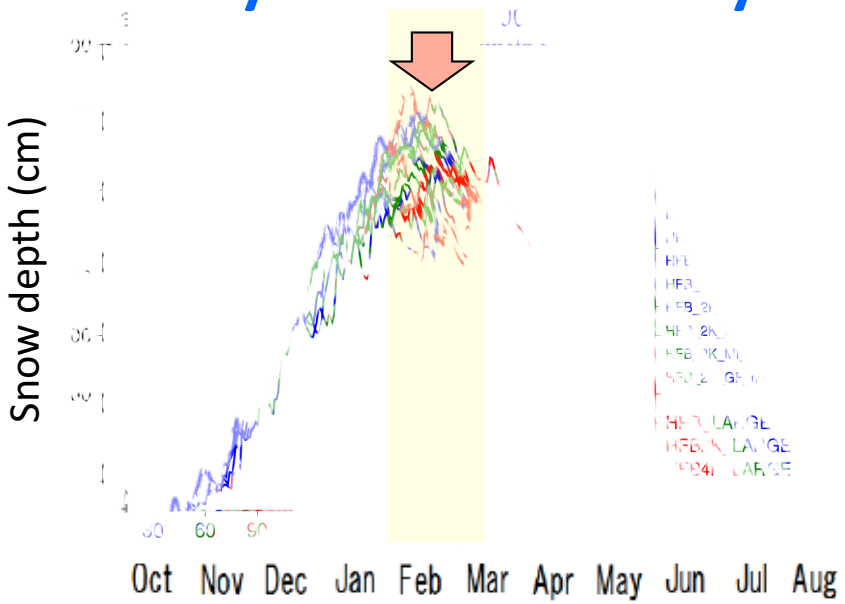
(1km domain)



Kawase et al. (2019, submitted)

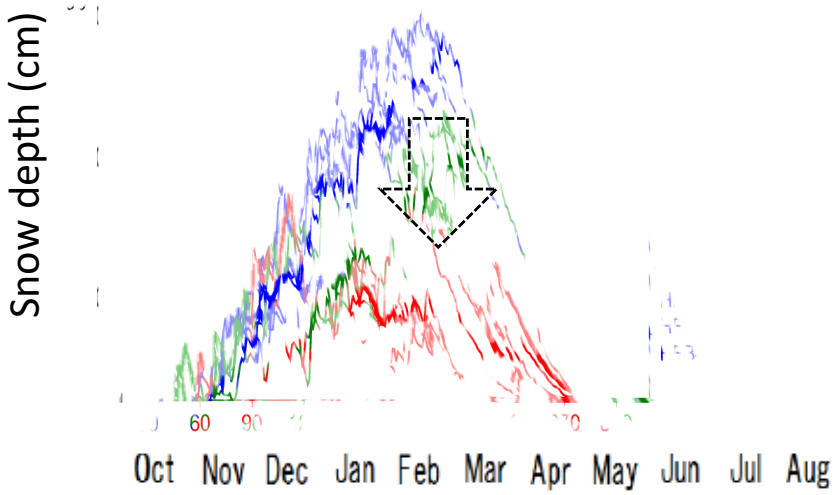
Seasonal variation of snow depth over Northern Alps

Heavy Snow-covered years

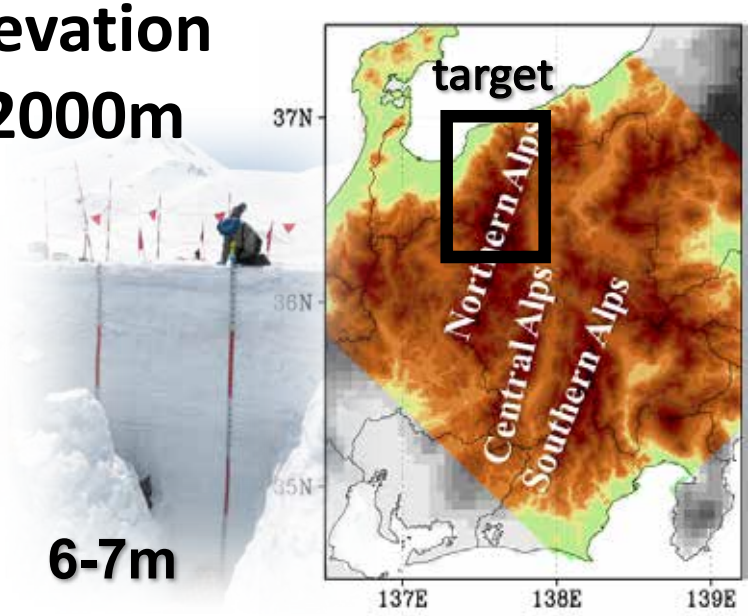


Light Snow-covered years

over 2000m



High elevation above 2000m



■ Heavy snow-covered years

Mid-winter snow depths under 2K/4K warming experiments are comparable to snow depth in the historical experiment.

■ Light snow-covered years

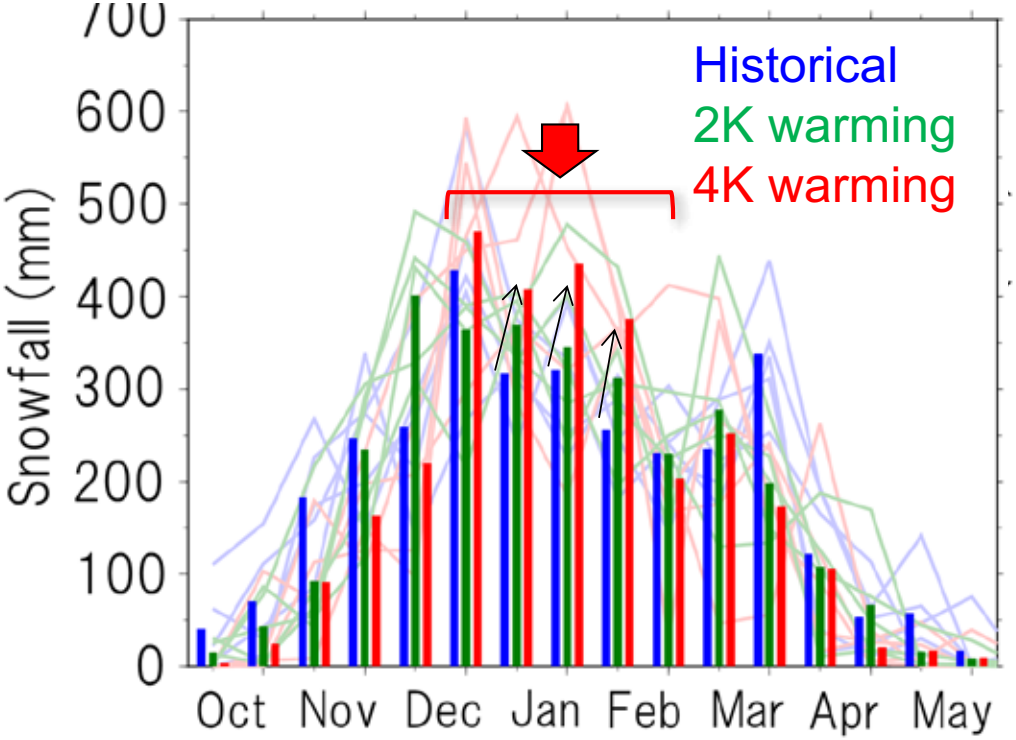
Snow depth will decrease even in mid-winter due to global warming.

The difference of snow cover between heavy and light snow-covered years gets larger due to global warming.

Seasonal variation of half-monthly snowfall

Snowfall over 2000 m ASL

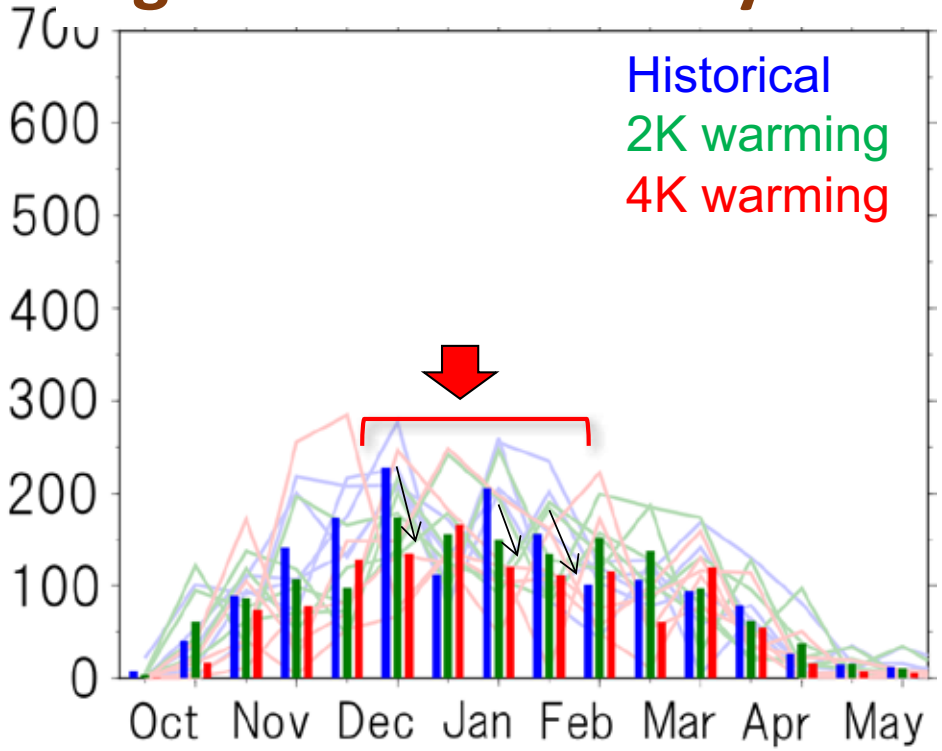
Heavy Snow-covered years



Increase in mid-winter snowfall due to global warming

➔ Similar snow depth in the three experiments.

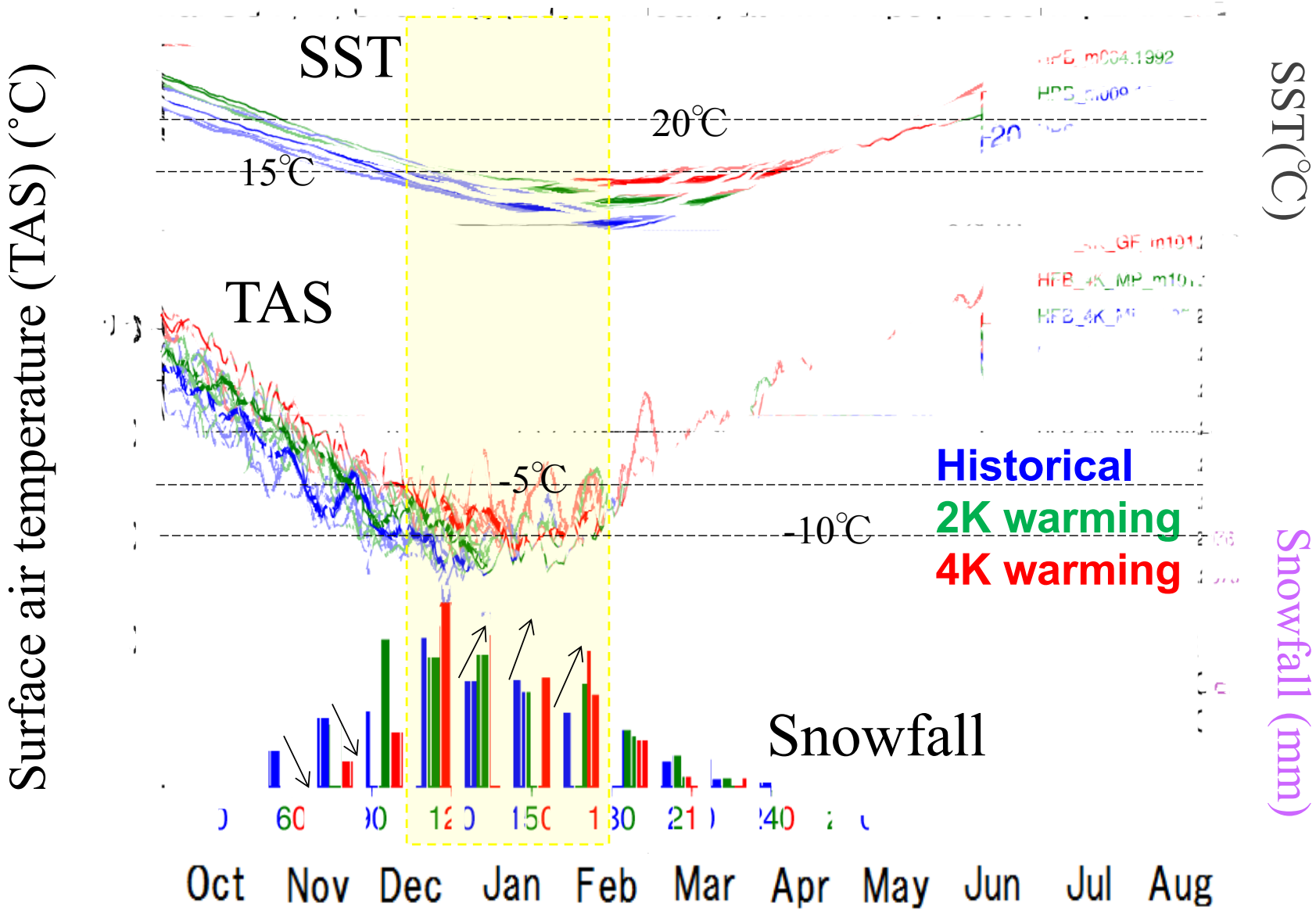
Light Snow-covered years



Decrease in mid-winter snowfall due to global warming

Seasonal variation of SST, air temperature, and snowfall

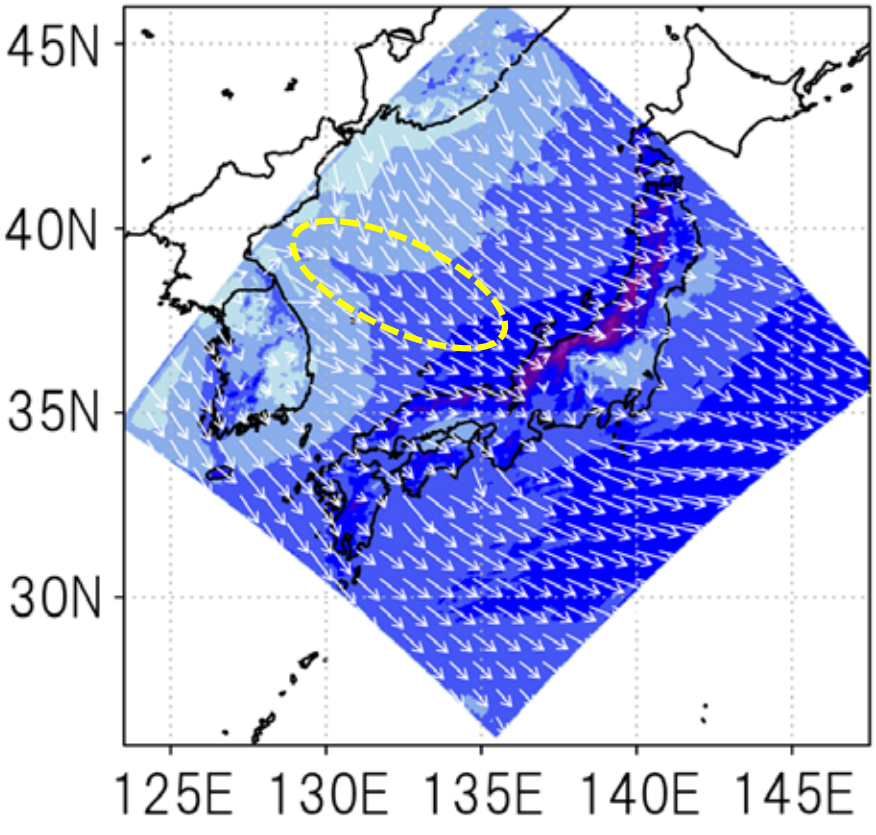
Heavy snow-covered years (high elevation>2000m)



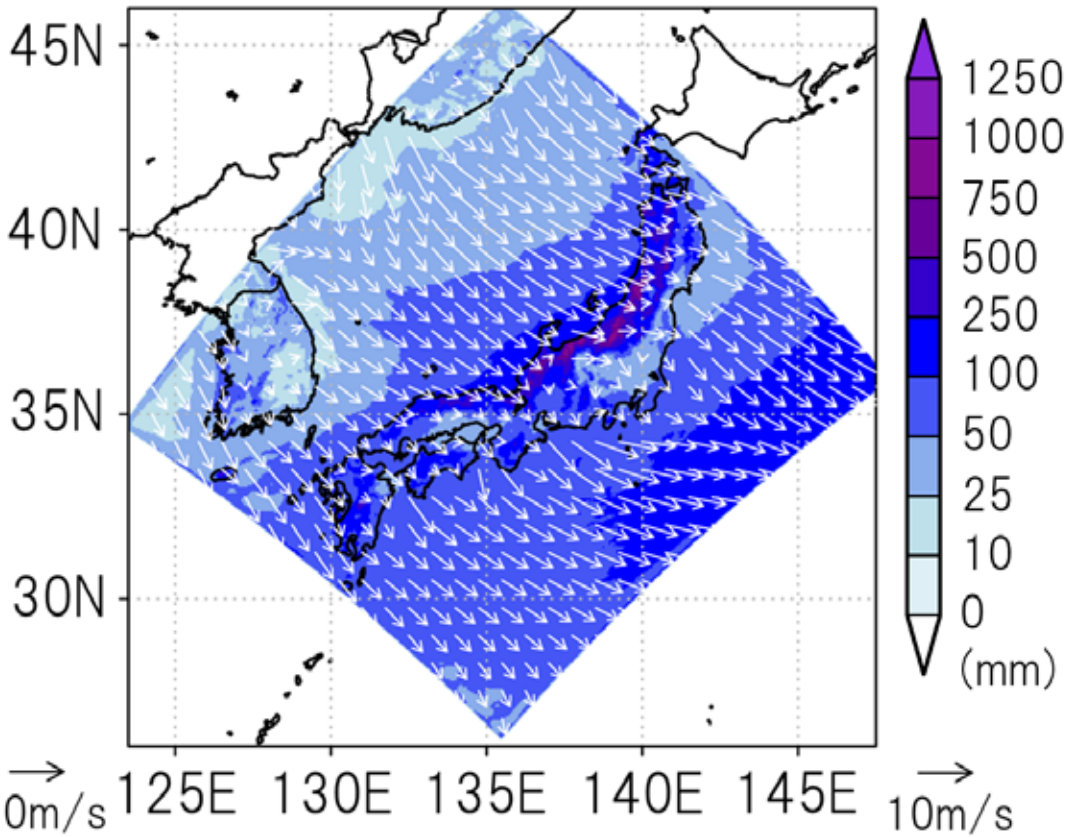
Surface wind (synoptic condition) and precipitation

Historical exp. (5-year-mean) [DJF]

Heavy snow-covered year



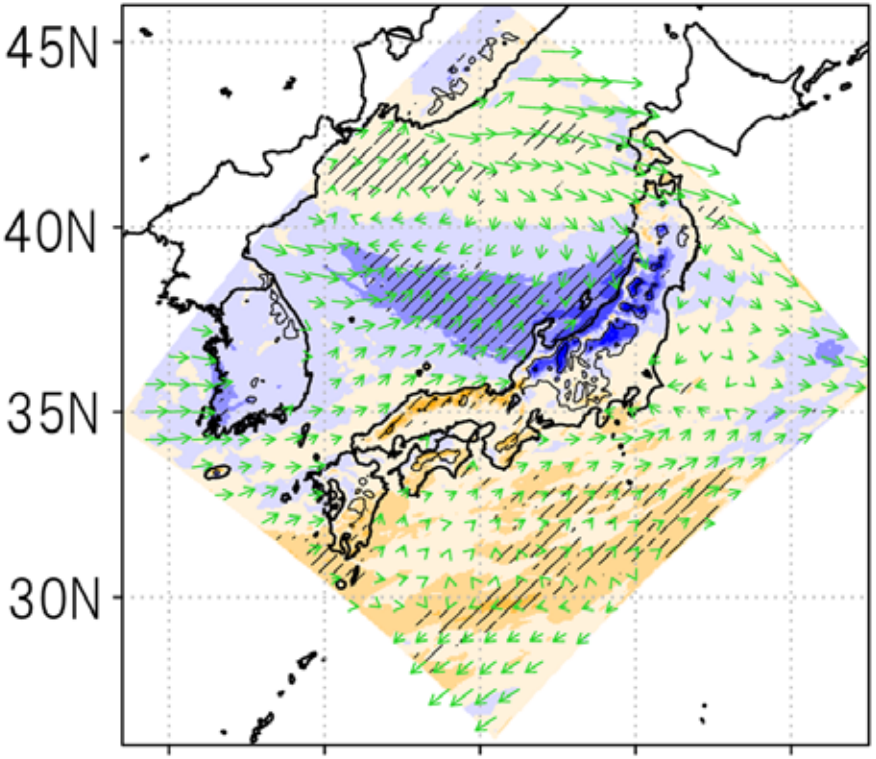
Median snow-covered year



Surface wind (synoptic condition) and precipitation

4K warming exp. – Historical exp. [DJF]
(5-year-mean)

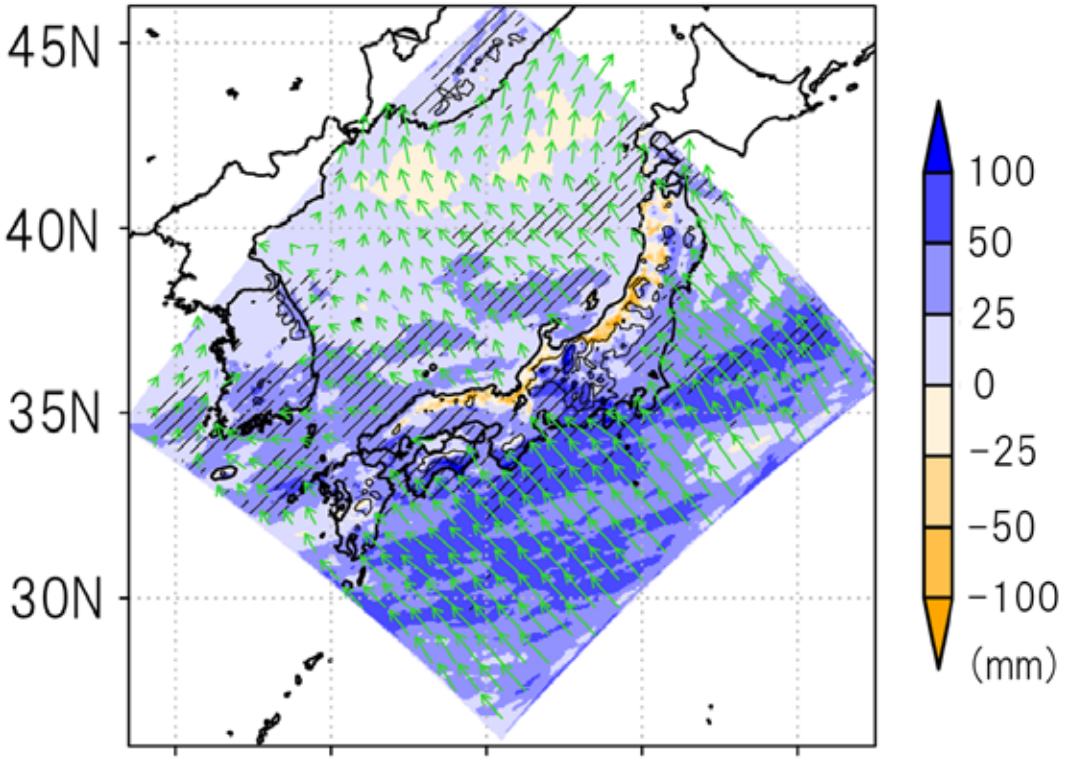
Heavy snow-covered year



.5m/s

- **No changes in northwesterly**
- **Enhanced convergence**

Median snow-covered year



2m/s

- **Weakened northwesterly (= weaken winter monsoon)**

similar to climatological change

Summary

We evaluated future changes in snowfall and snow cover at high elevations of the Japan's Northern Alps using a regional climate model with 1 km grid-spacing.

- In heavy snow-covered years, mid-winter snowfall increases at high elevations of Japan's Northern Alps due to global warming. Mid-winter snow depth is comparable to present one in the 4 K warming climate.

- In light snow-covered years, mid-winter snow cover largely decreases due to global warming.

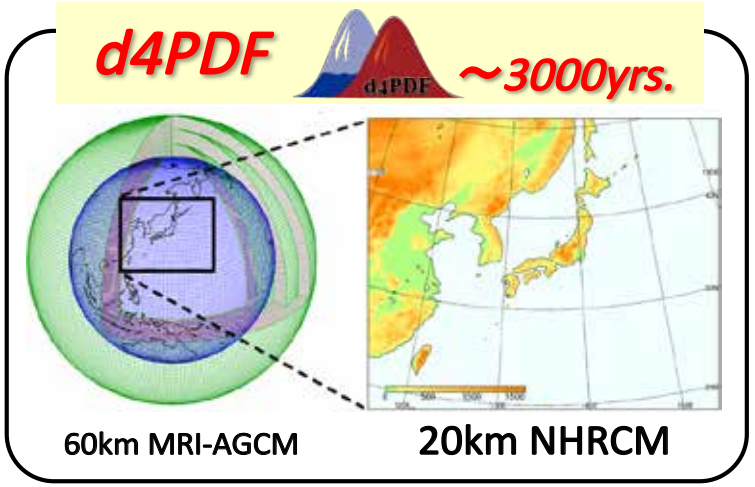
- A contrast of mid-winter snow cover between heavy and light snow-covered years gets larger due to global warming.

- Changes in synoptic condition are different between the heavy snow-covered years and medium snow-covered year.


2019/4/22 Tateyama Murodo
(ptarmigan)
Thank you

Additional downscaling and selection of years

SI-CAT



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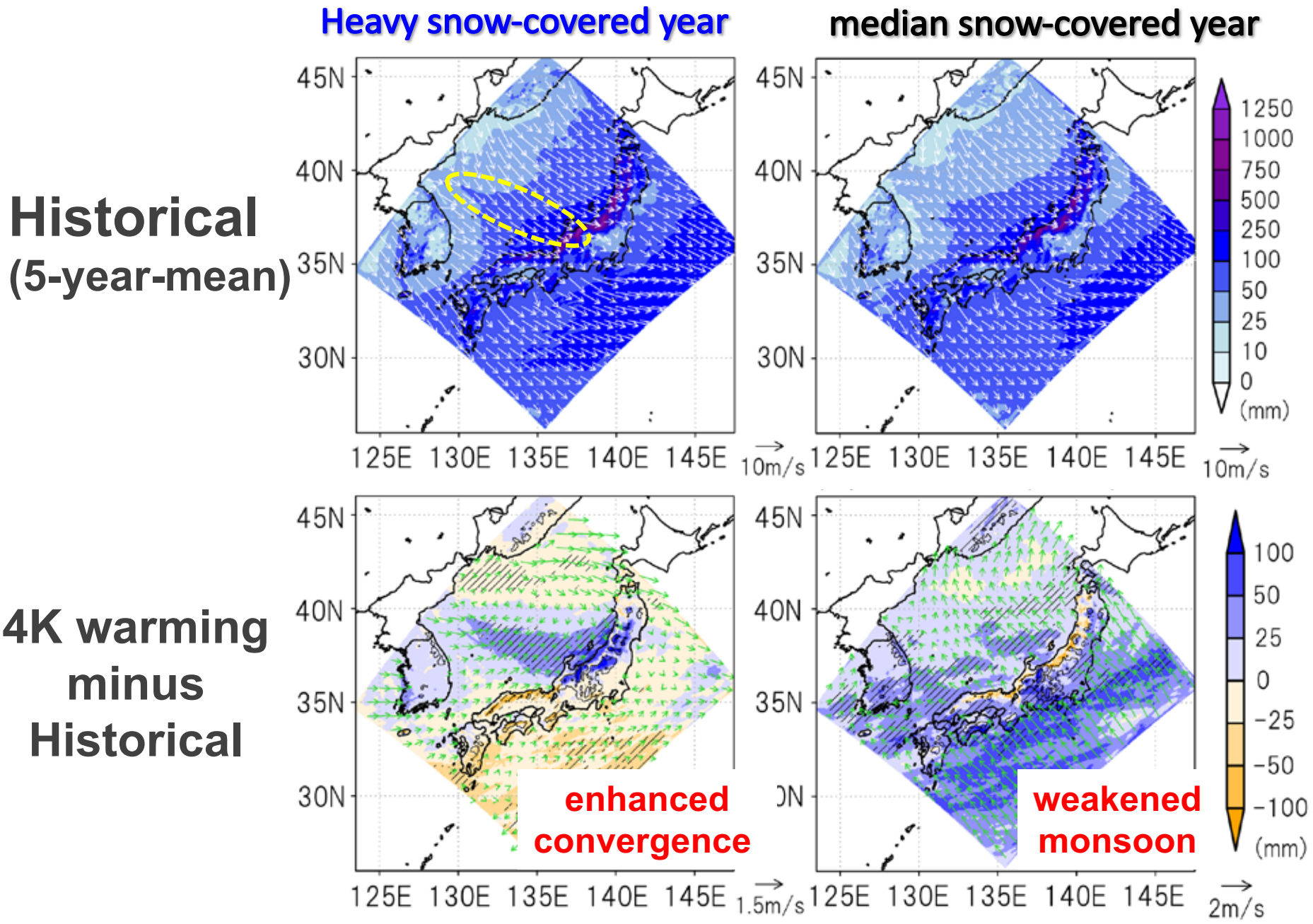
Physical processes in 1km NHRCM

Microphysics	Bulk-type cloud microphysics (Ikawa et al.1991)
Radiation	Clear-sky radiation scheme (Yabu et al. 2005) Cloud radiation scheme (Kitagawa et al. 2000)
Boundary-layer	Improved Mellor-Yamada-Nakanishi-Niino (MYNN) Level 3 (Nakanishi and Niino 2004)
Land surface	Improved MRI/JMA Simple Biosphere (iSiB) (Hirai and Oh'izumi 2004)
Urban model	Square Prism Urban Canopy Scheme (SPUC) with snow cover process (Aoyagi and Seino 2011; Ito et al. 2018)

Future changes in precipitation and synoptic circulation



Kawase et al. (2019, submitted)

Many mountainous areas in Japan

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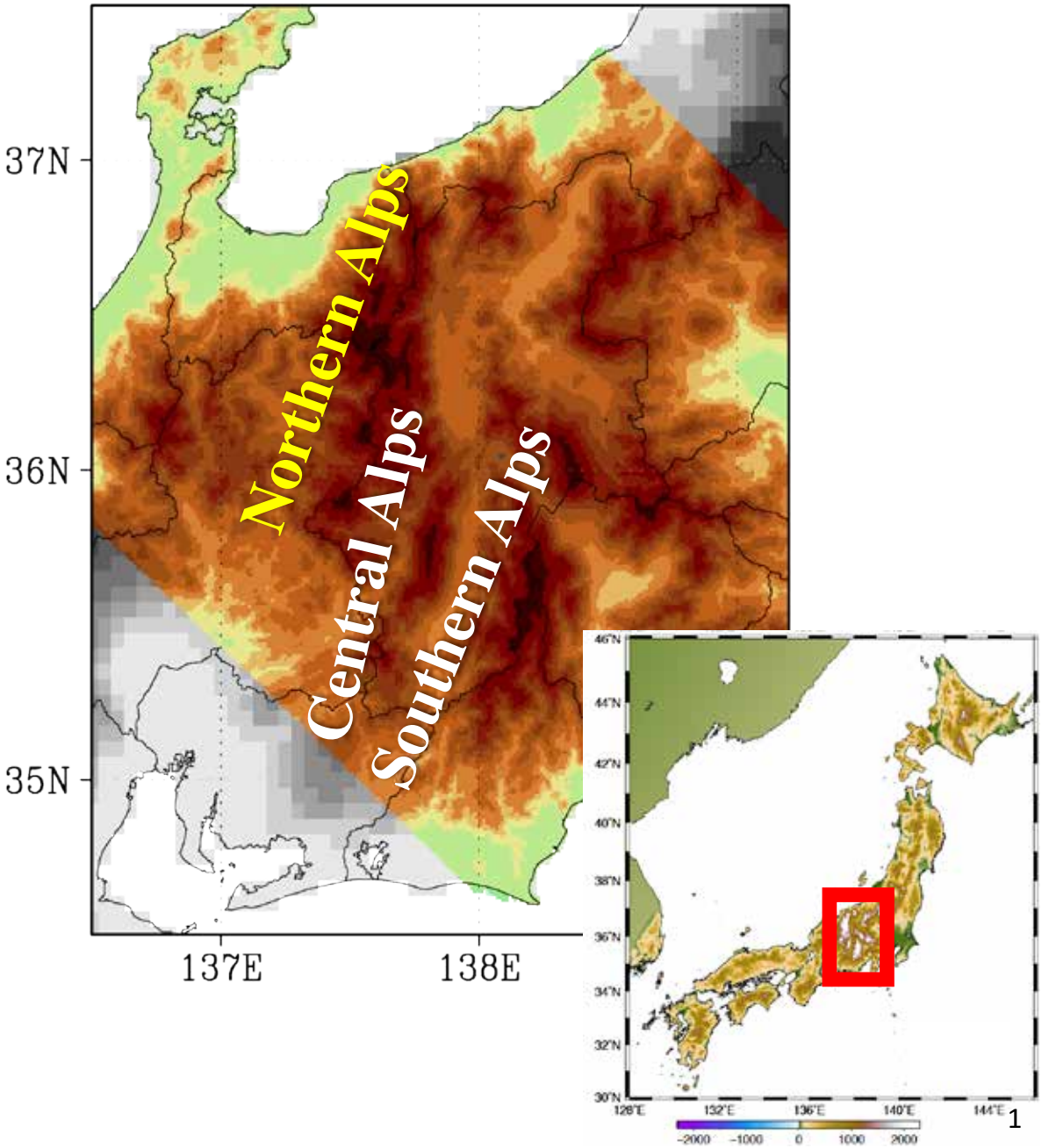
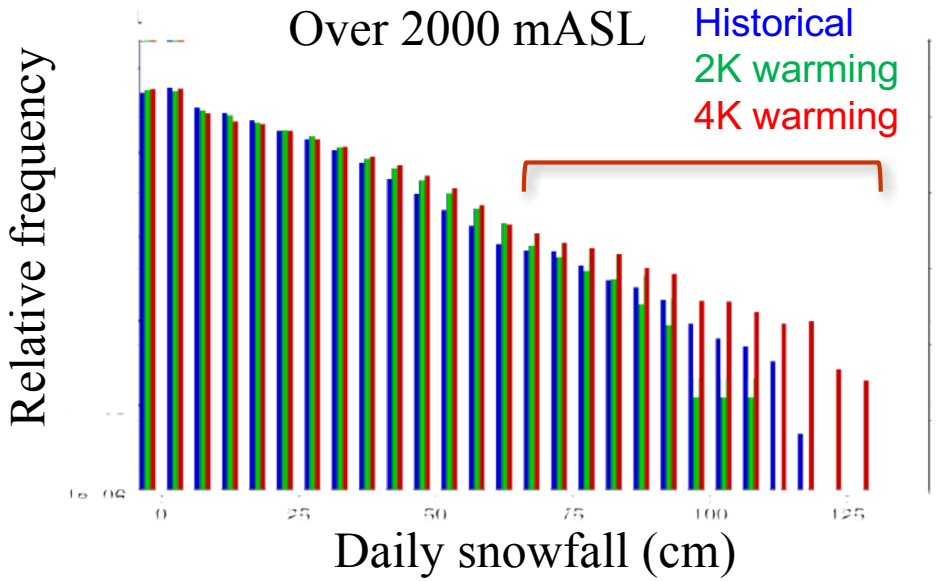
Mountain ranges in the central Japan are called as ***Japan's Alps***, which is named after European Alps.

Japan's Northern Alps has enormous snow cover.



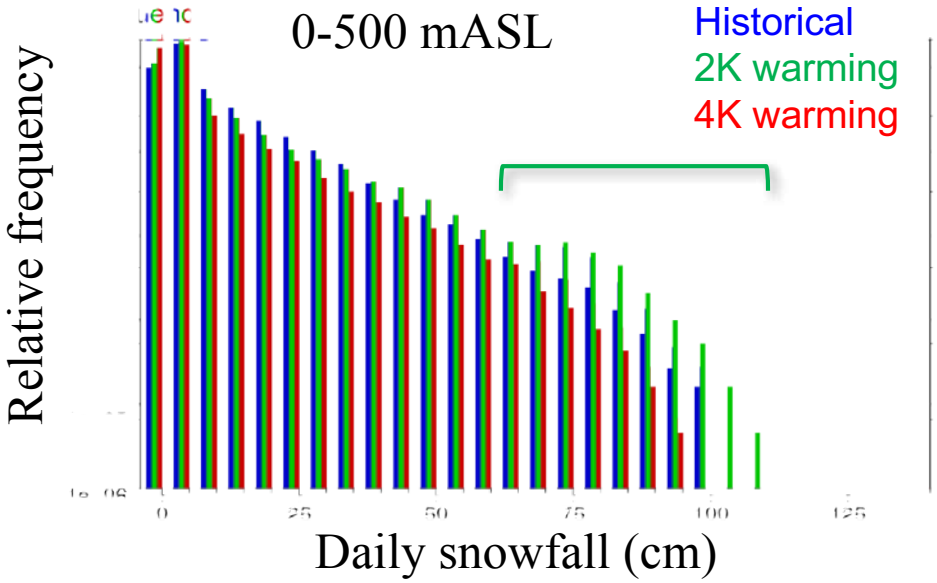
Future changes in daily snowfall intensity

Heavy snow-covered years



High-elevations

- Weak daily snowfall decreases.
- Heavy daily snowfall over about 50 cm/day occurs more frequently under 4K warming.



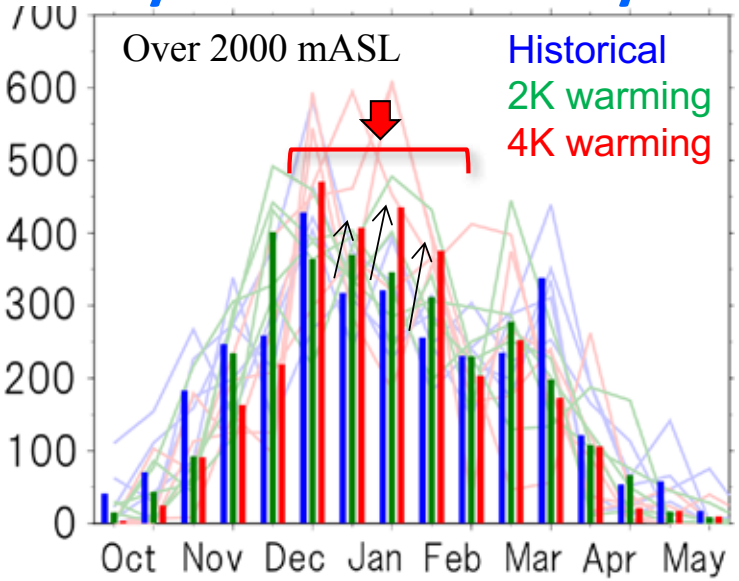
Low-elevations

- Under 4K warming, daily snowfall frequency decreases in all range of snowfall intensity.
- Heavy snowfall over 40 cm/day increases under 2K warming.

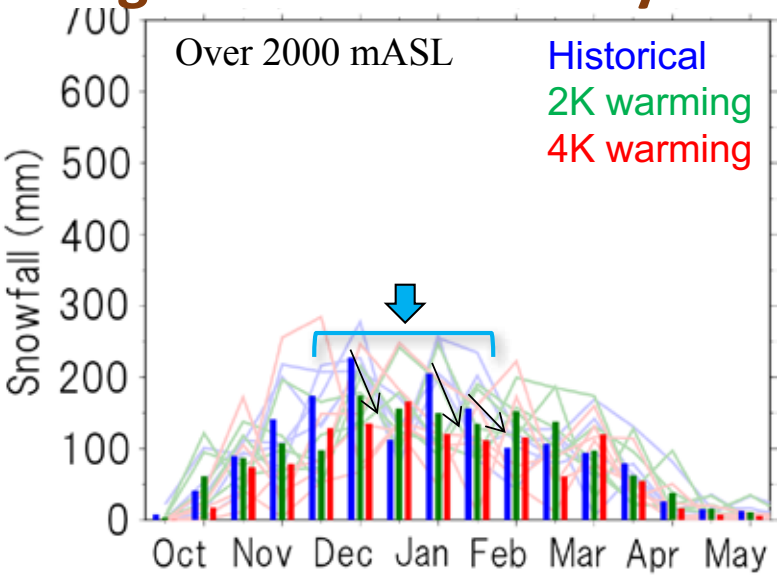
Seasonal variation of half-monthly snowfall and rainfall

Snowfall

Heavy Snow-covered years

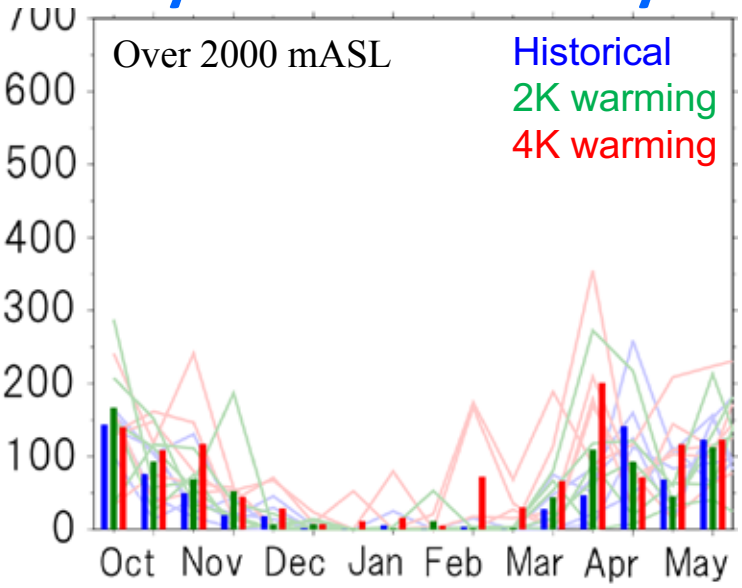


Light Snow-covered years

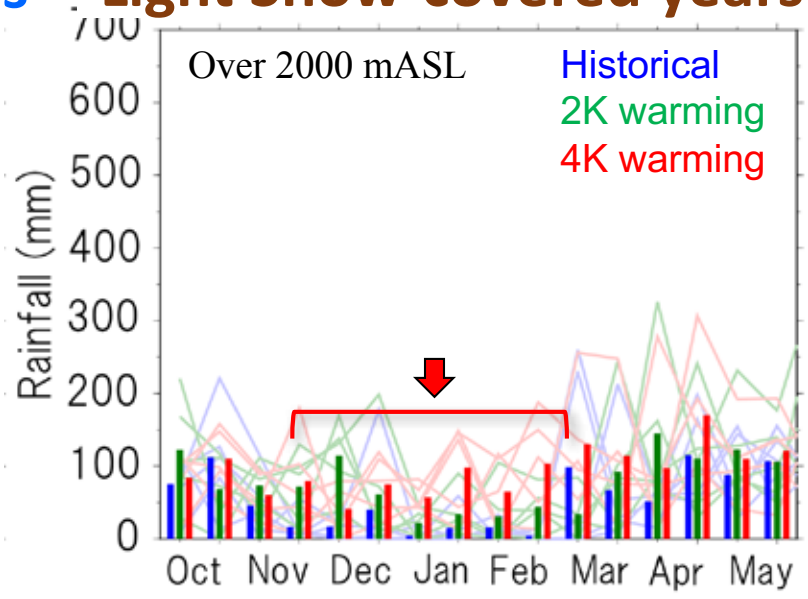


Rainfall

Heavy Snow-covered years



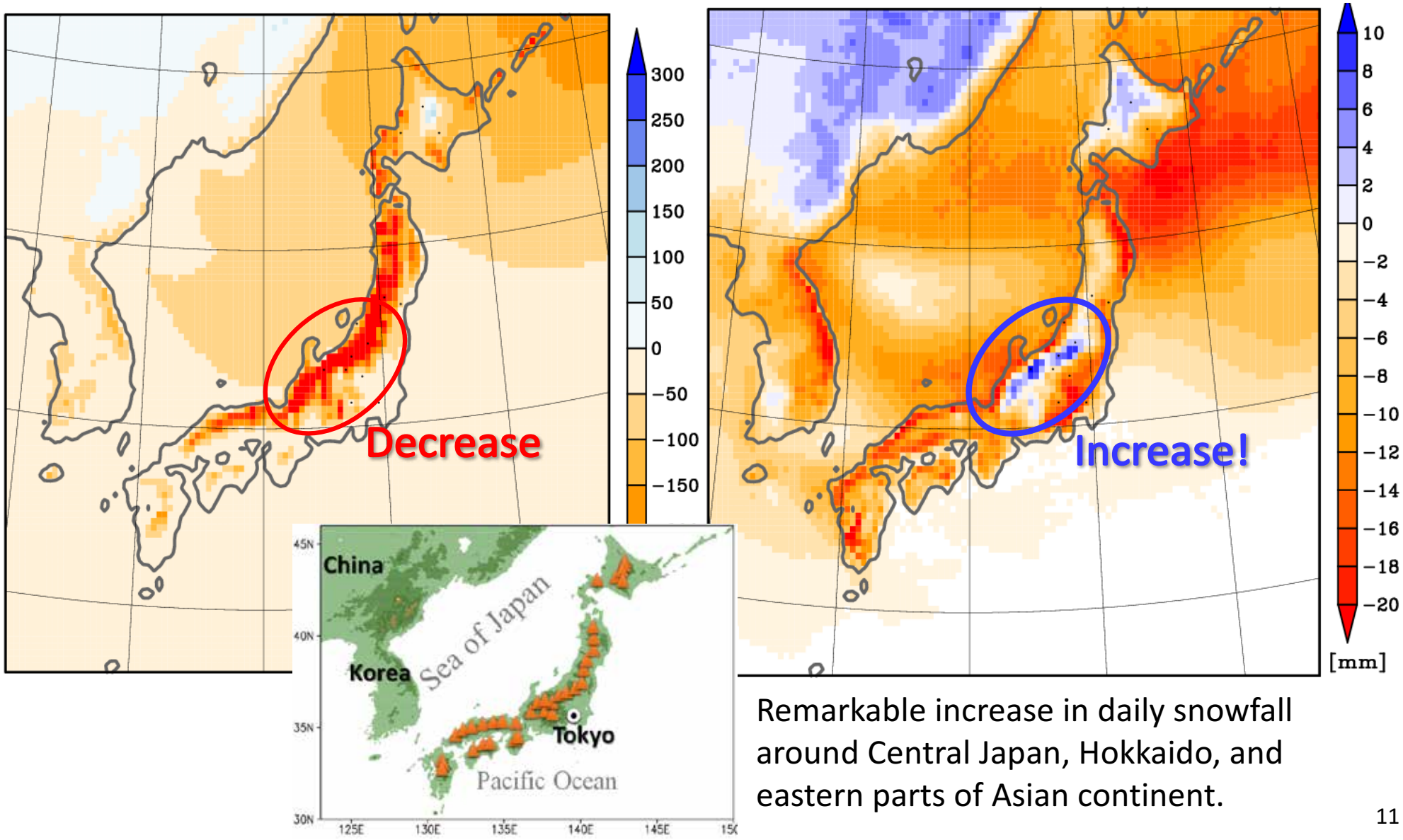
Light Snow-covered years



Future changes in extremely heavy daily snowfall

Total snowfall changes

Heavy daily snowfall changes
(occurring every 10 years)



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

Many mountainous areas in Japan

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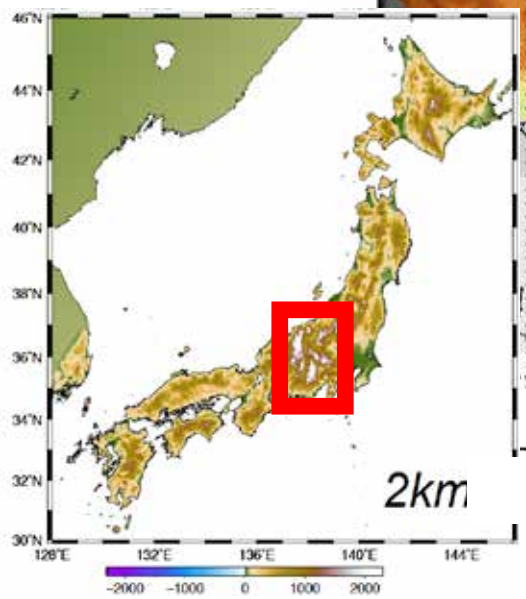
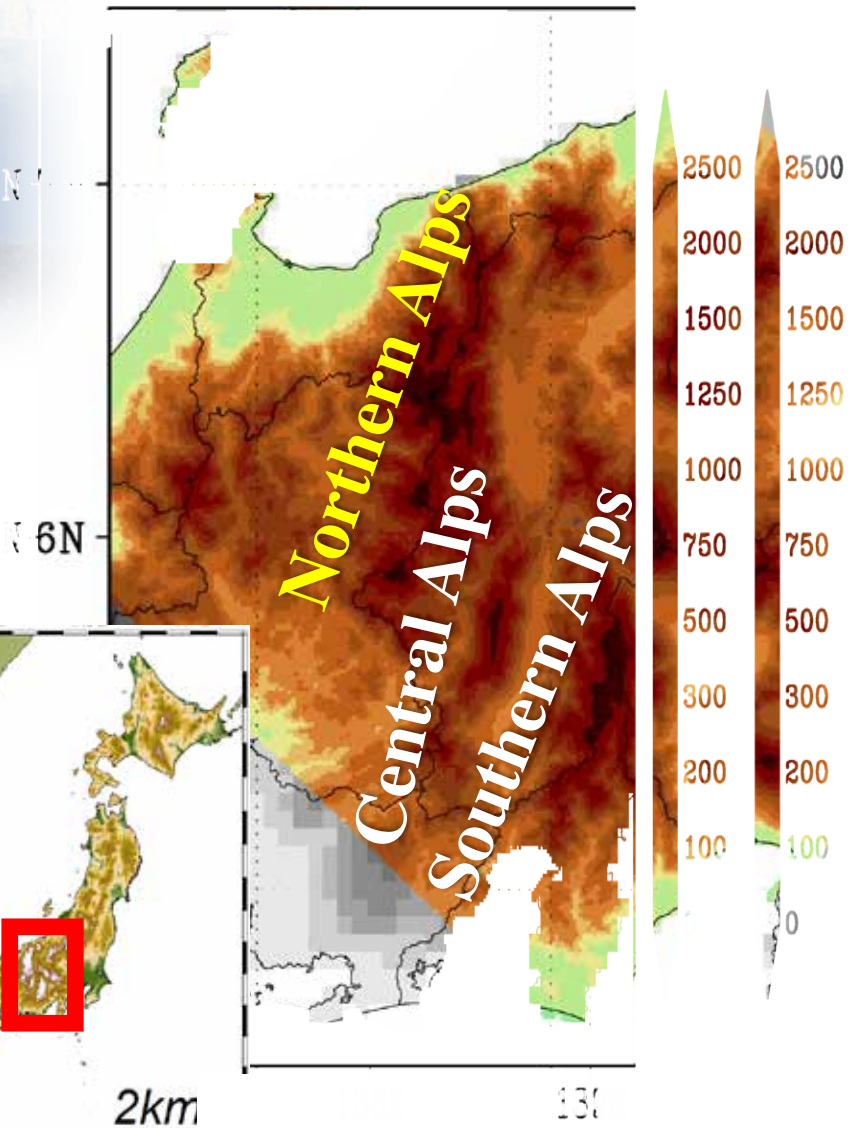
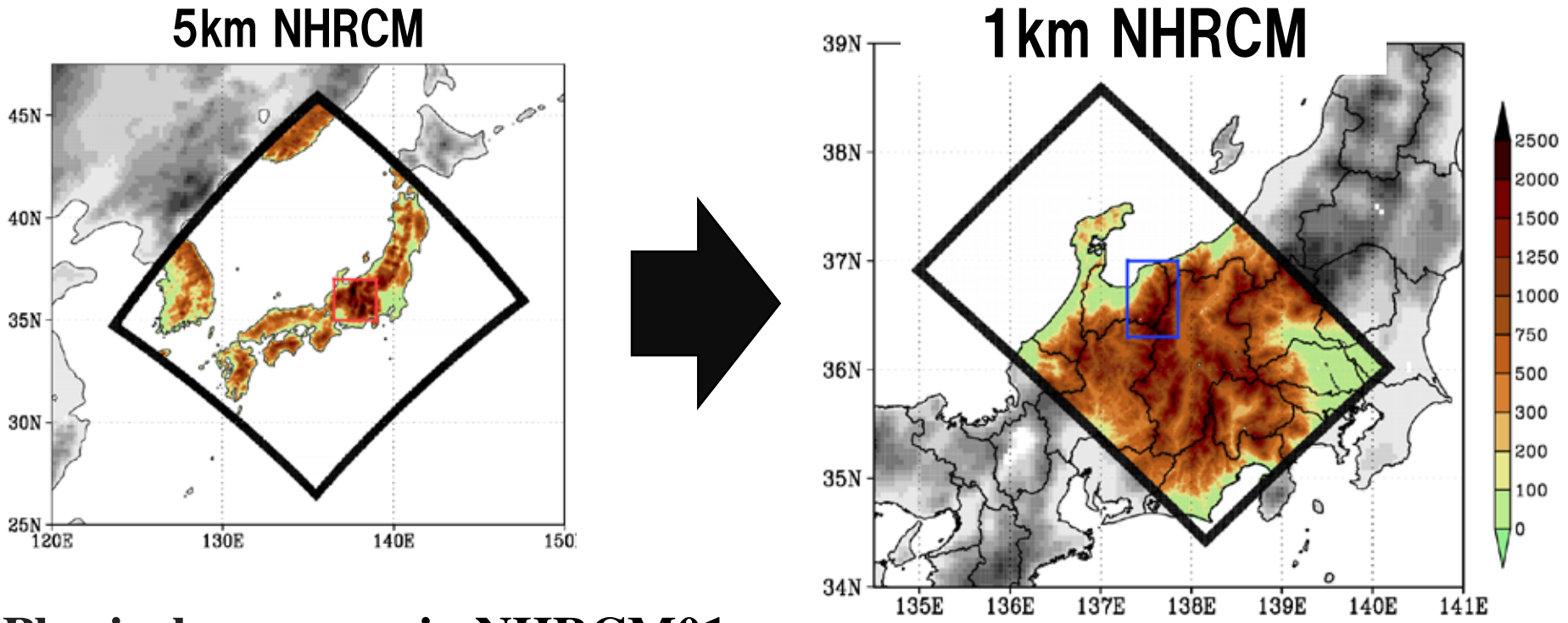
Japan's Northern Alps has enormous snow cover every year.





➔ Mechanism of snowfall in Japan

Specification of NHRCM01

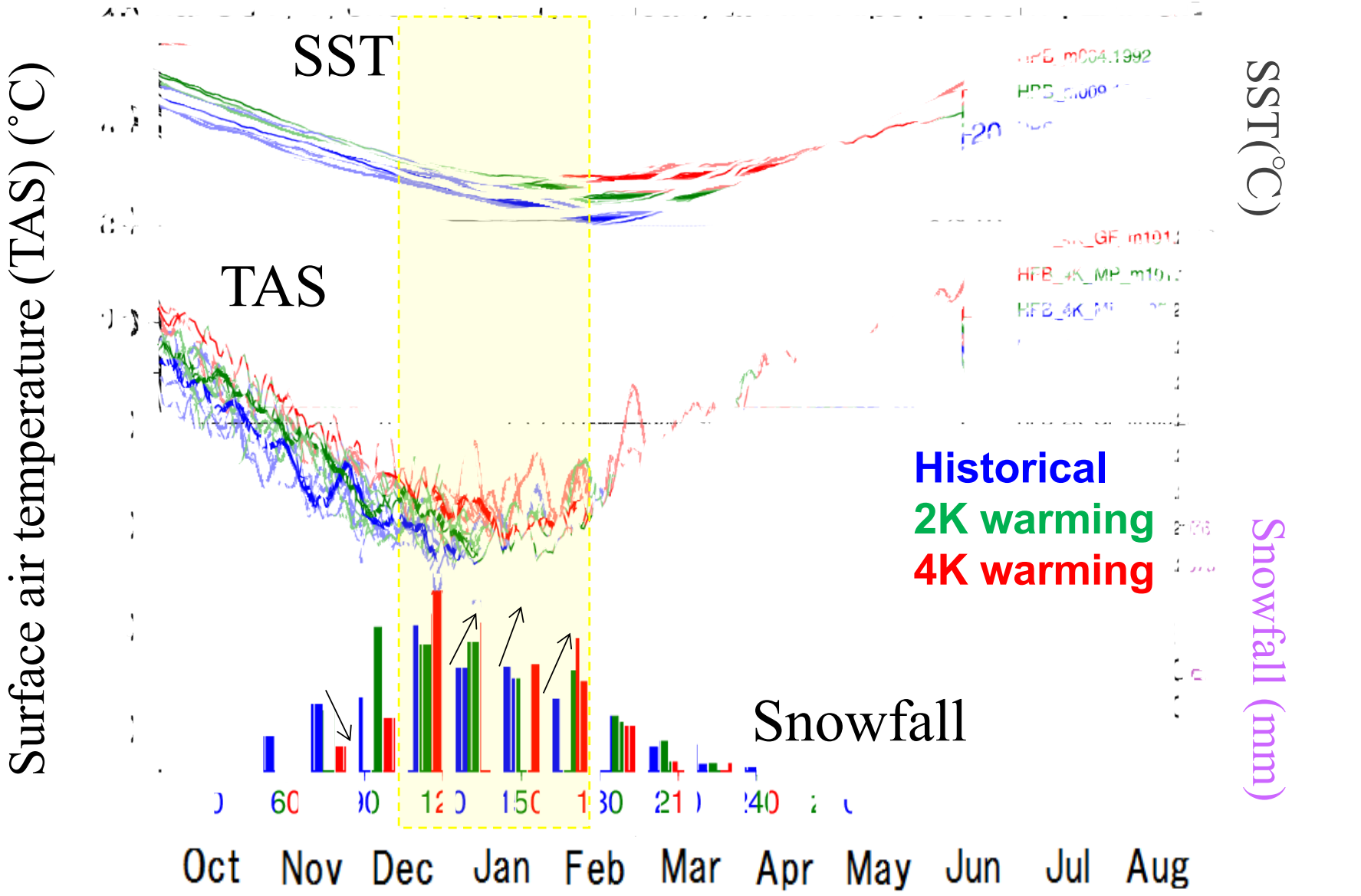


Physical processes in NHRCM01

Microphysics	Bulk-type cloud microphysics (Ikawa et al.1991)
Radiation	Clear-sky radiation scheme (Yabu et al. 2005) Cloud radiation scheme (Kitagawa et al. 2000)
Boundary-layer	Improved Mellor-Yamada-Nakanishi-Niino (MYNN) Level 3 (Nakanishi and Niino 2004)
Land surface	Improved MRI/JMA Simple Biosphere (iSiB) (Hirai and Oh'izumi 2004)
Urban model	Square Prism Urban Canopy Scheme (SPUC) with snow cover process (Aoyagi and Seino 2011; Ito et al. 2018)

Seasonal variation of SST, air temperature, and snowfall

Heavy snow-covered years (high elevation>2000m)

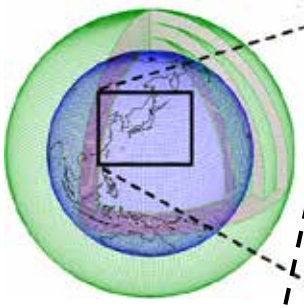


Kawase et al. (2019, in prep.)

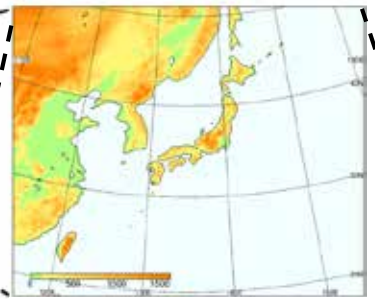
SI-CAT

Social Implementation Program
on Climate Change Adaptation Technology

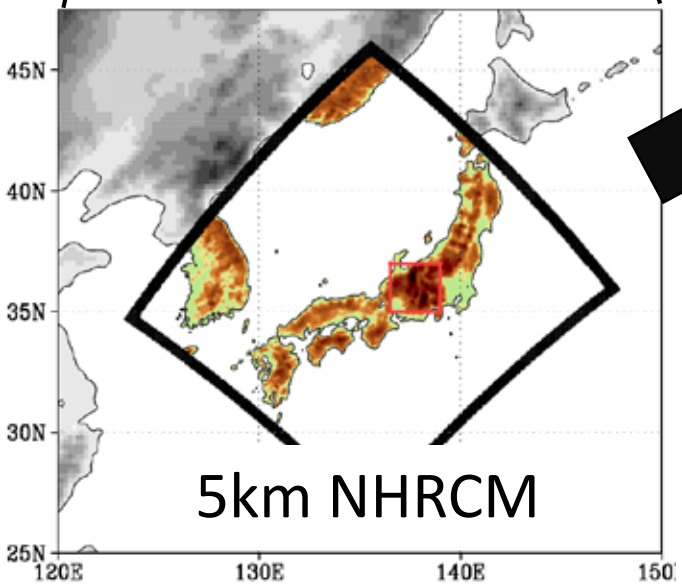
SI-CAT **contributes to the development of adaptation plans by local governments** and the creation of new enterprises, in consideration of the steady adaptation of various needs to climate change.



d4PDF
60km MRI-AGCM



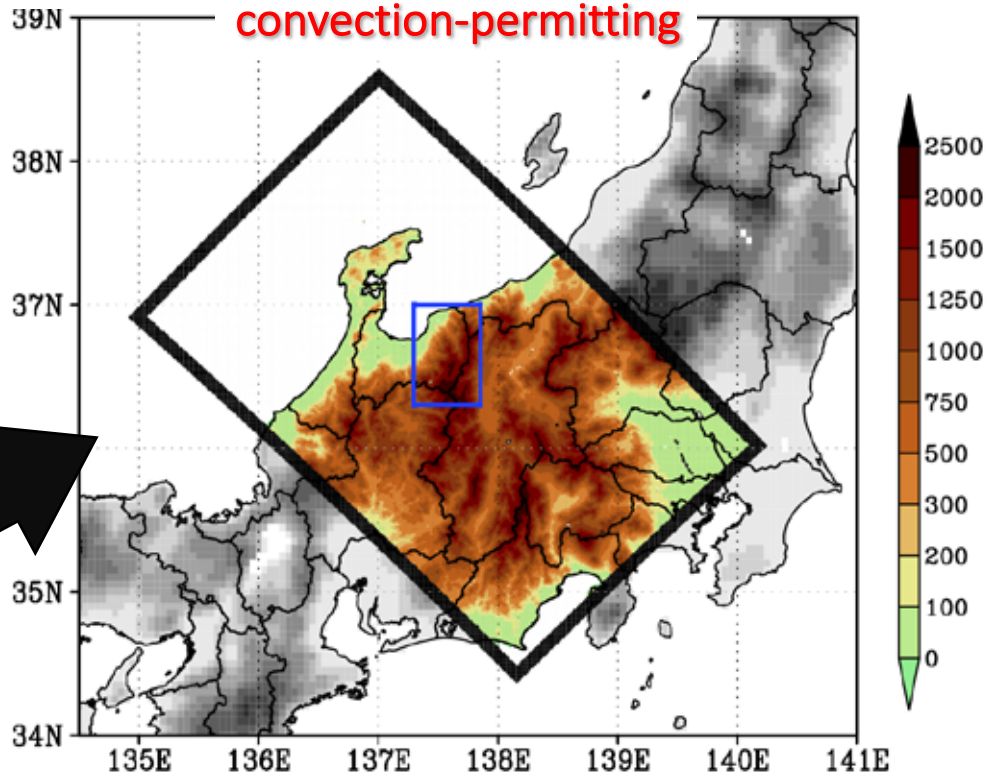
d4PDF
20km NHRCM



5km NHRCM

1km NHRCM

convection-permitting

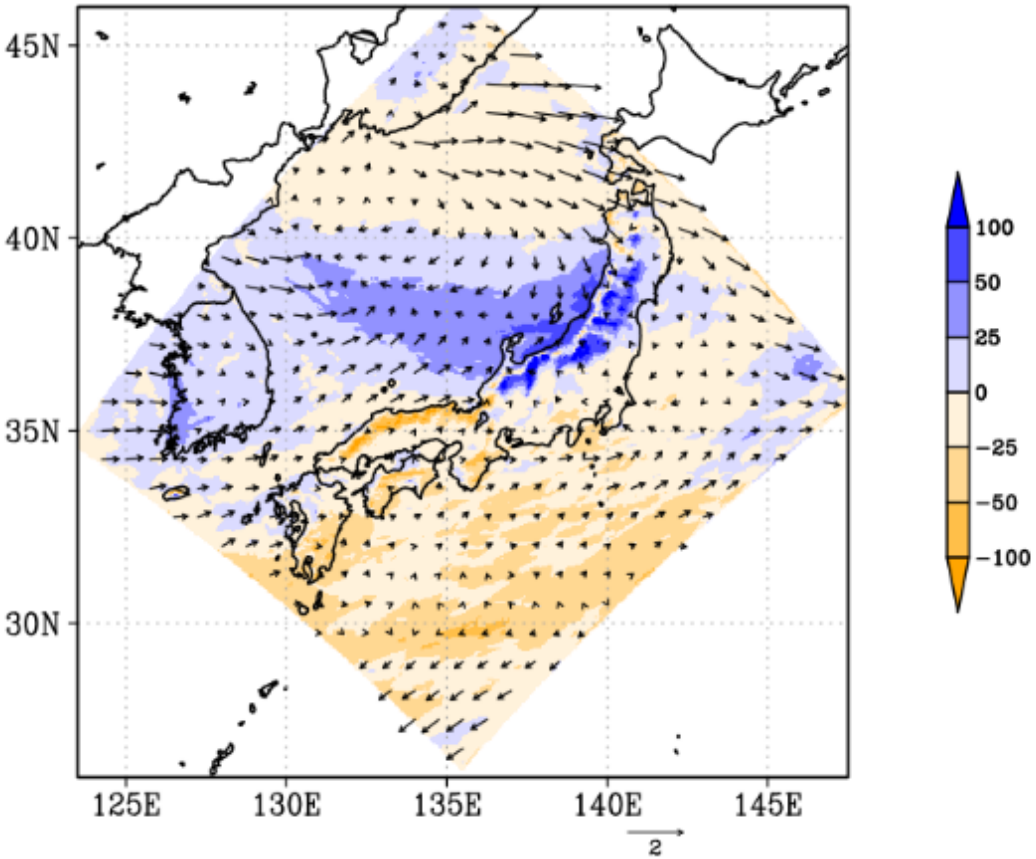


For projections of **future snow cover changes** over high mountainous areas

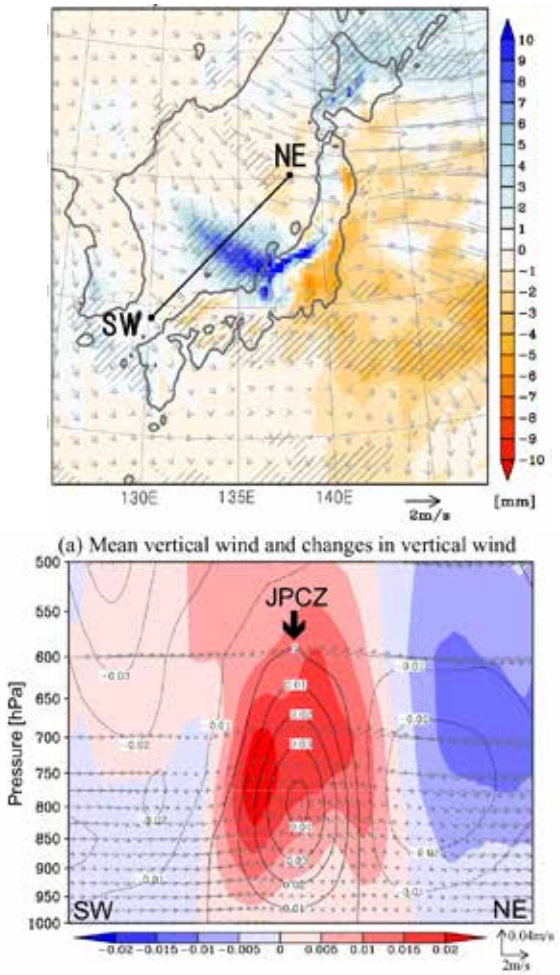
Future changes in synoptic circulation

Heavy snow-covered years (composite)

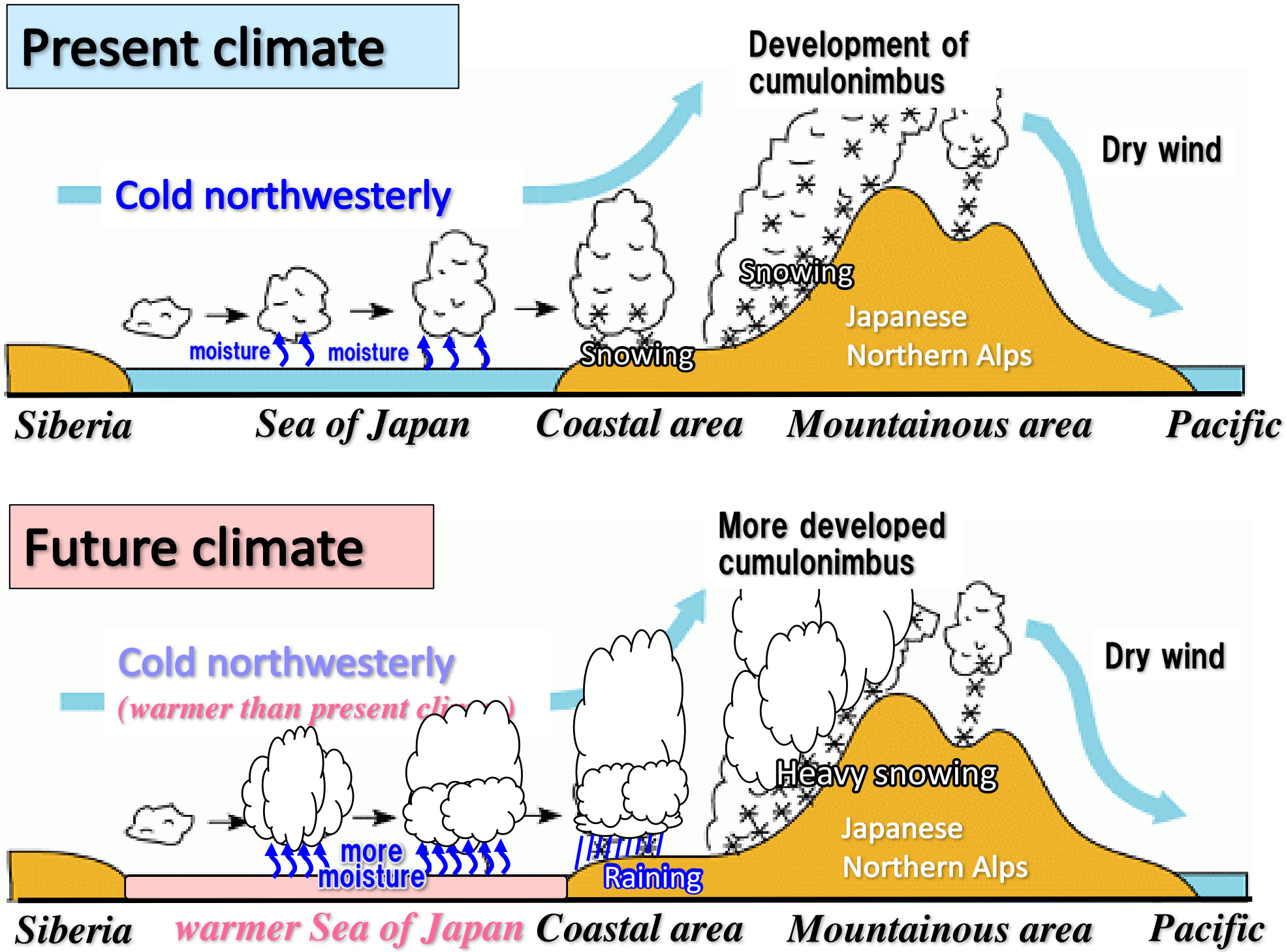
Future Change in DJF surface wind and precipitation under +4K climate



Composite of heaviest 50 daily snowfall events (20km NHRCM)



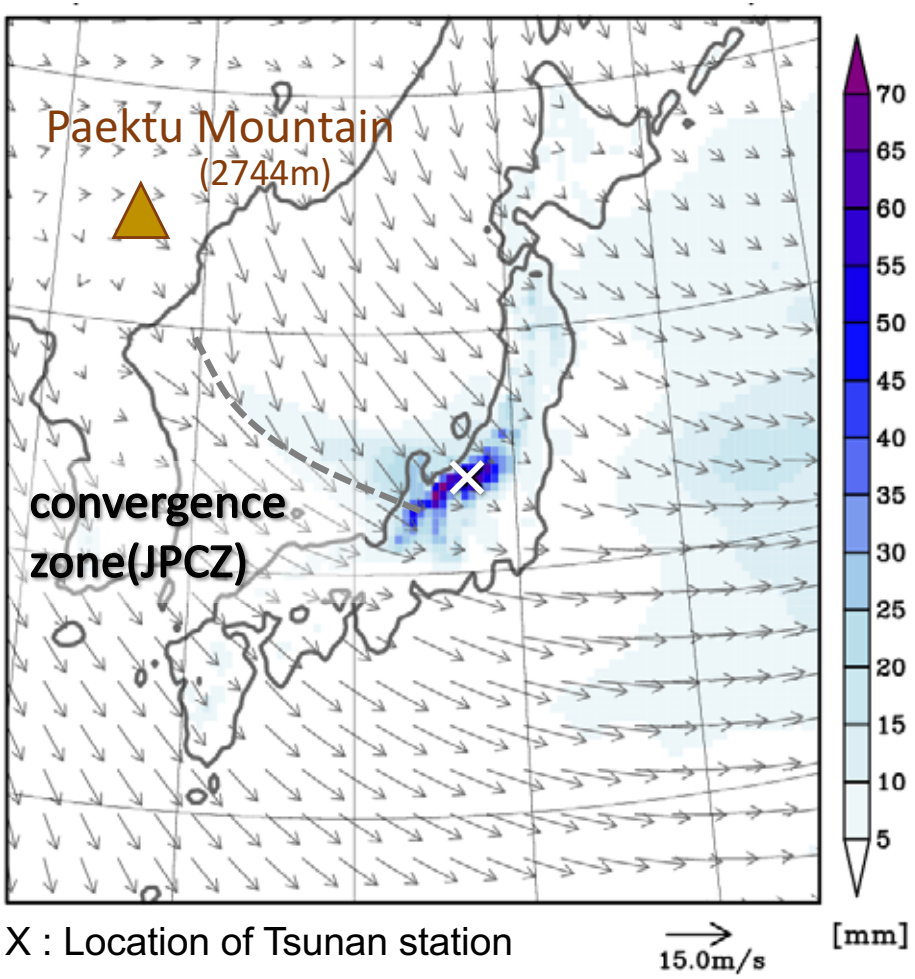
Intensified convergence zone


Present climate
Development of cumulonimbus
Cold northwesterly
Dry wind
Snowing
Japanese Northern Alps
moisture
moisture
Snowing
Siberia
Sea of Japan
Coastal area
Mountainous area
Pacific
Future climate
More developed cumulonimbus
Cold northwesterly
(warmer than present cli
Dry wind
Heavy snowing
Japanese Northern Alps
more moisture
Raining
Siberia
warmer Sea of Japan
Coastal area
Mountainous area
Pacific

Why increase? Composites of top 50 heavy snowfall events

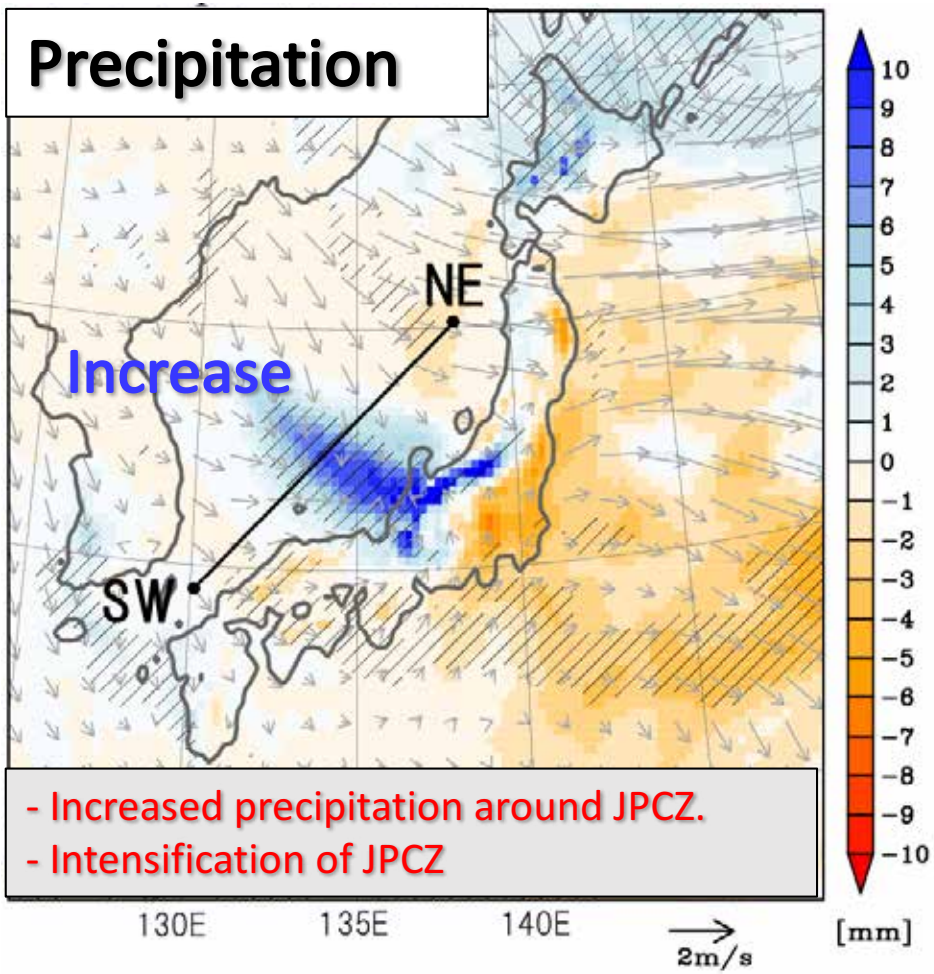
Precipitation(snowfall+rainfall) and surface wind

Historical experiments



X : Location of Tsunan station

Future exp. – Historical exp.

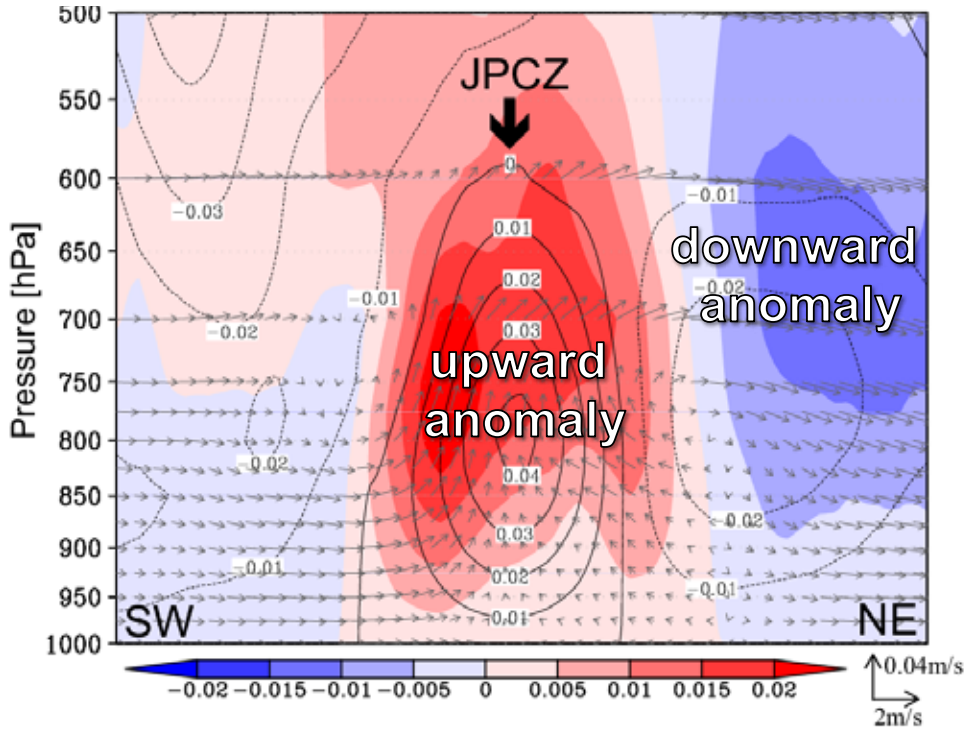


JPCZ: Japan sea Polar air mass Convergence Zone

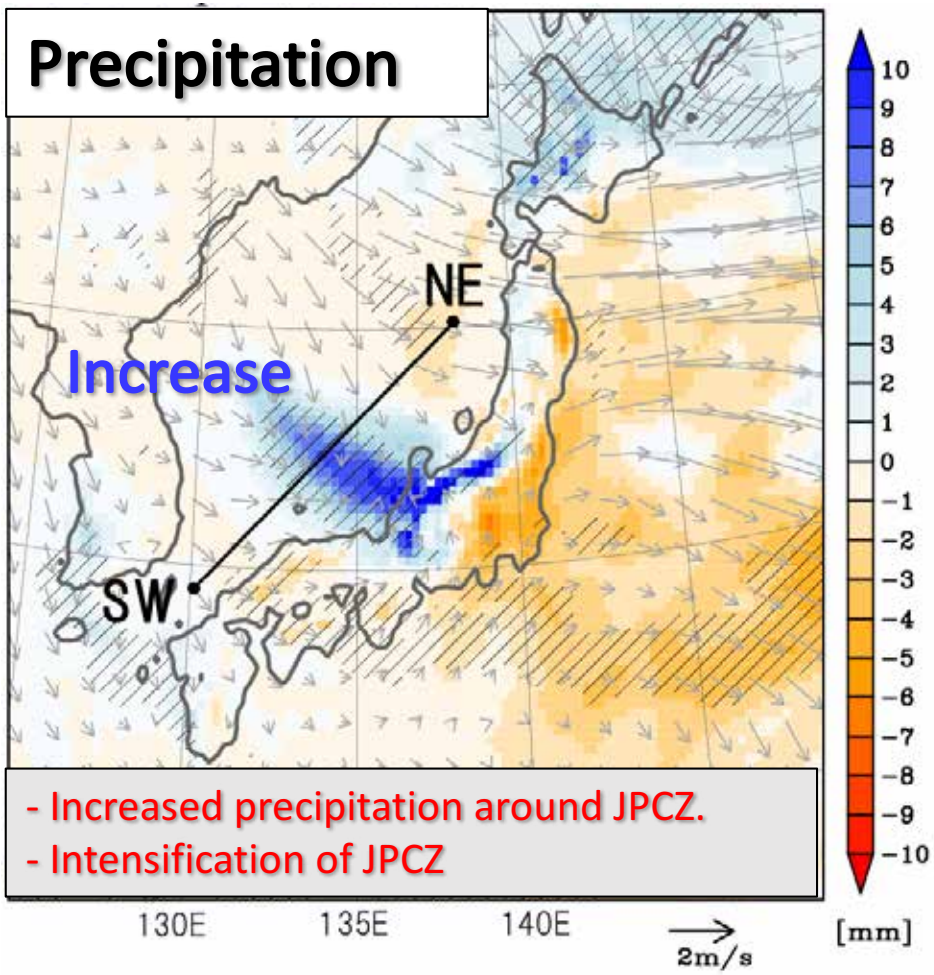
Why increase? Composites of top 50 heavy snowfall events

Precipitation(snowfall+rainfall) and surface wind

Mean vertical wind and differences Future exp. – Historical exp.



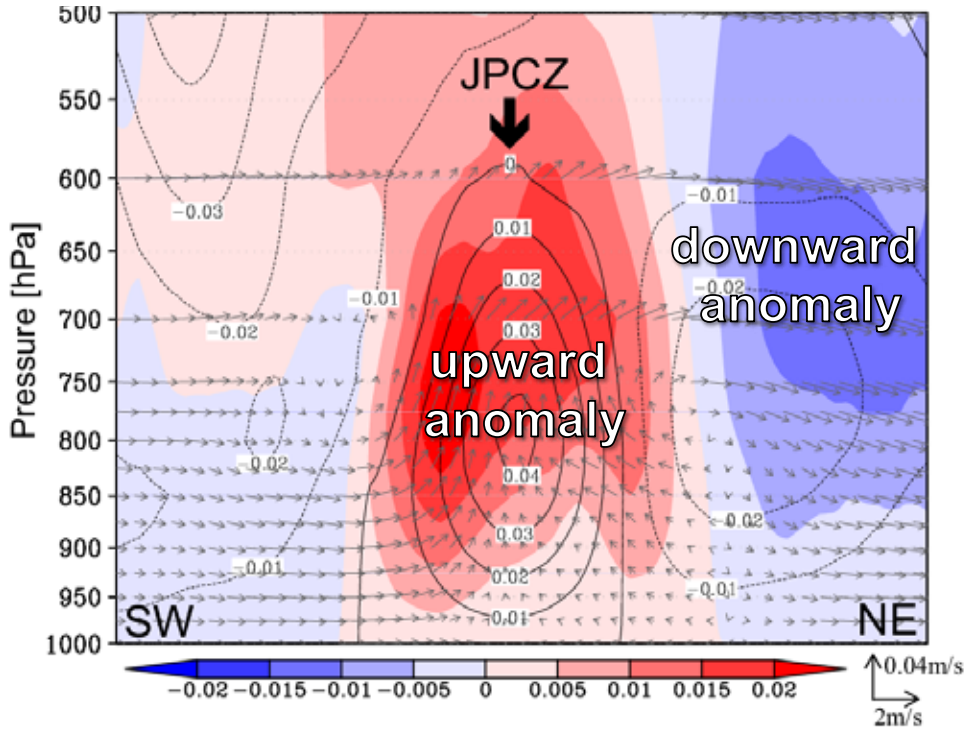
Enhancement of JPCZ
(convergence)



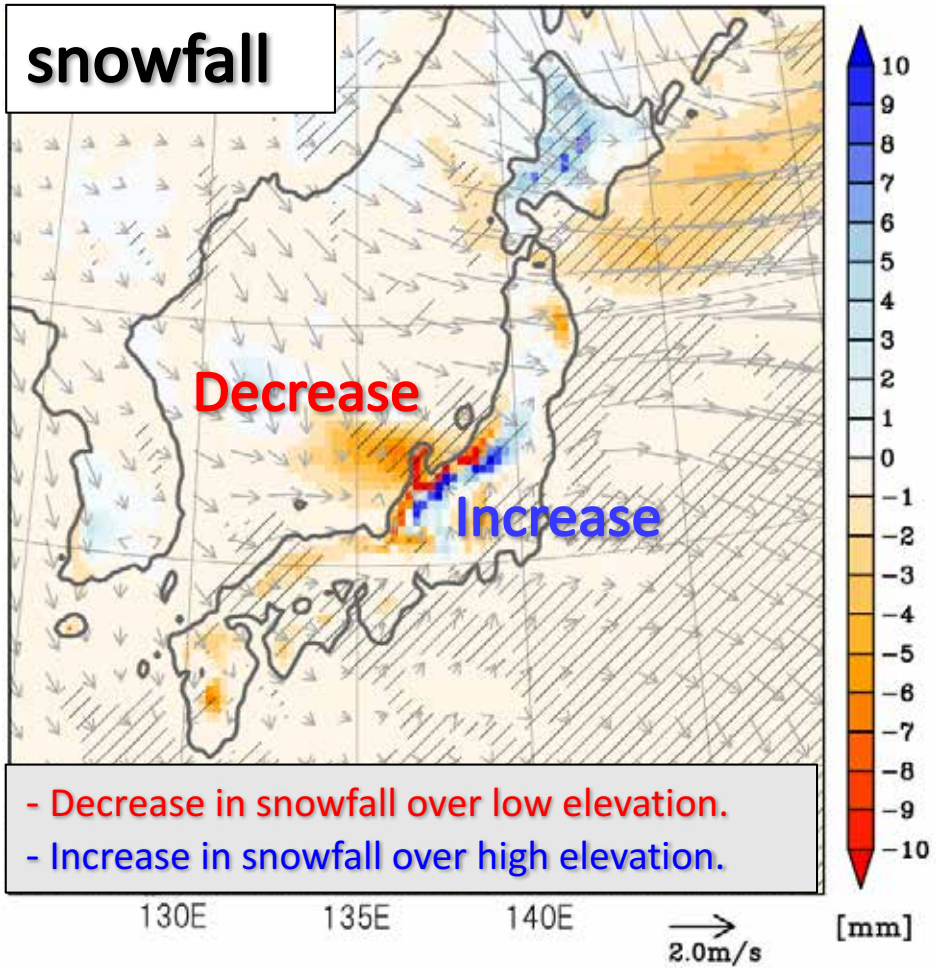
Why increase? Composites of top 50 heavy snowfall events

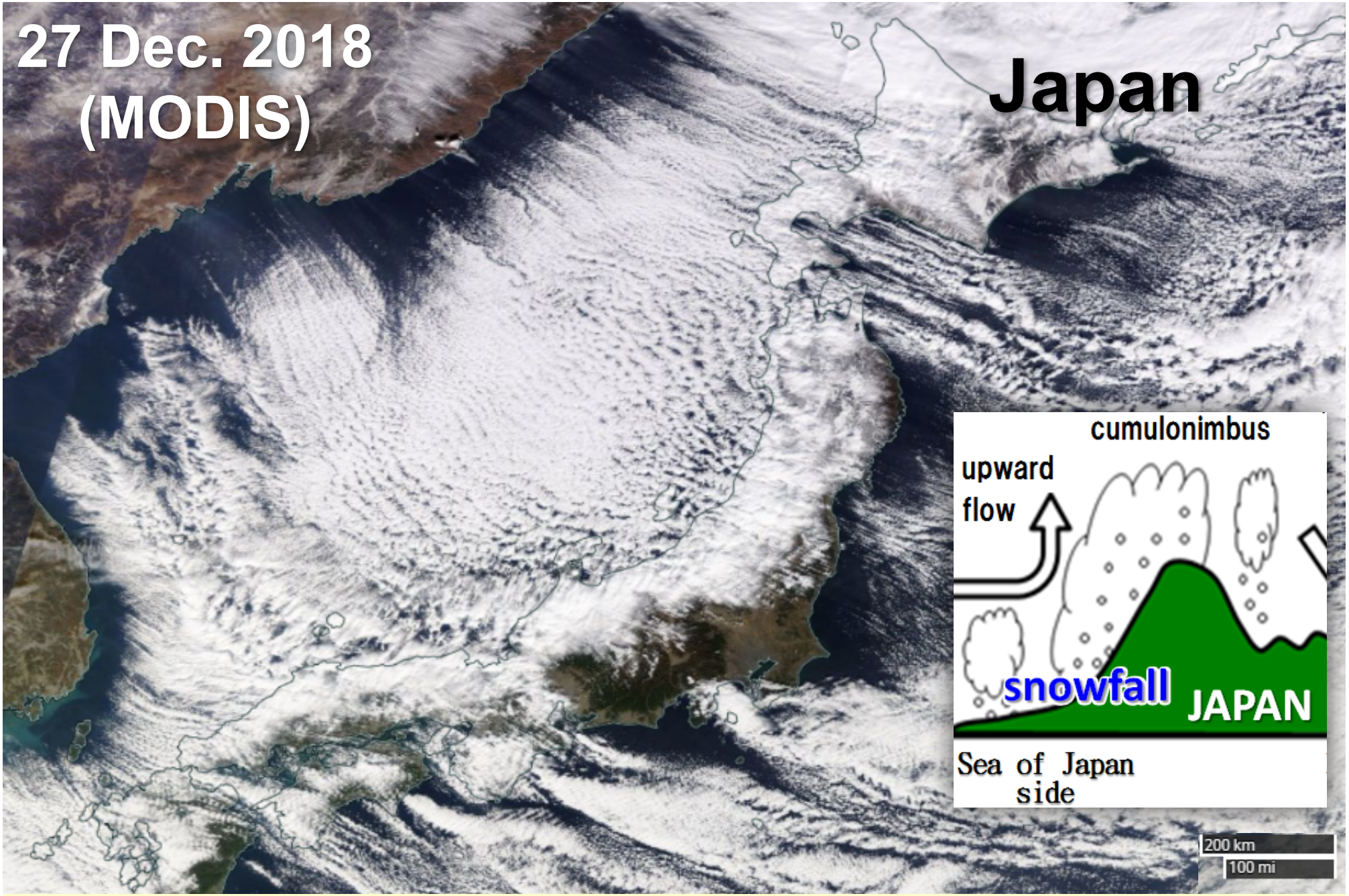
Precipitation(snowfall+rainfall) and surface wind

Mean vertical wind and differences Future exp. – Historical exp.



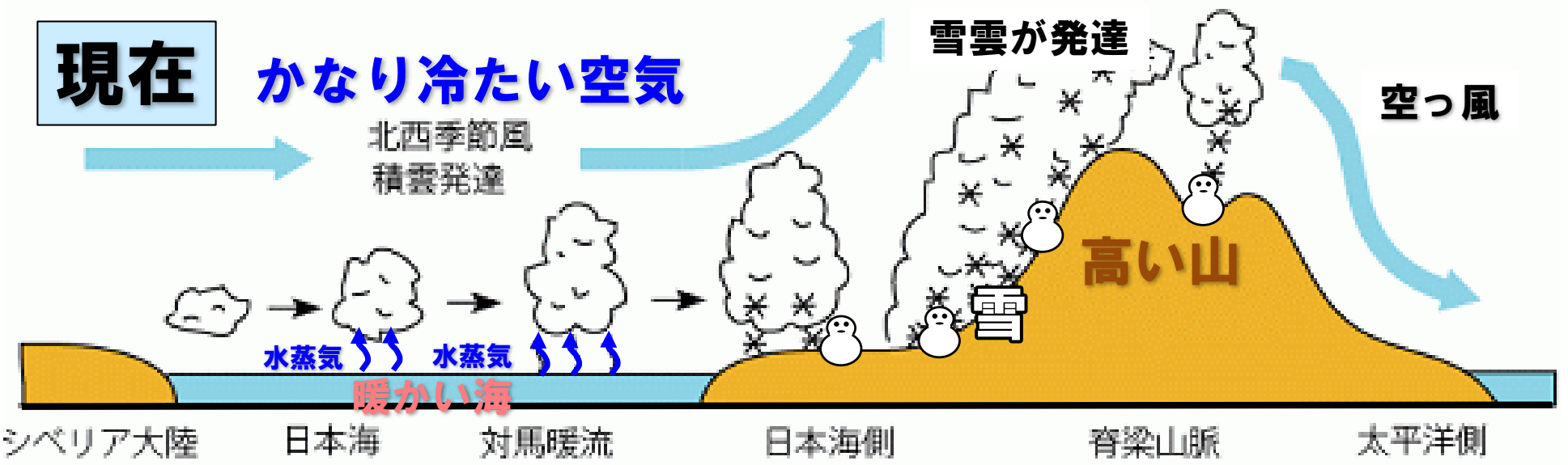
Enhancement of JPCZ
(convergence)



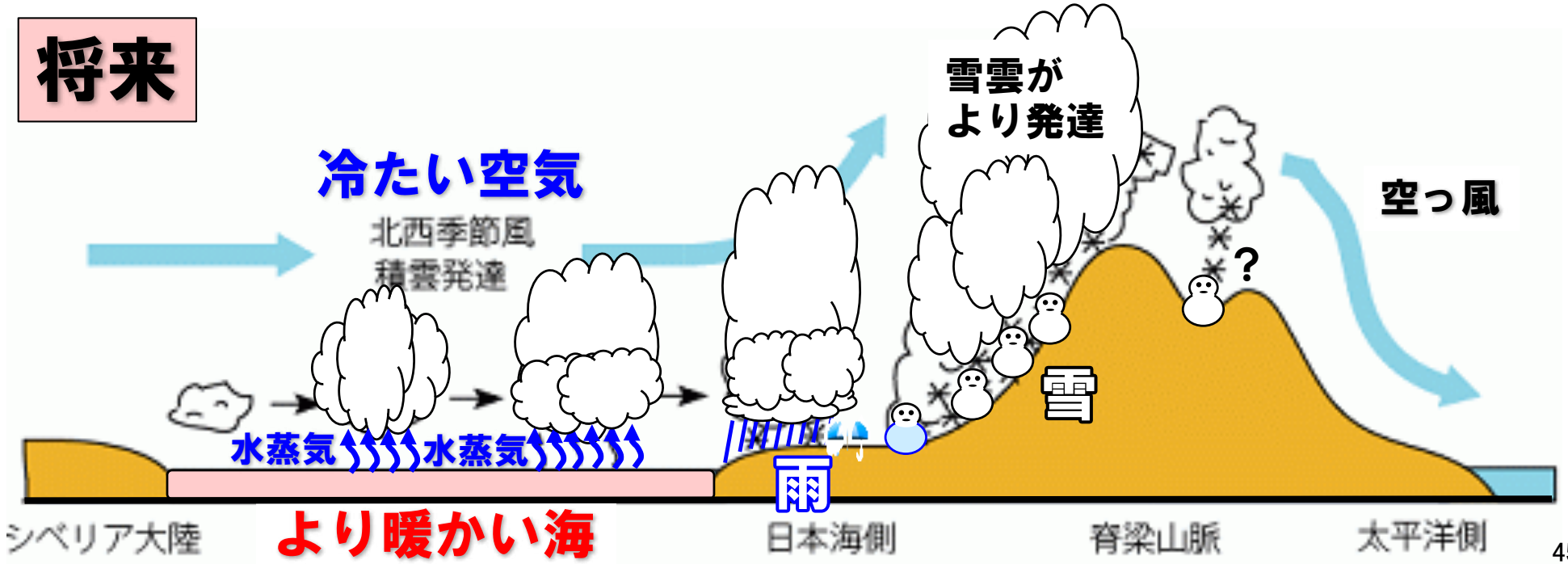


- Similar to the **lake effect in snowfall of the Great Lakes**

日本海側の山沿いで大雪が増える理由

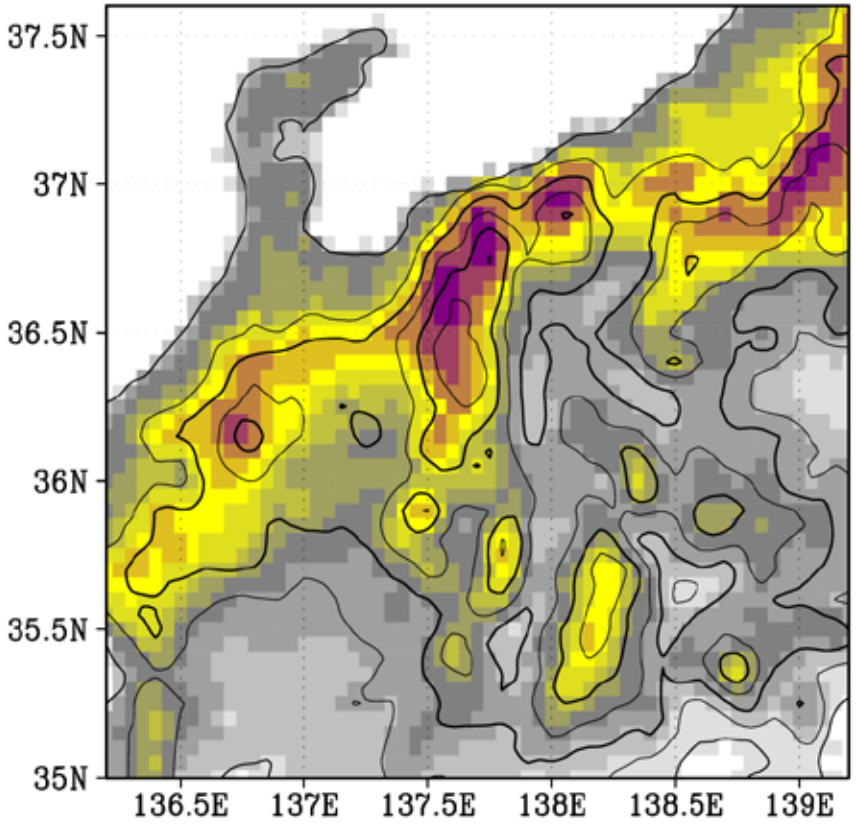


松江地方気象台より引用、一部改変

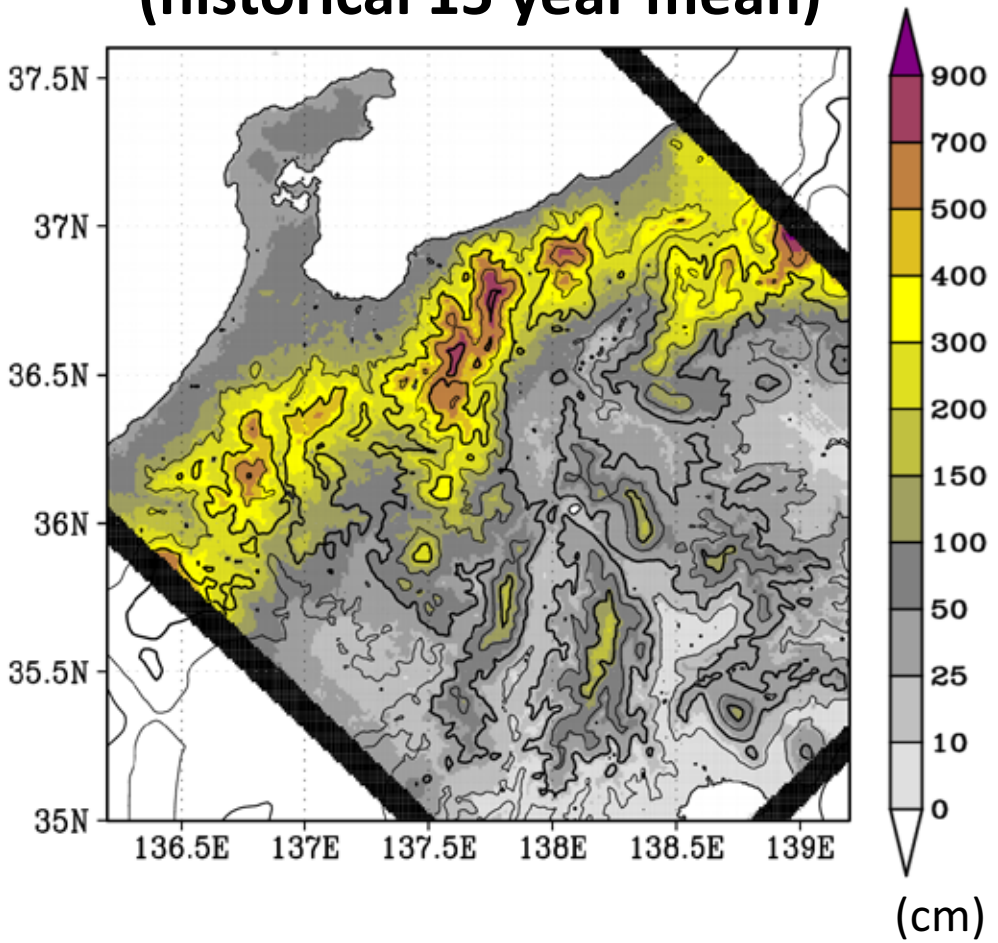


15-year-mean annual maximum snow depth

5km NHRCM
(historical 15 year mean)



1km NHRCM
(historical 15 year mean)

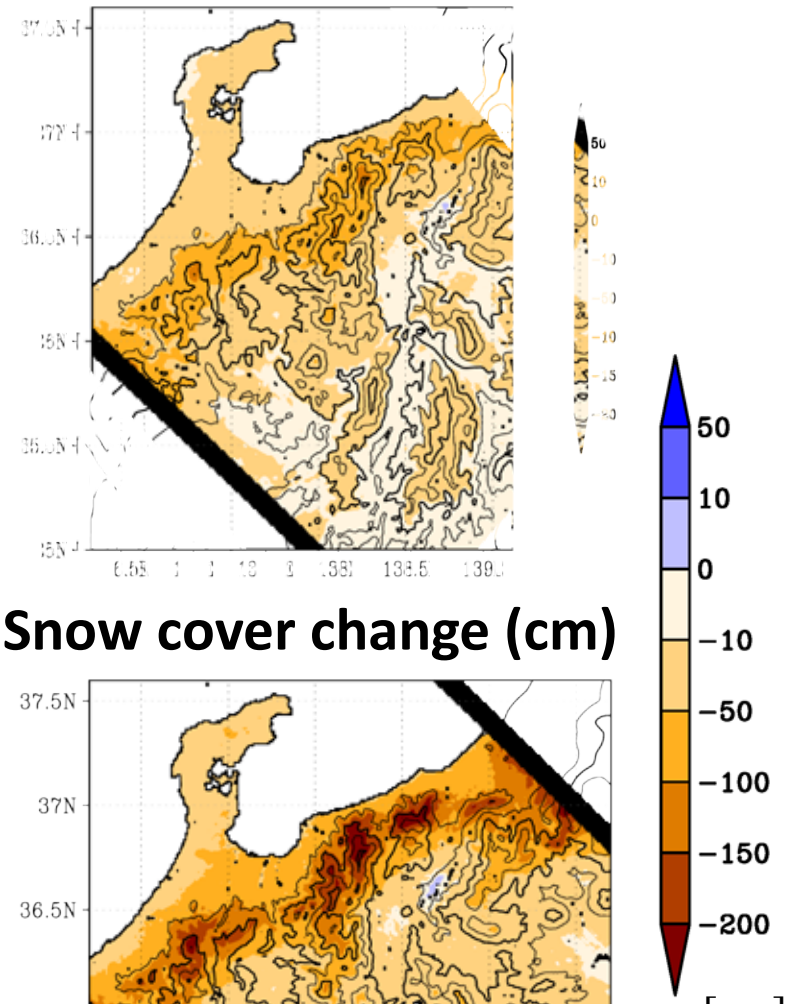


Future changes in 15-year-mean maximum snow depth

2K warming climate

4K warming climate

Snow cover change (cm)



Snow cover change (%)