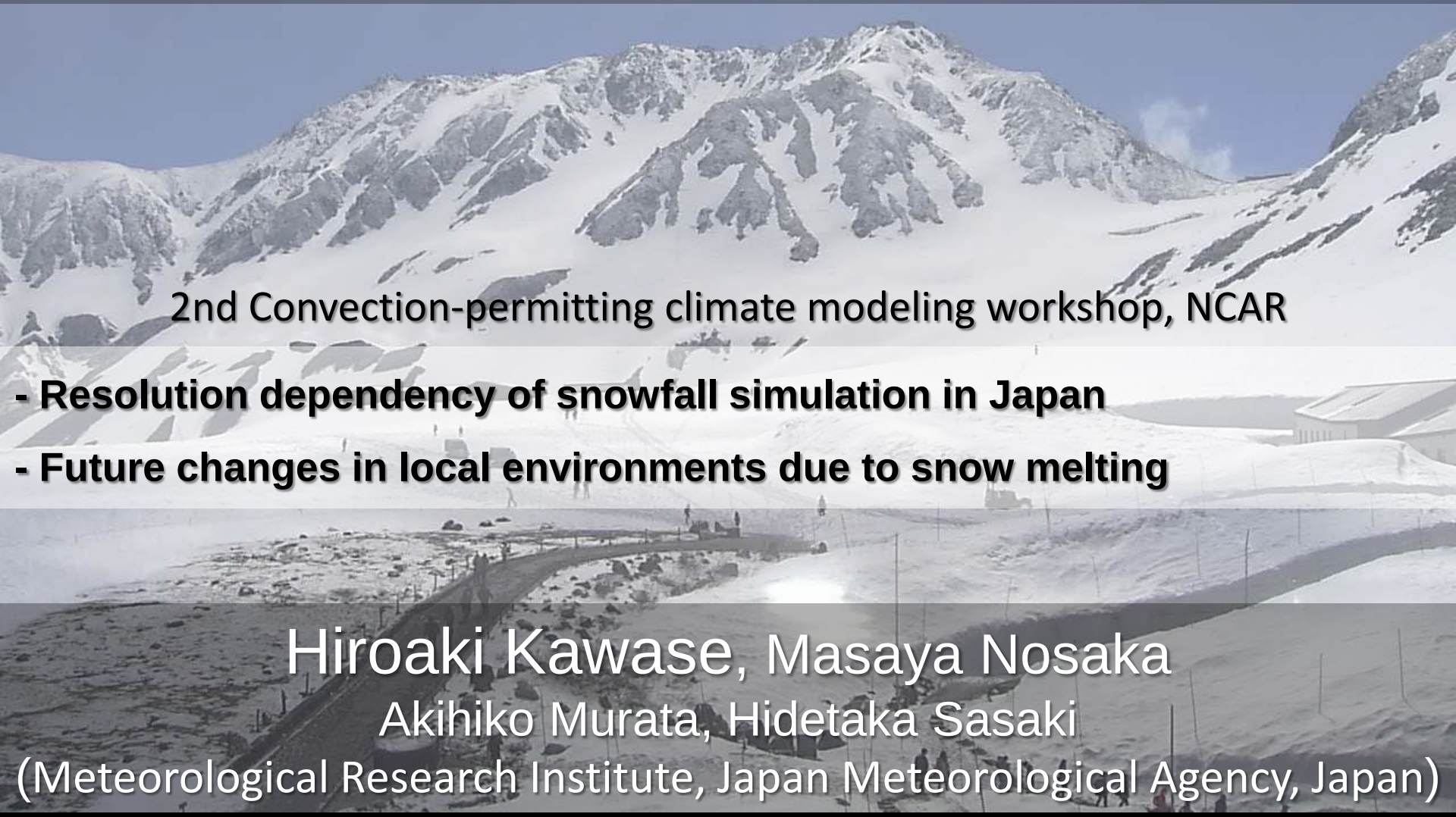
Importance of convection-permitting climate model on projecting future climate changes in winter and early spring.



2nd Convection-permitting climate modeling workshop, NCAR

- Resolution dependency of snowfall simulation in Japan

- Future changes in local environments due to snow melting

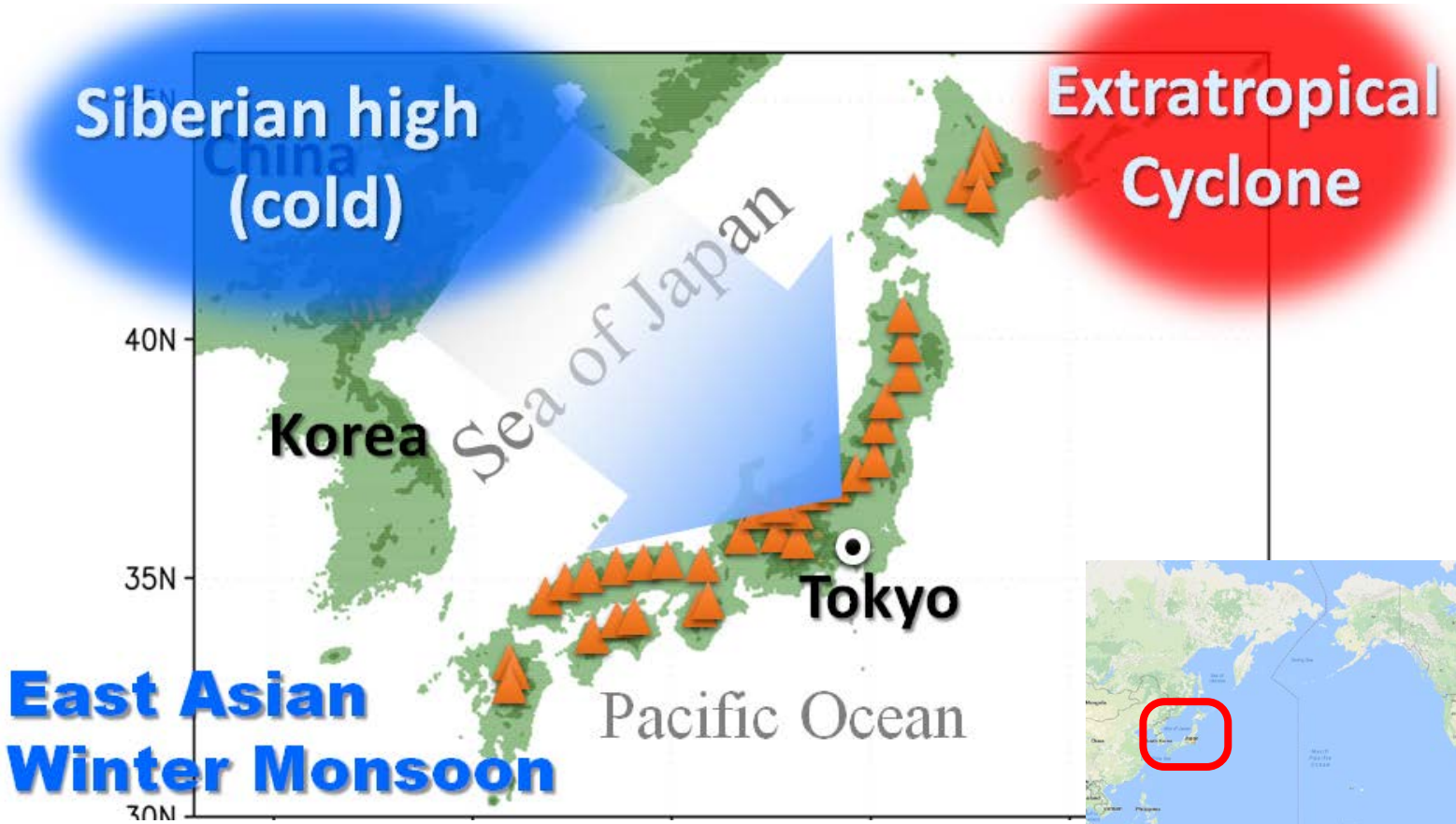
Hiroaki Kawase, Masaya Nosaka
Akihiko Murata, Hidetaka Sasaki
(Meteorological Research Institute, Japan Meteorological Agency, Japan)

Kawase et al. 2018, SOLA; Nosaka et al. 2018, GRL, submitted

Introduction

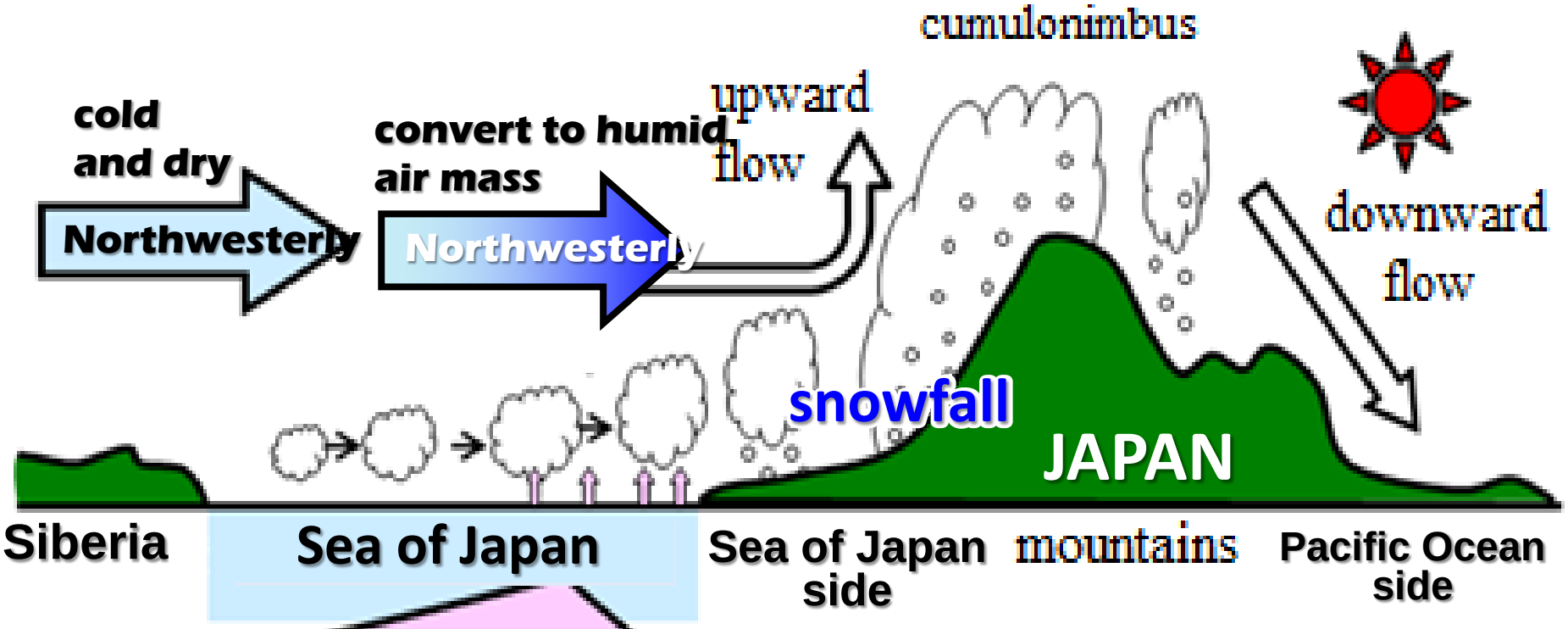
➢ Japan have a lot of snowfall in winter, especially mountainous areas in the Sea of Japan side.

Synoptic condition during heavy snowfall in Sea of Japan side



Introduction

➢ Japan have a lot of snowfall in winter, especially mountainous areas in the Sea of Japan side.



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

Snow in Japan

Yuzawa town (340mASL), Niigata prefecture, Feb, 2006

Introduction

- Japan Meteorological Agency (JMA) has many observational stations, called AMeDAS, which mainly observe temperature, precipitation, and wind. Some stations observe snow depth, but there is few snow observations in the mountainous areas.

- In the future climate projection, previous studies showed that total snowfall and maximum snow depth will dramatically decrease in most parts of Japan due to global warming.

  [*Inoue and Yokoyama, 2003; Hara et al.*, 2008; *Kawase et al.*, 2013, 2015; JMA, 2017]

- It is not clear whether regional climate models can well simulate/project the snowfall including the mountainous area in Japan. Snow cover largely changes surface conditions, such as surface roughness and energy balance.

Purpose

Our objectives are

1. To investigate the resolution dependency of snowfall simulation in Japan, mainly Sea of Japan side
2. To project future changes in local environmental field associated with snow disappearance in early spring

Experimental design 1

Model: Nonhydrostatic Regional Climate Model (NHRCM)
[Sasaki et al., 2008]

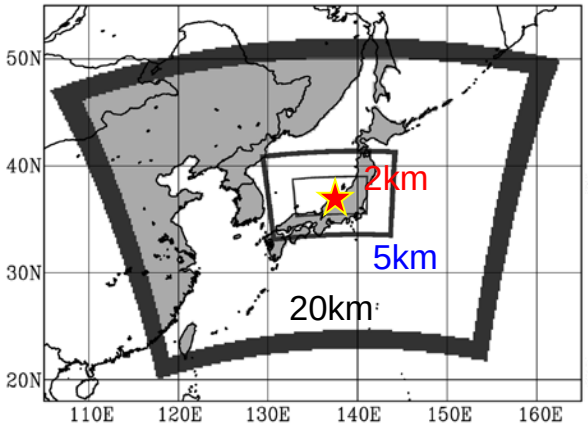
Boundary: The Japanese 55-year Reanalysis (JRA55)
[Kobayashi et al., 2015]

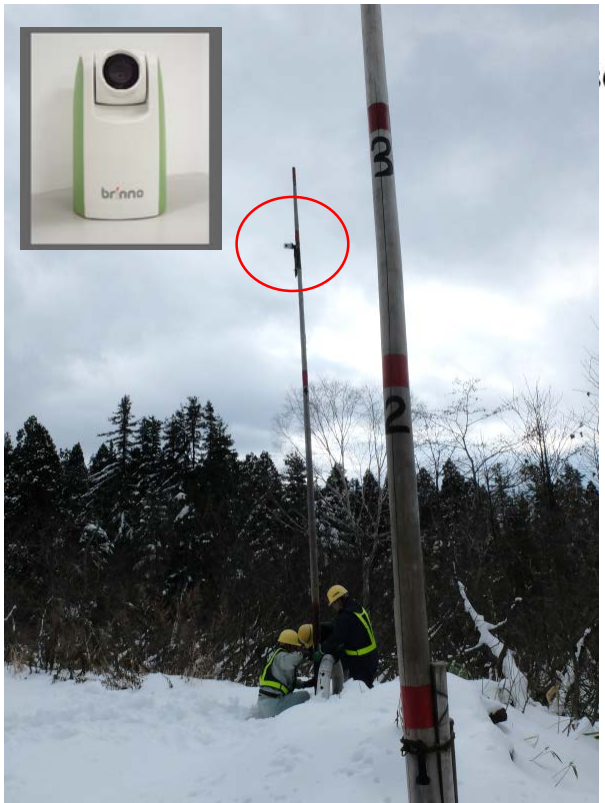
Grid-spacing: 20km -> **5km(NHRCM05)** -> **2km(NHRCM02)**
Nesting: One-way
Vertical coordinate: Terrain-following, 60 levels.

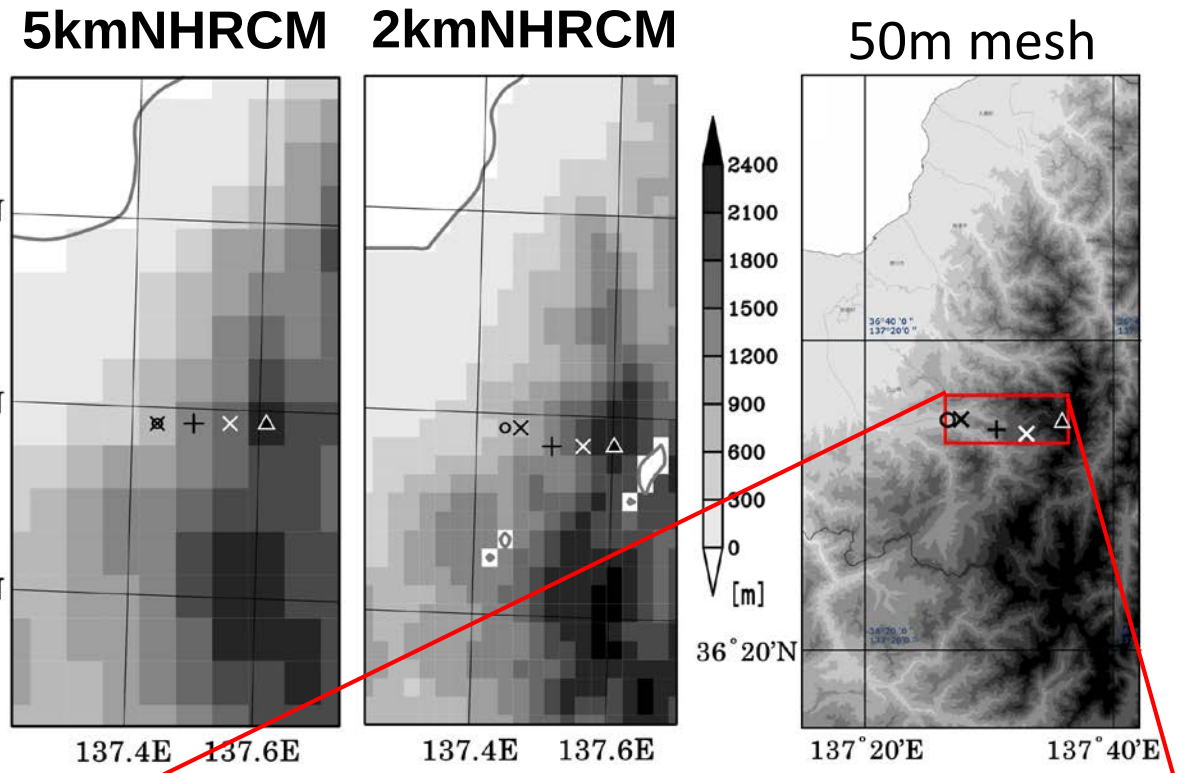
Target: 2000/01 – 2016/17
Integration: Sep. 1 – following Aug. 31

[Physics]
Cumulus convection: K-F scheme for 20km/5km [Kain and Fritsch, 1993]
Cloud microphysics: Ikawa et al. (1991) for 20km/5km/2km
Boundary condition: MYNN [Nakanishi and Nino, 2004]
Land surface: Improved MJ-SiB [Hirai and Oh'izumi, 2004]

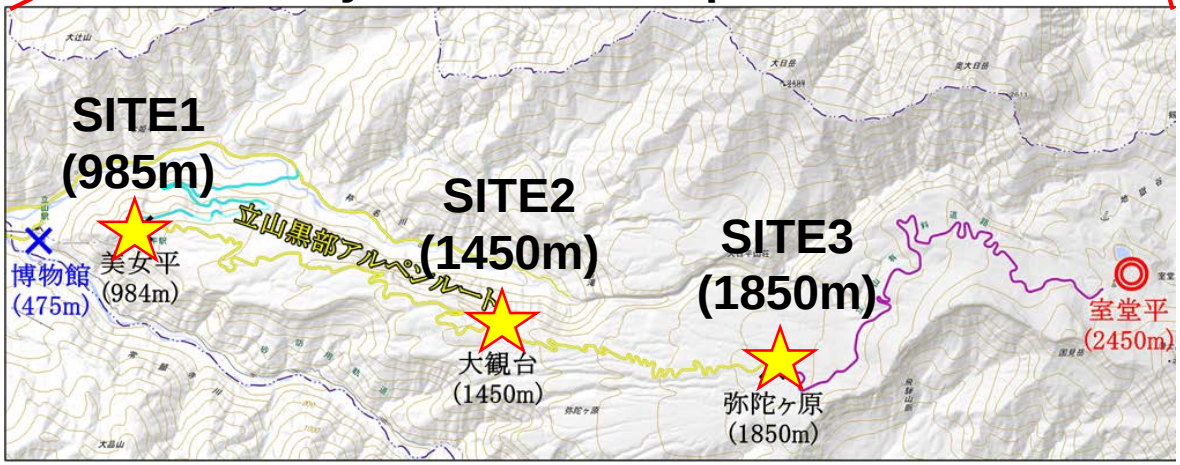
Comparison with snow observation





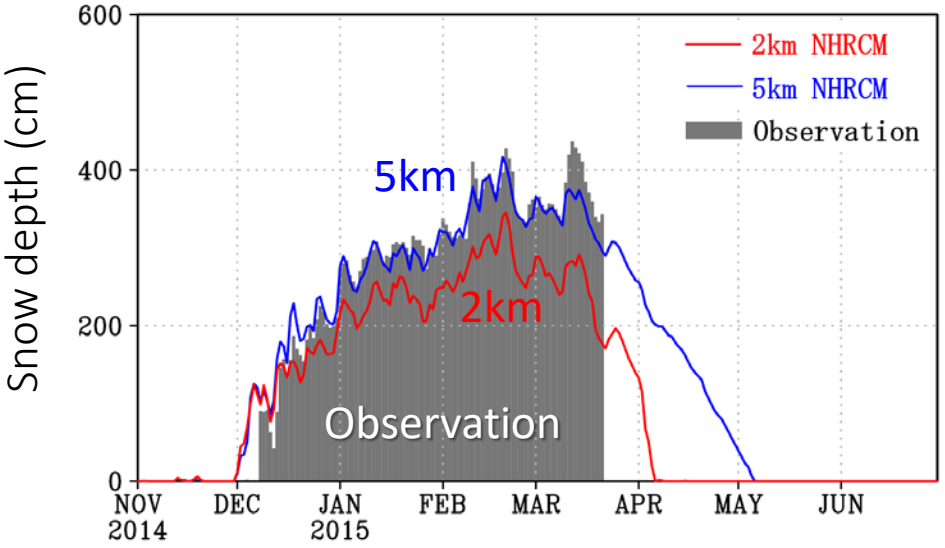


Tateyama-Kurobe Alpine Route

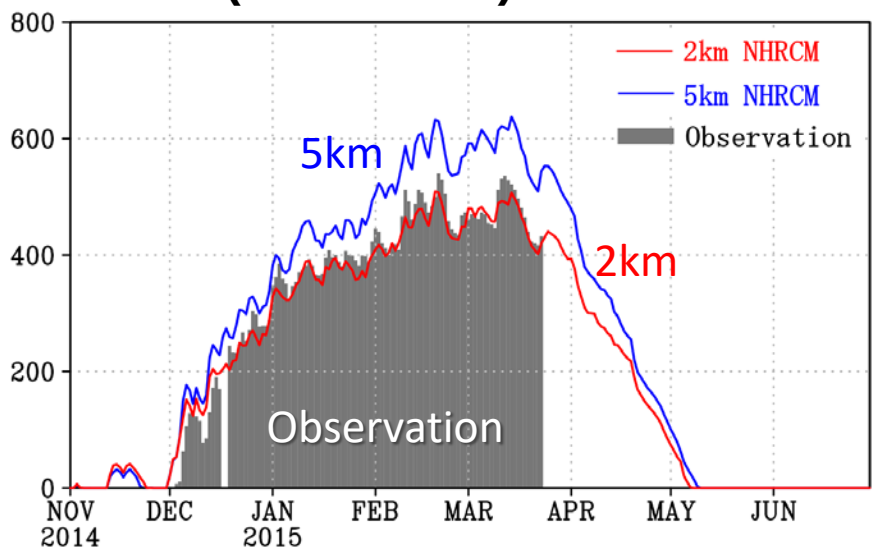


Time series of snow depth in 2014/15

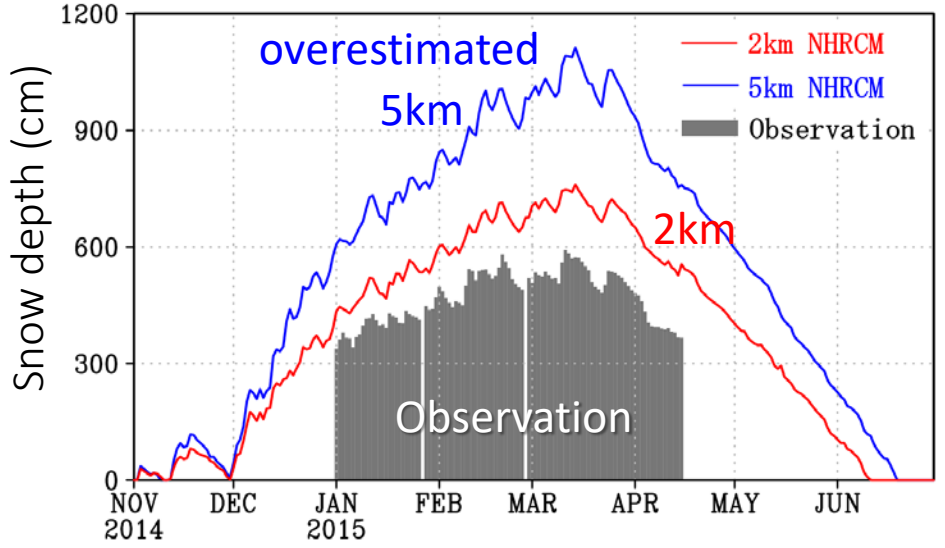
Site 1 (984 mASL)



Site 2 (1450 mASL)



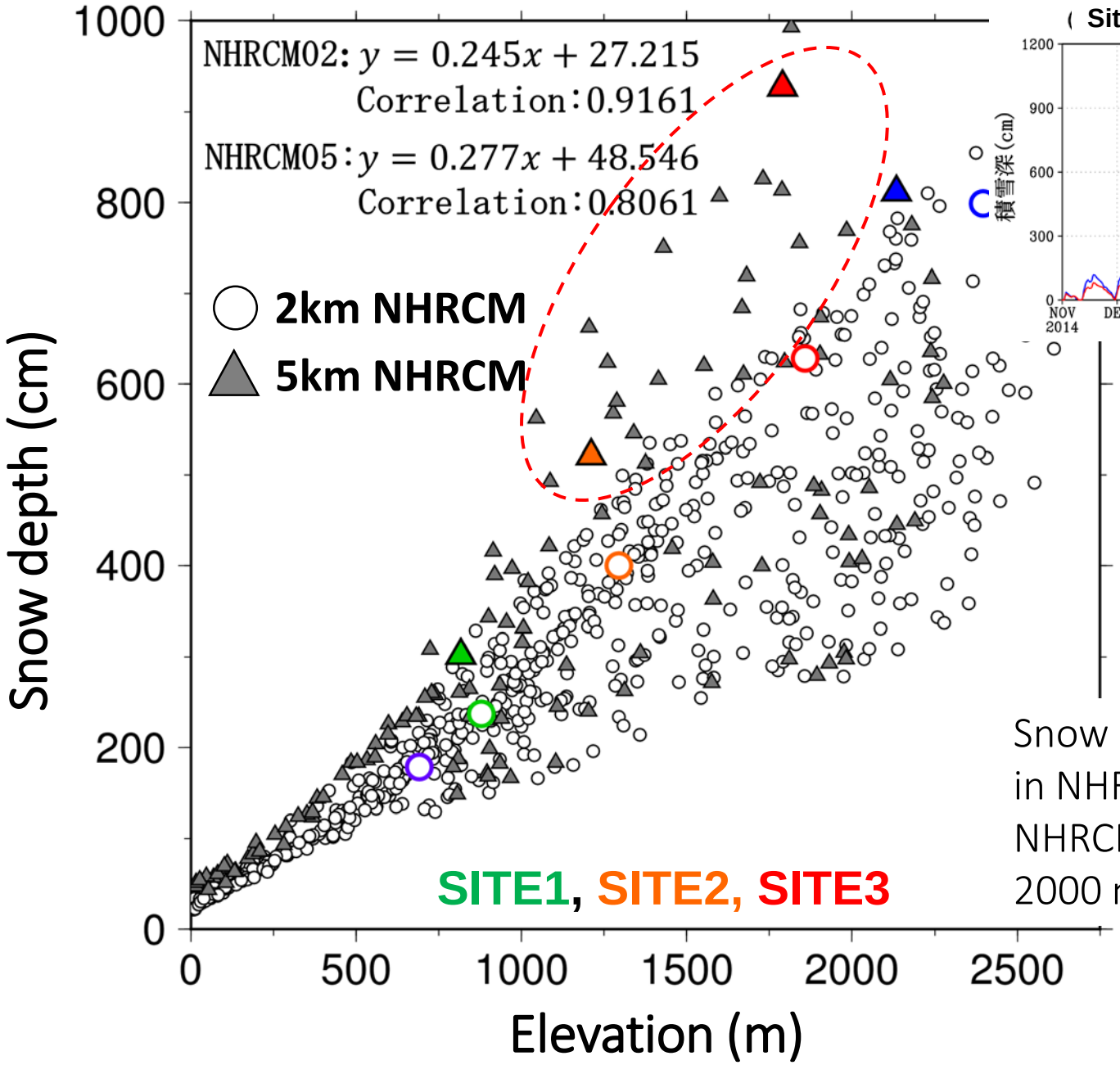
Site 3 (1850 mASL)

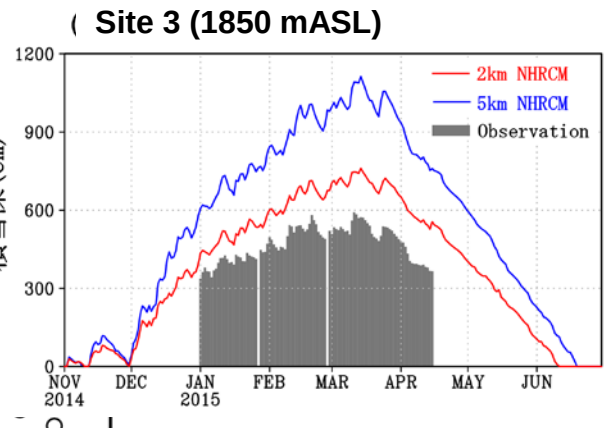


SITE	Elevation (observation)	Elevation (NHRCM05)	Elevation (NHRCM02)
SITE1	984 m	817 m	879 m
SITE2	1450 m	1210 m	1295 m
SITE3	1850 m	1790 m	1858 m

Snow depth is largely overestimated at SITE3, especially by NHRCM with 5 km grid spacing.

Relation between 17-years-mean maximum snow depth and elevation

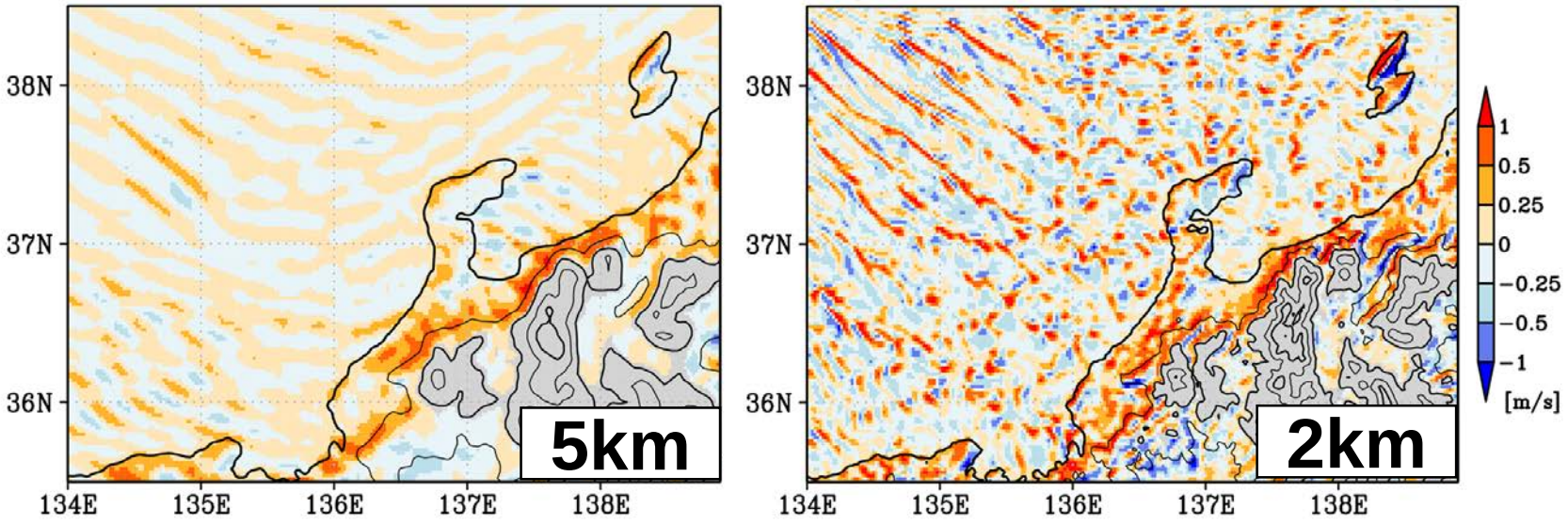




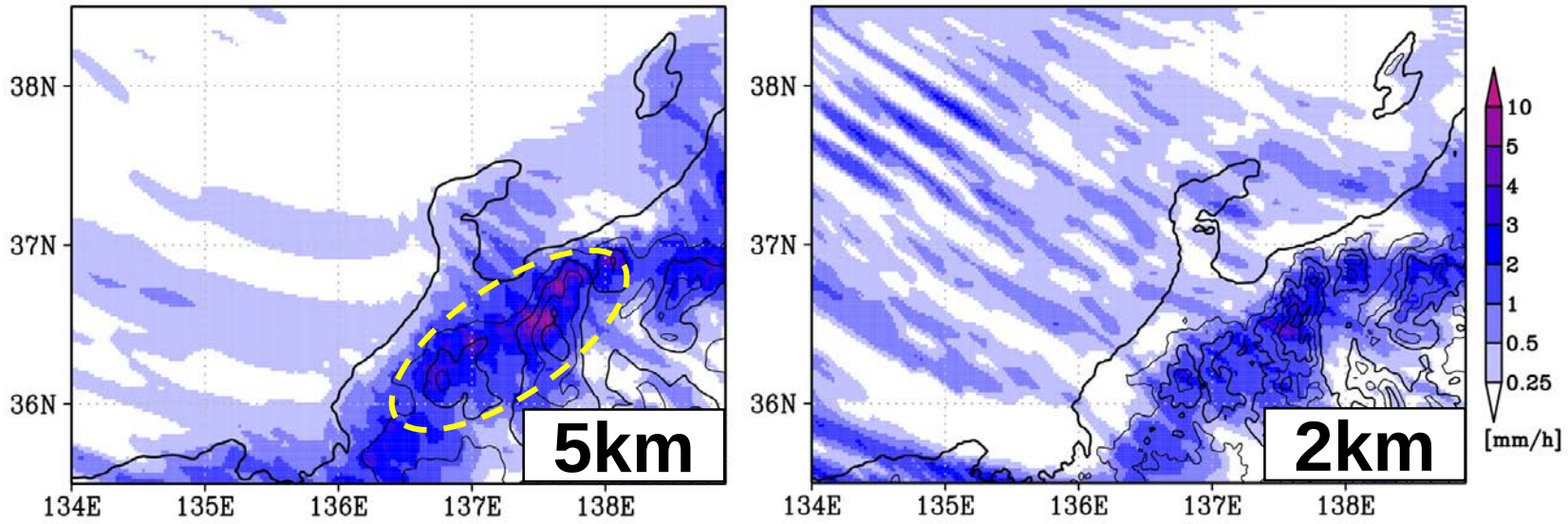
Snow depth is much larger in NHRCM05 than that in NHRCM02 around 1000-2000 mASL

Typical heavy snowfall case (Jan. 14, 2017)

Vertical wind at 900 hPa (06Z Jan. 14, 2017)

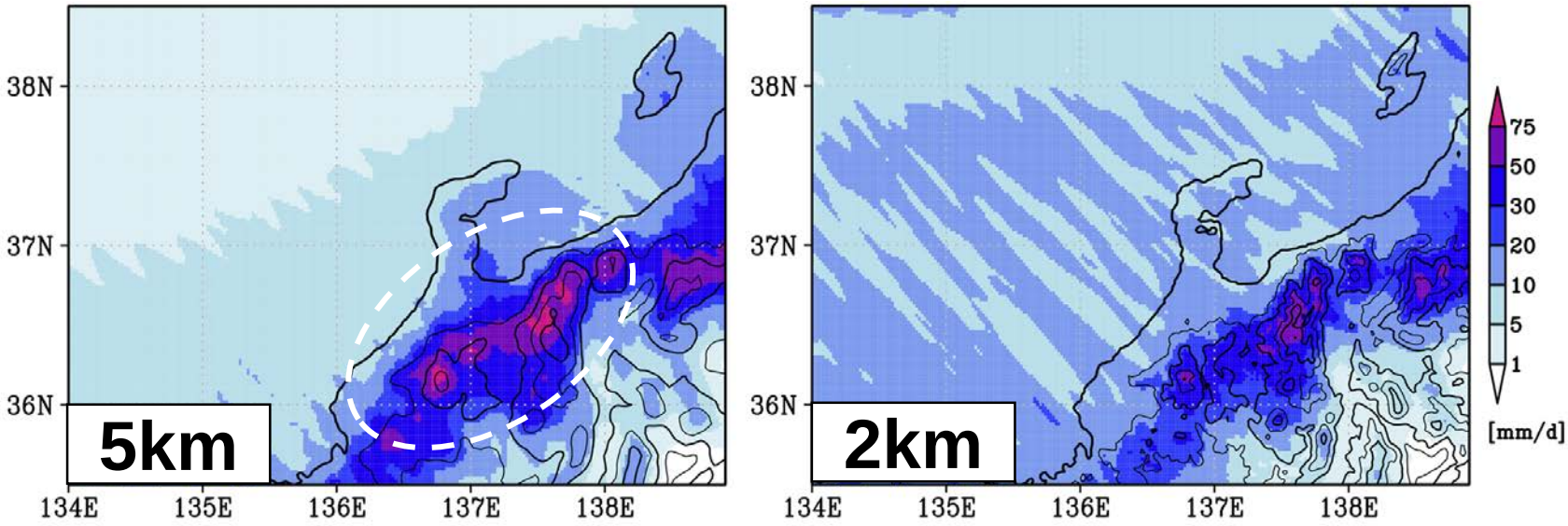


Hourly precipitation (06Z Jan. 14, 2017)



Typical heavy snowfall case (Jan. 14, 2017)

Daily total precipitation (Jan. 14, 2017)



The convection-permitting models are needed to simulate the convective precipitation over Sea of Japan, which also influences mountainous snowfall and snow depth in Japan.

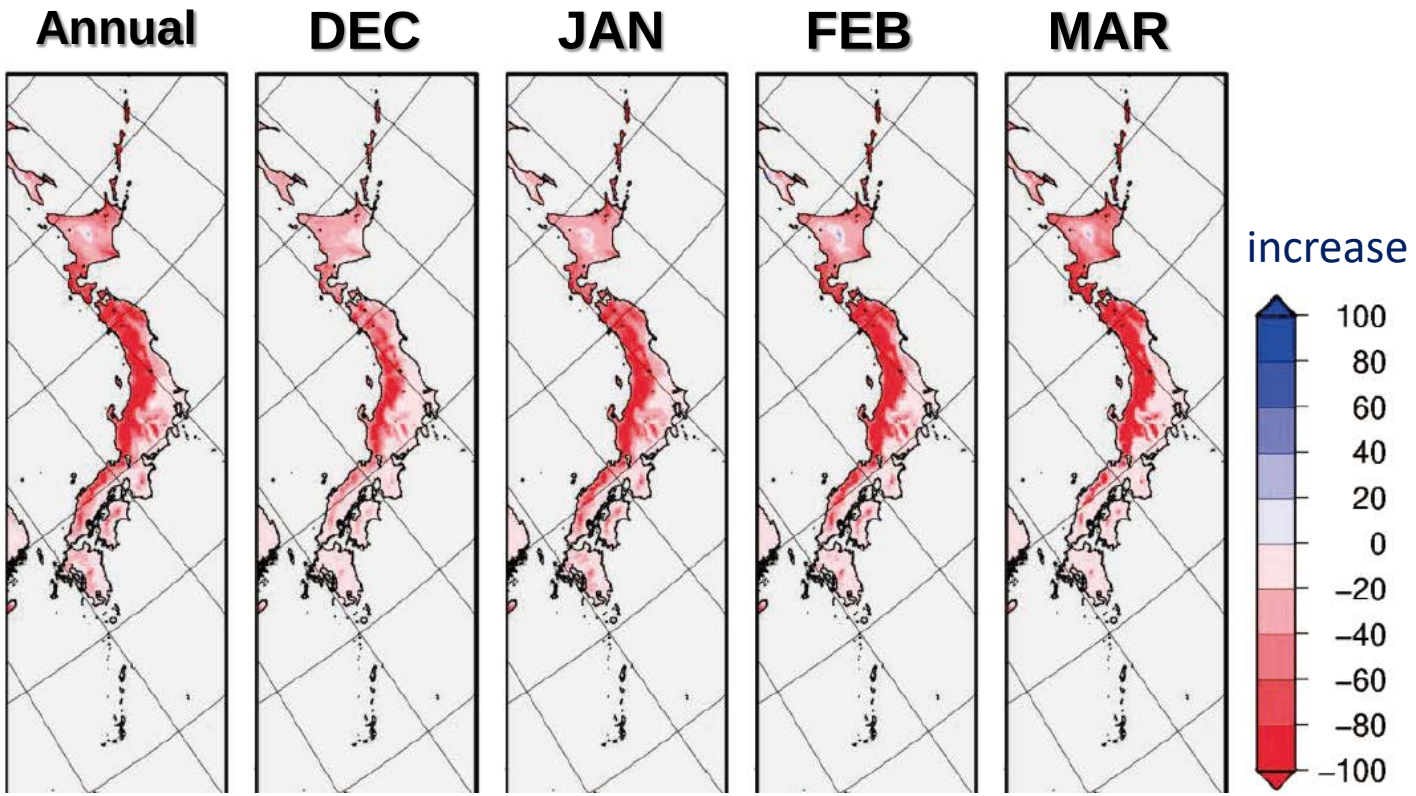
Next topic: Future projections in snow cover and the environment field around surface.

Future changes in snow in Japan

Changes in Maximum snow depth

RCP8.5
2076-2095

5km NHRCM
downscaled from
20km MRI-AGCM



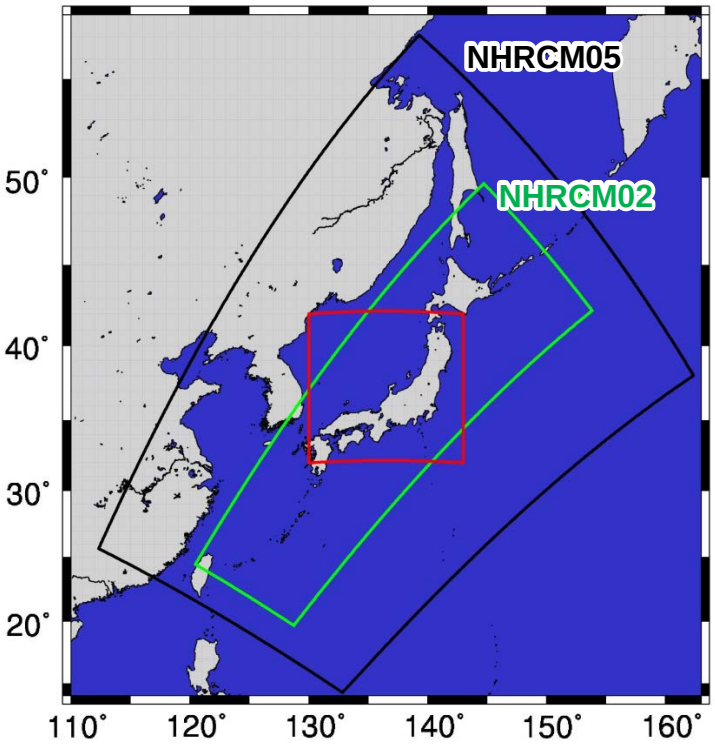
Japan Meteorological Agency (2017)

- Future changes in the snow cover will change surface conditions, which may influence the low-level atmosphere.

➔ We investigate that influence using 2km NRHCM.

Experimental Design 2

TOUGOU



This experiment is conducted for the evaluation of future climate changes in Japan supported the Integrated Research Program for Advancing Climate Models (Funding: TOUGOU program).

Numerical Model

Non-Hydrostatic Regional Climate Model (NHRCM) [Sasaki et al., 2008]

The horizontal resolutions

2 km and **5 km**

Vertical coordinate

Terrain-following 60 levels.

Boundary conditions

20km AGCM (MRI-AGCM3.2S) [Mizuta et al., 2012]

Present climate

Term: 1980 to 1999 (20 years)

SST: reanalysis SST (COBE-SST)

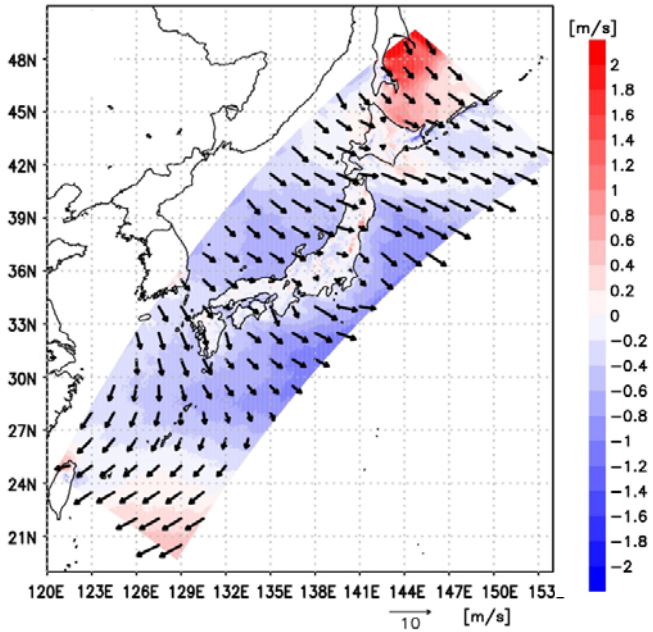
Future climate

Term: 2076 to 2095 (20 years)

SST: COBE SST added by three SST anomaly derived from CMIP5 (RCP8.5)

Future changes in maximum surface wind

Winter(DEC-MAR)



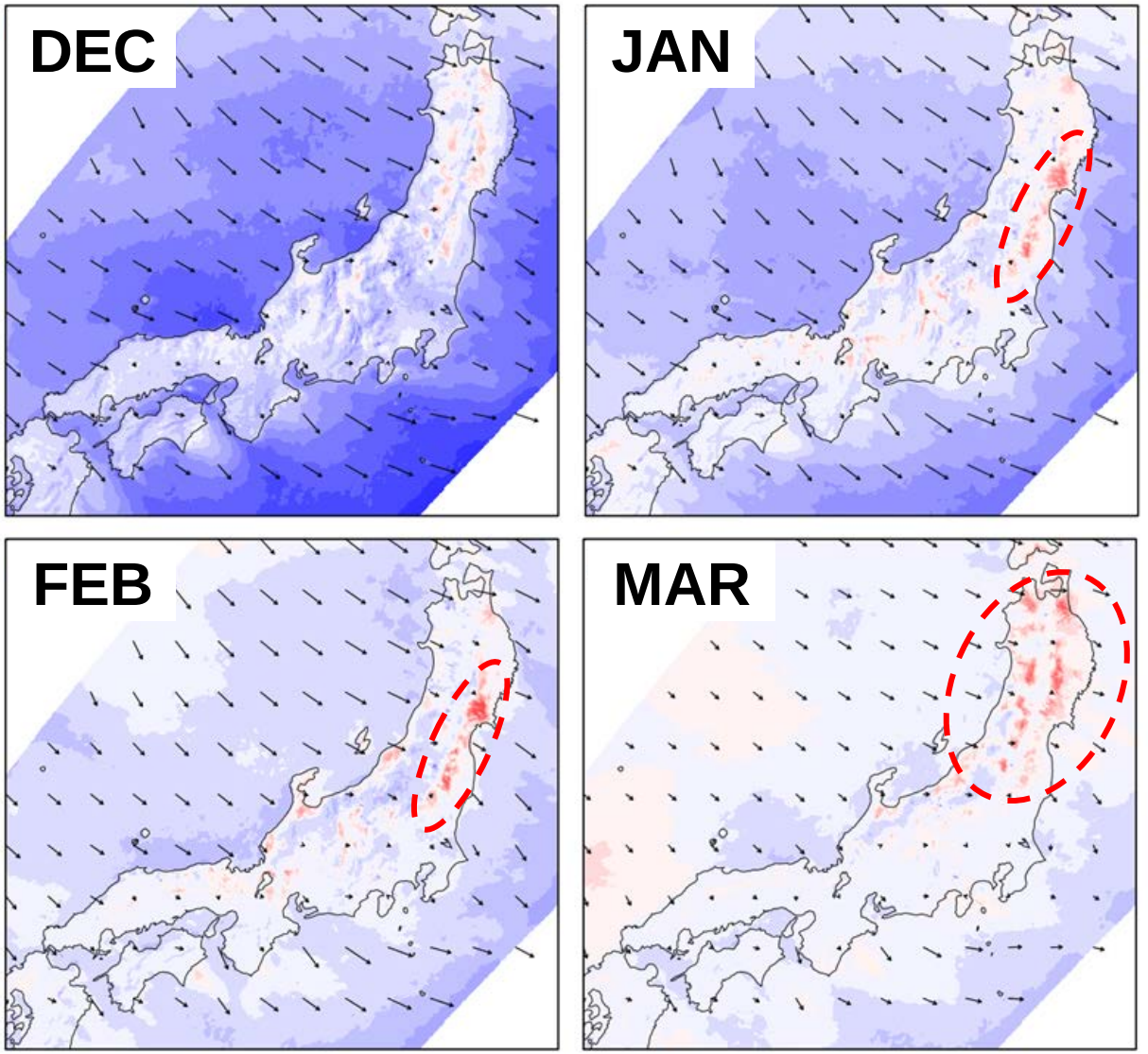
Vector: wind in present climate

Blue: Wind will weaken

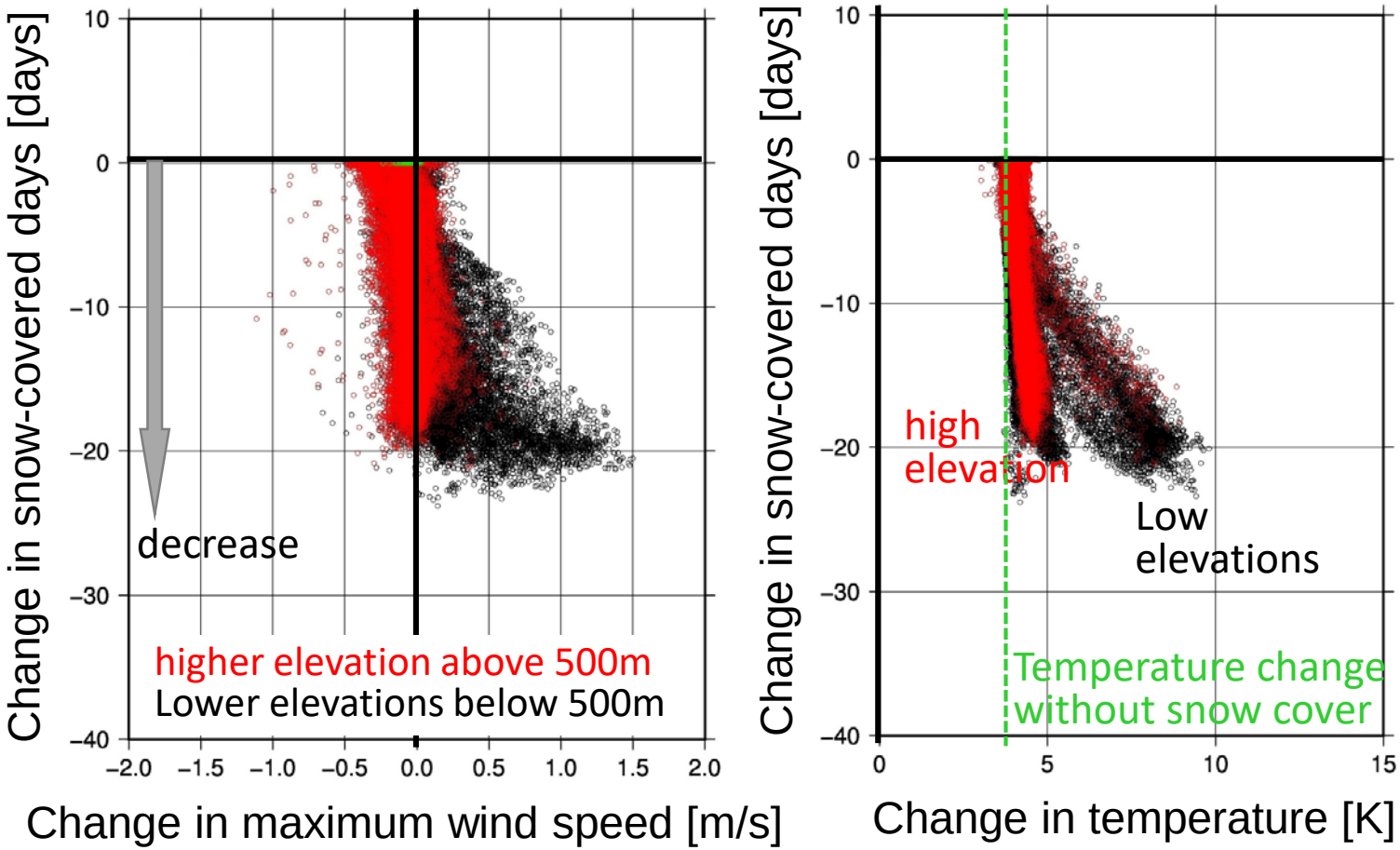
Red: Wind will strengthen in the future

Synoptic-scale wind will weaken because of weakened winter monsoon, but locally …

Monthly mean maximum surface wind



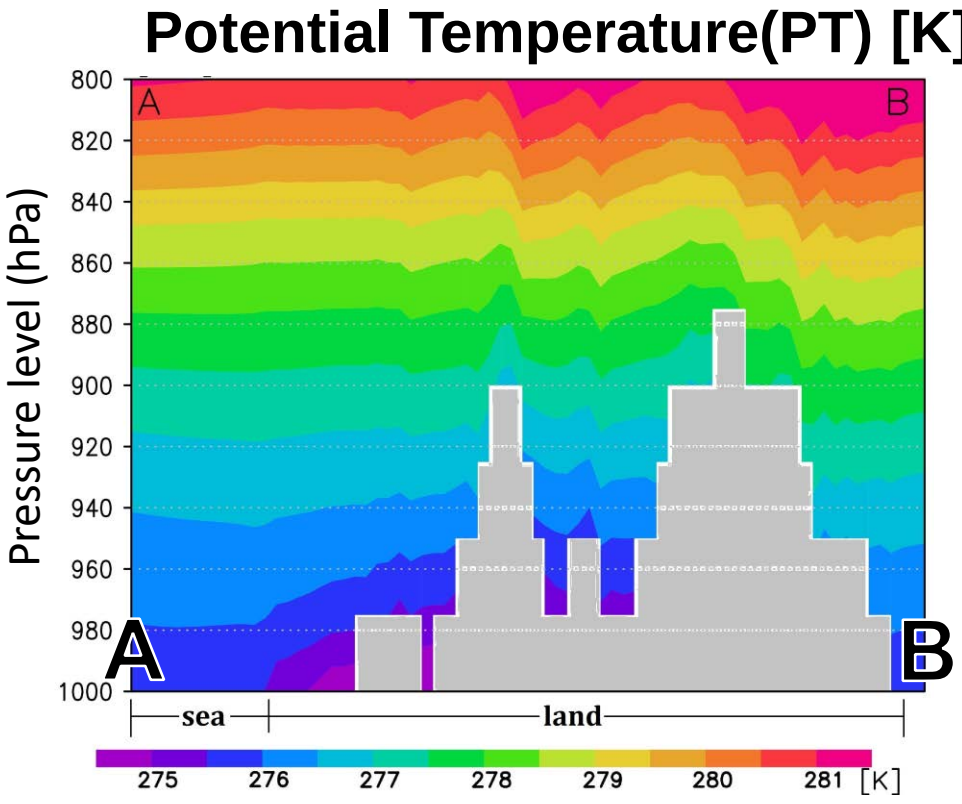
Changes in snow-covered days, wind, and temperature

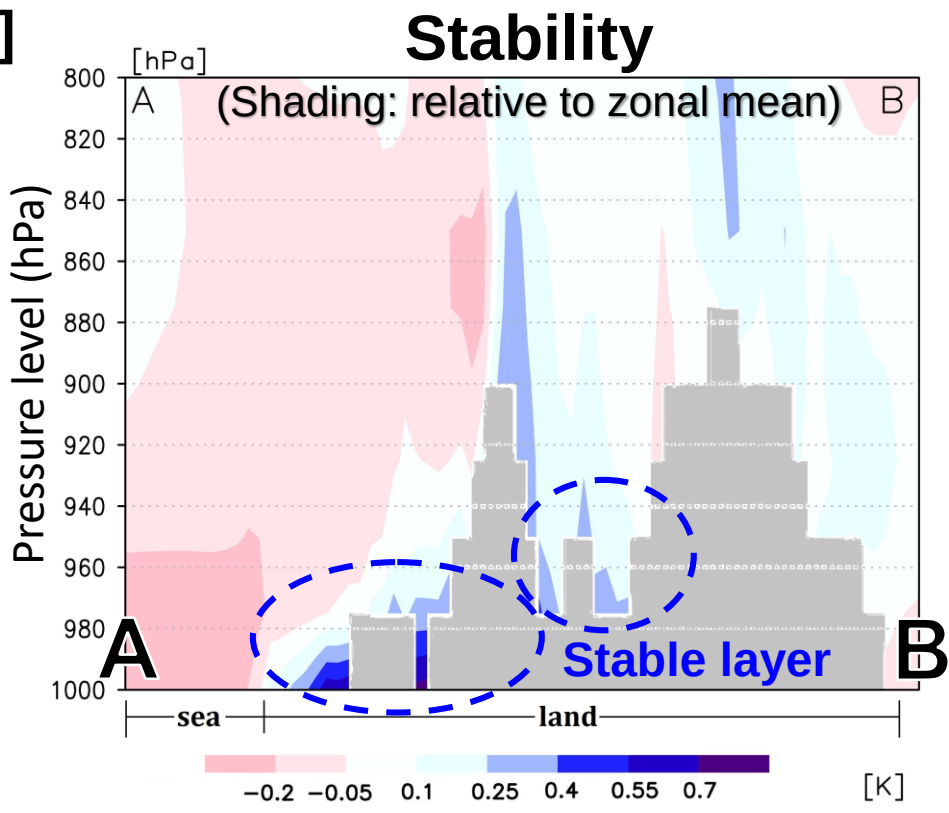


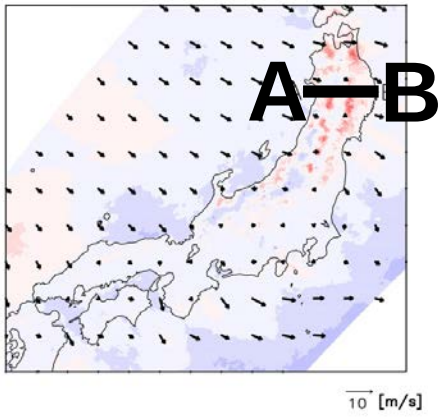
Changes in surface wind and temperature are related to decreases in snow covered days mainly at lower elevations (below 500m).
The relations are unclear at the higher elevations (above 500m).

This is not a simple ice-albedo feedback.

Vertical cross section





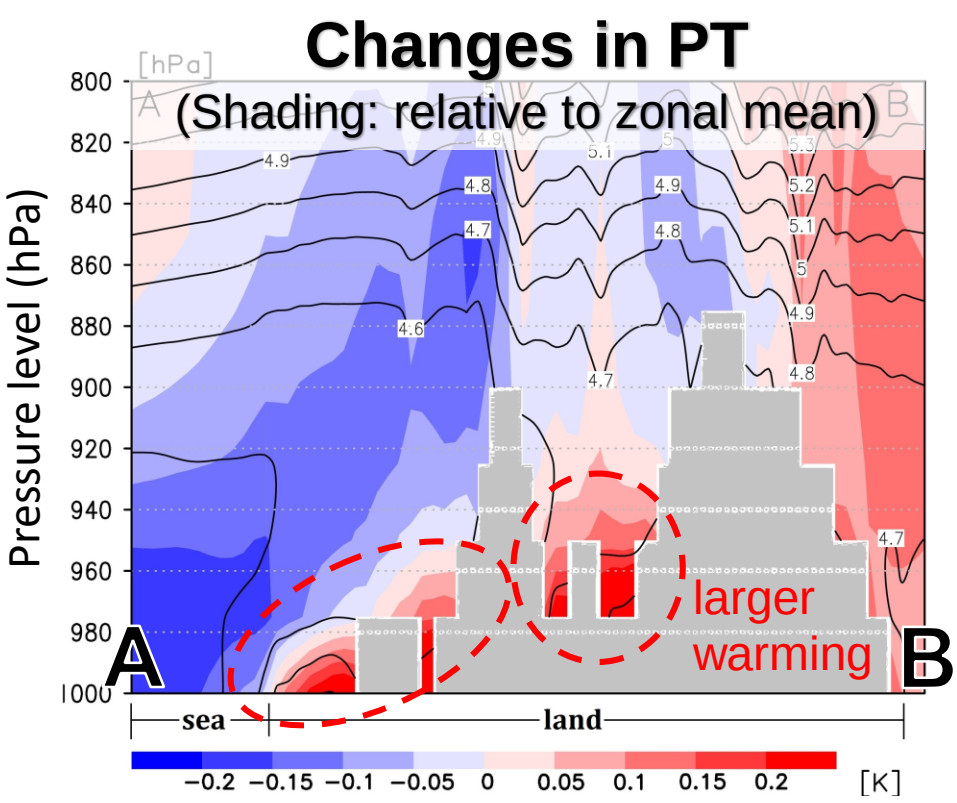


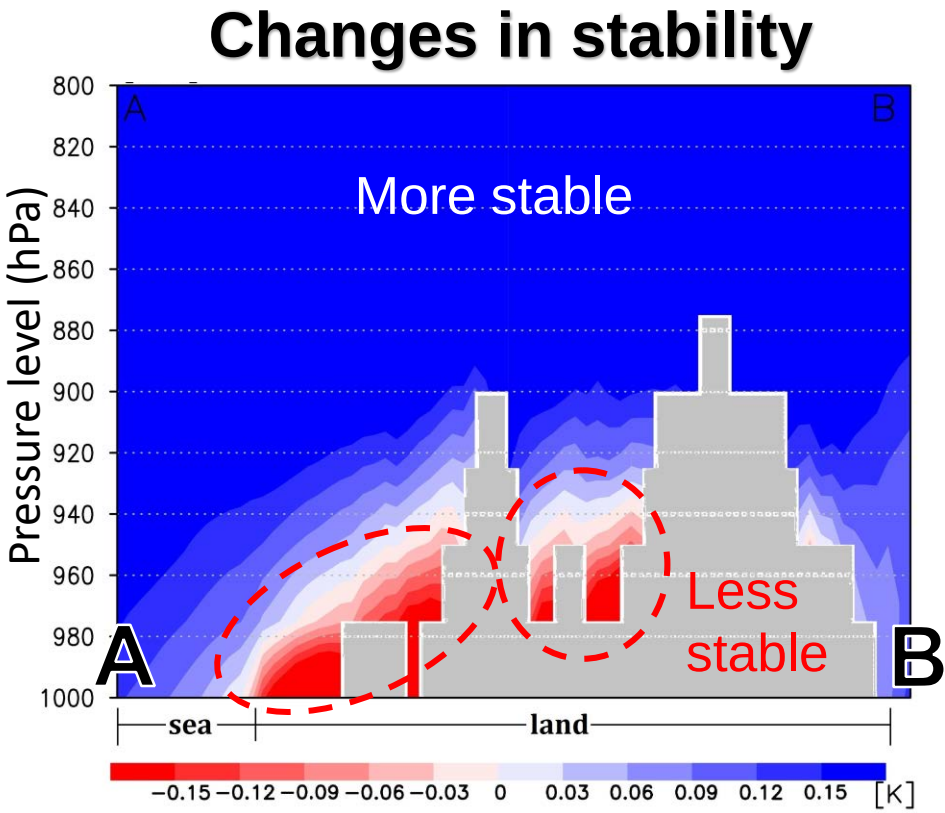
Simplified stability

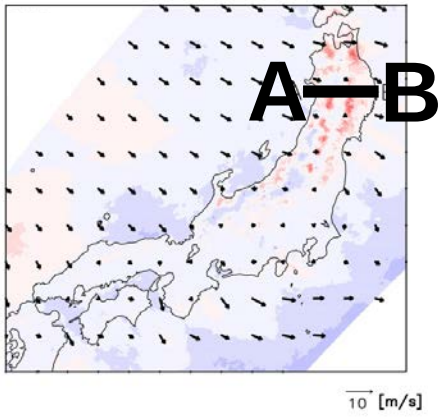
$dPT_{XX} = PT(XX\text{-}50\ hPa) - PT(XX\ hPa).$

Stable layers appear at the low elevations and basins.

Vertical cross section







- Larger warming appears at the low elevations and basin in the future climate.
- The stable layers get less stable in future climate.

Speculations of future local environment changes

Snow disappearance due to global warming rises ground surface temperature in early spring.

■ Low elevation/basin

- Ground surface heating warms the surface air and collapses the stable layer, which accelerates surface air warming and strengthens surface wind throughout the vertical momentum and thermal exchanges.

■ High elevation/mountain

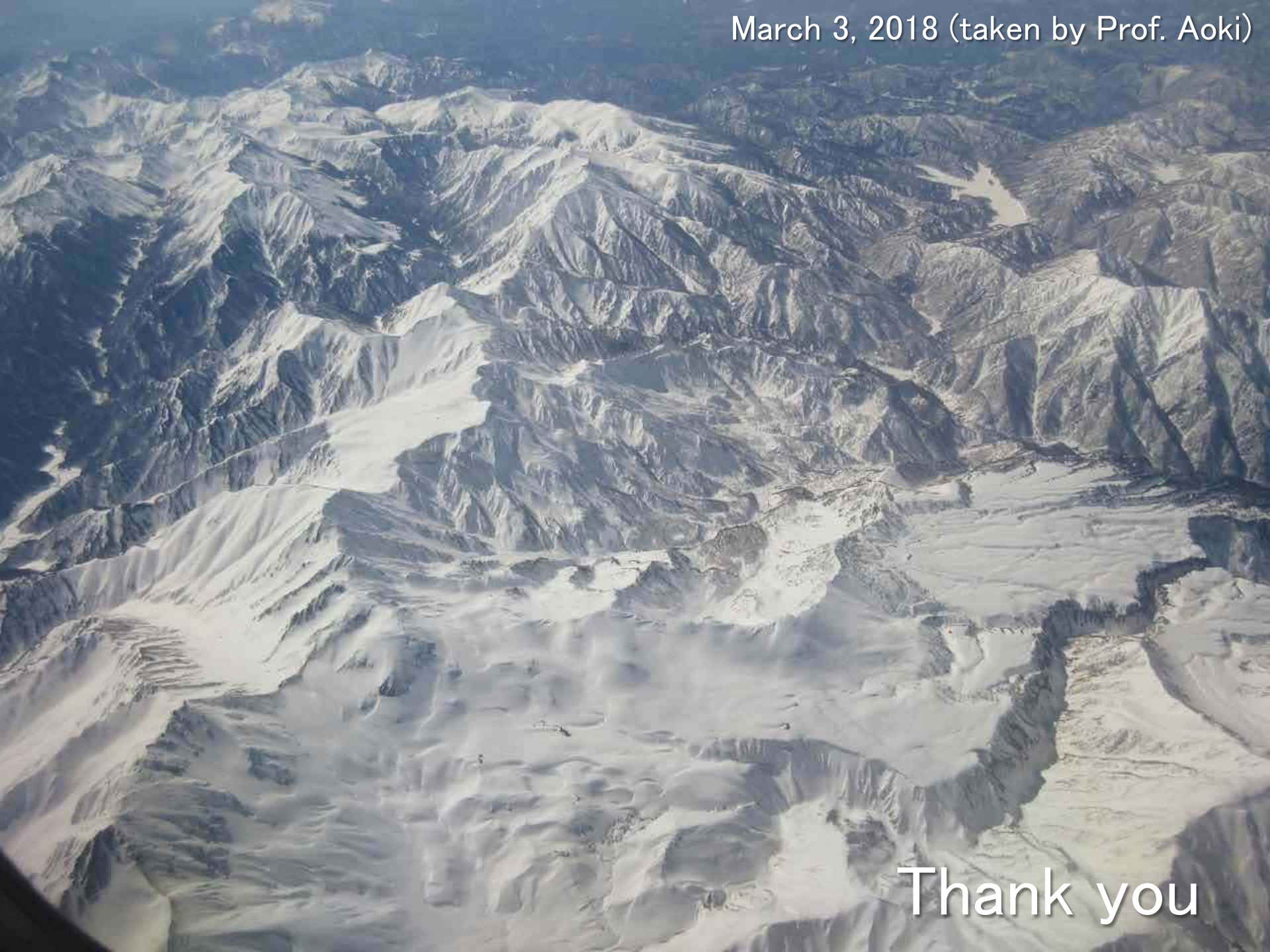
- Stable layer does not develop in the present climate because of ambient strong wind in winter.
- The wind is not strengthened and surface air warming is similar to (a little larger than) surrounding atmosphere.

Conclusion

- Convection-permitting models are need to simulate **convective precipitation over Sea of Japan**, which **influences snowfall and snow cover in the mountains area**. [Kawase et al. 2018, (in Japanese)]
- High-resolution simulations project **locally strengthened surface wind** and **rapid surface warming** at **low elevations** in some snowy areas.
- The snow reduction due to global warming will locally accelerate surface warming and strengthen surface winds **throughout the collapse of the stable layer** at the low elevations **where a stable layer exists in the present climate.**

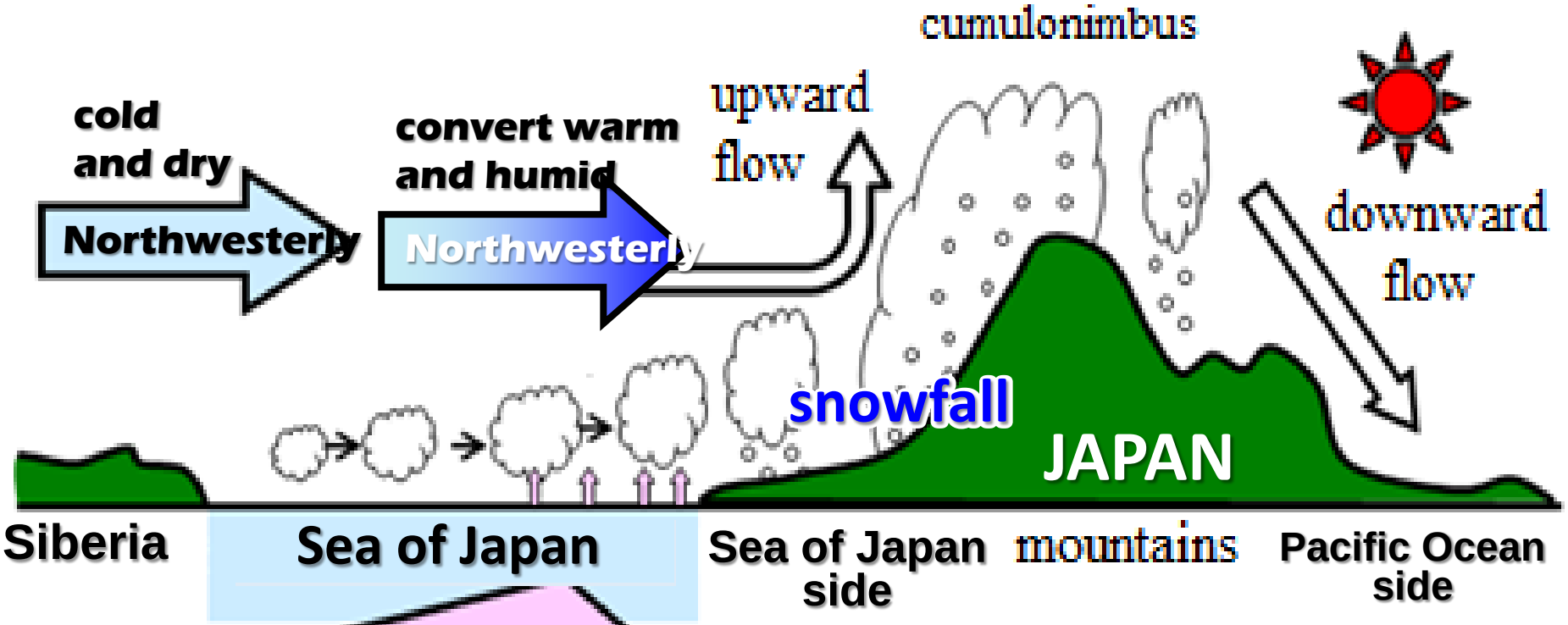
[Nosaka, Kawase et al. 2018, (submittted)]

High-resolution regional models are needed for both resolving convective precipitation over the ocean and resolving complex topography for the future projection in winter and early spring.

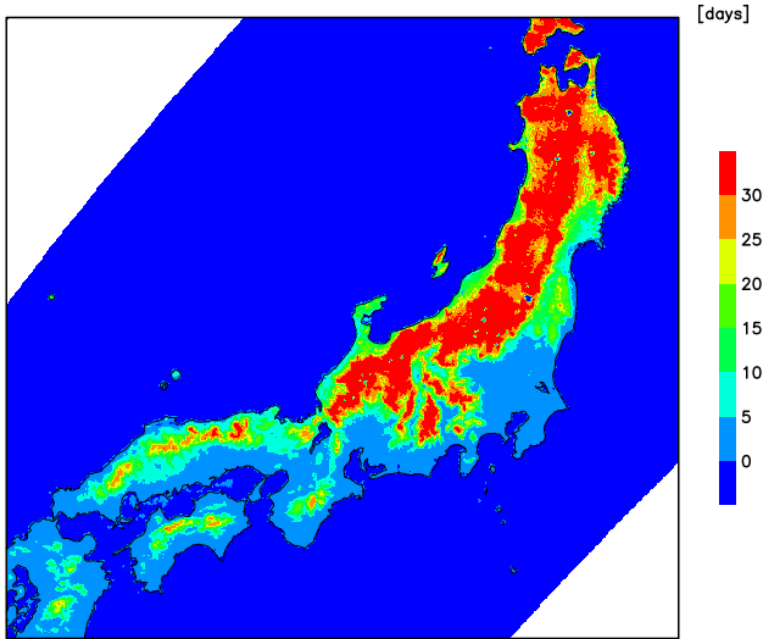

March 3, 2018 (taken by Prof. Aoki)
Thank you

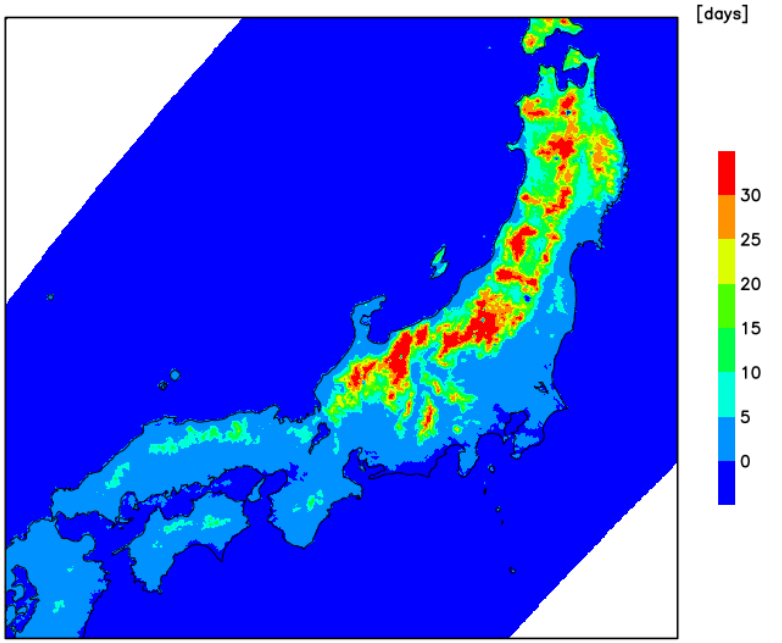
Introduction

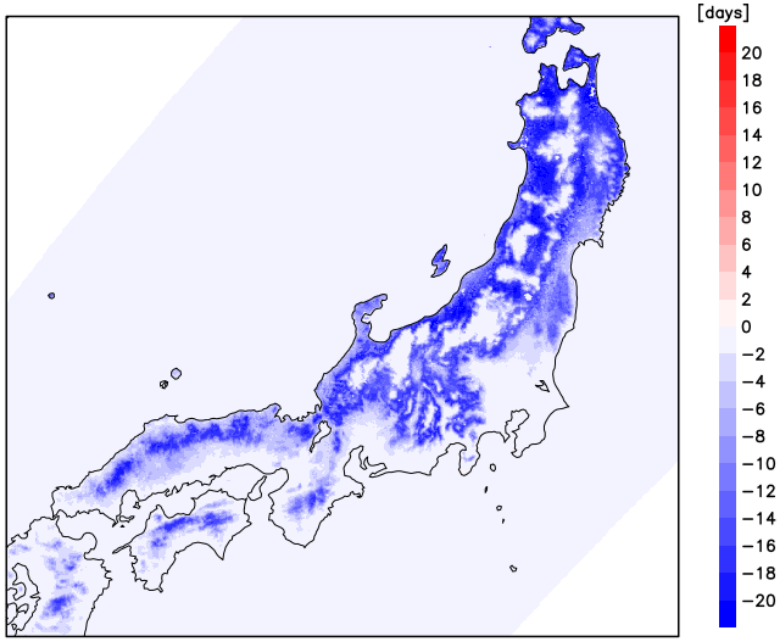
➢ Japan have a lot of snowfall every year, which is important for water resources, while heavy snowfall and deep snow cover affect human lives, e.g., traffic accidents and avalanches.

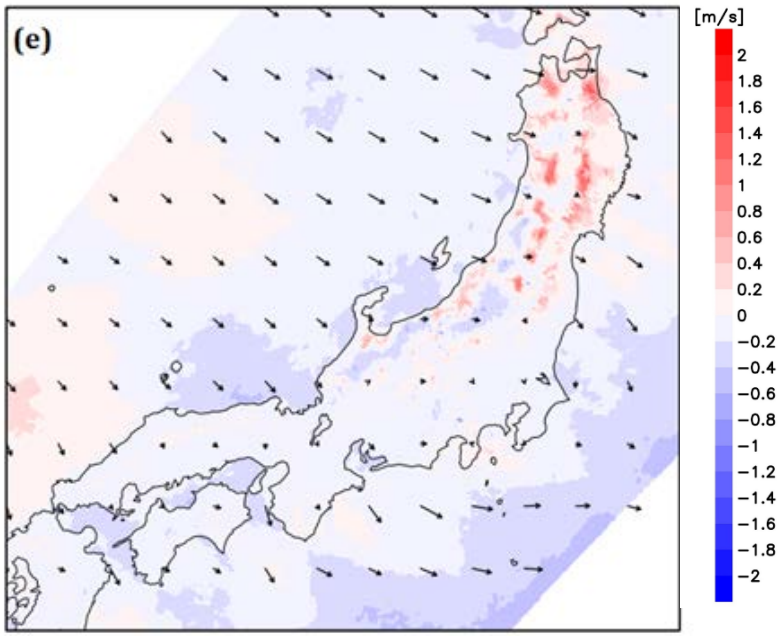


Colder air from Siberia and warmer SST result in more developed snow clouds and heavier snowfall



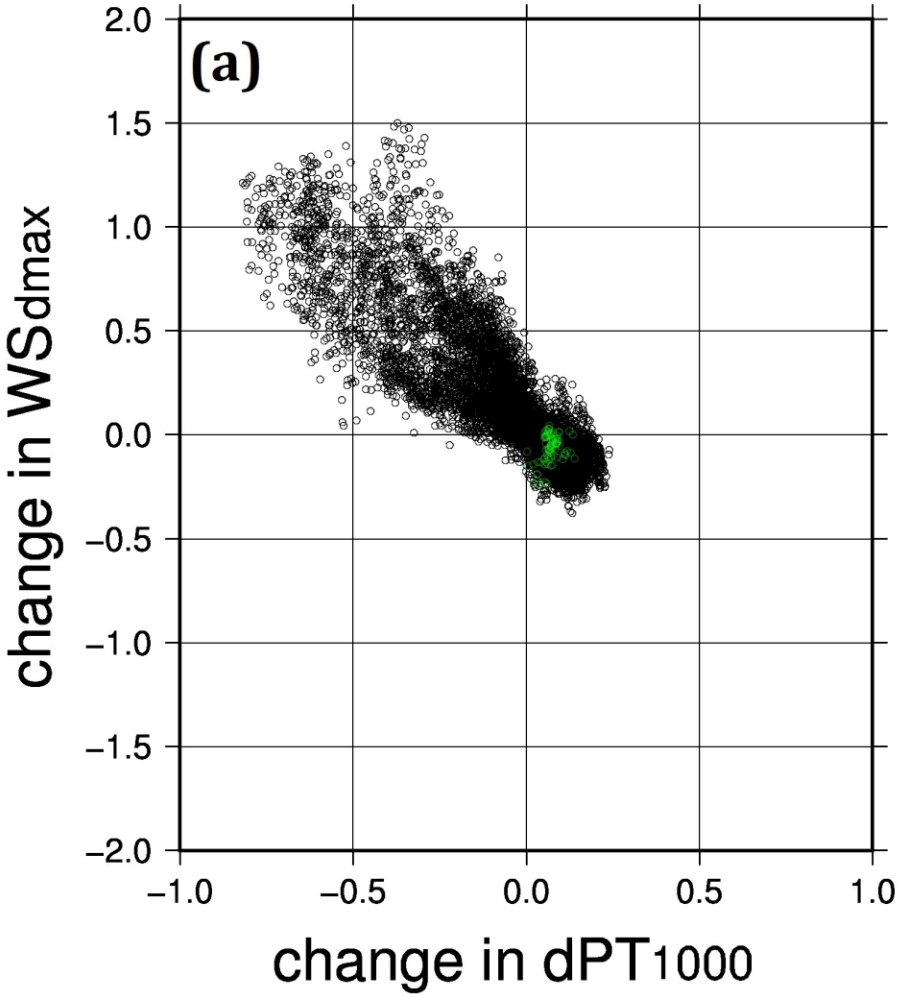


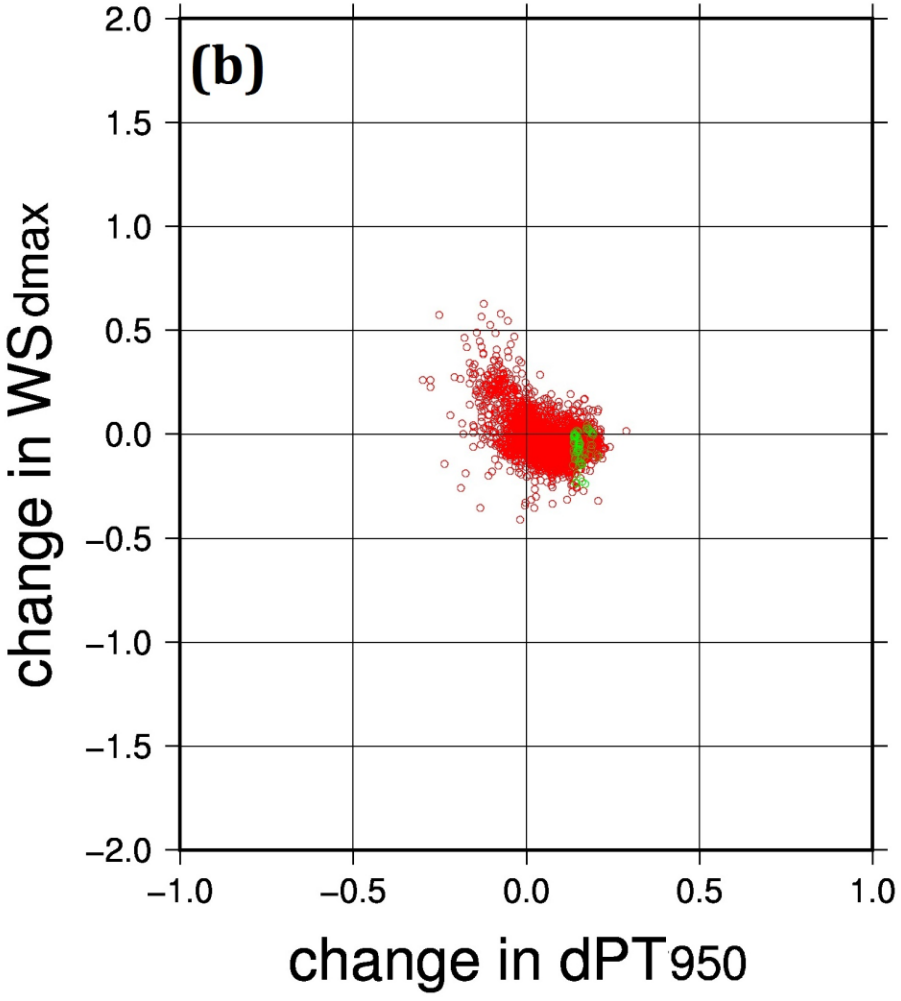




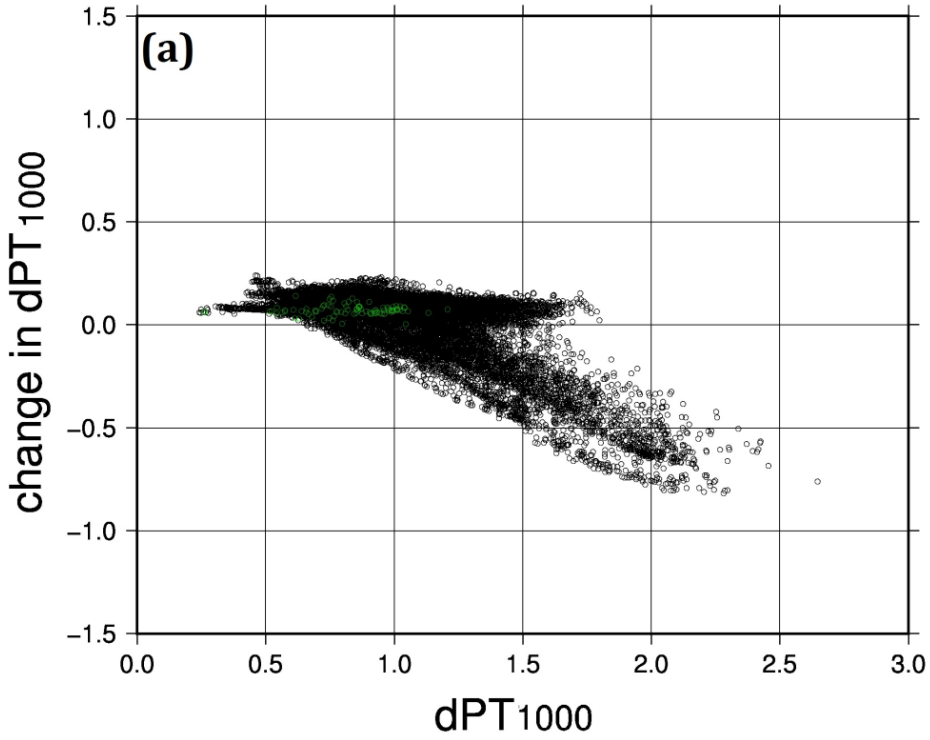
GrADS: IGES/COLA

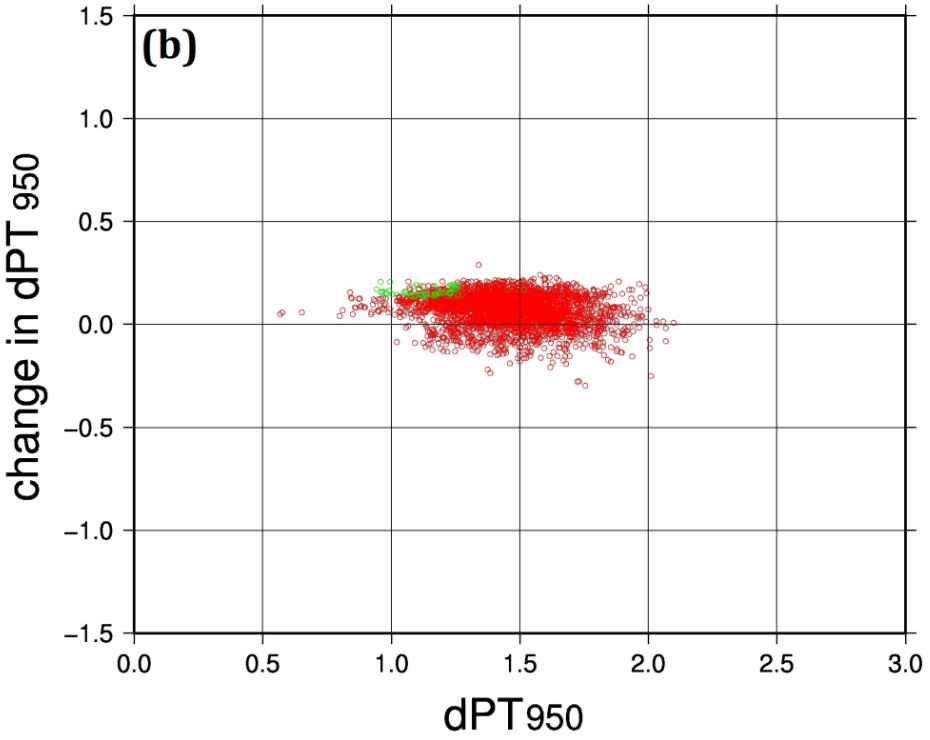
Summary


(a)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−1.0
−0.5
0.0
0.5
1.0
change in WSdmax
change in dPT1000


(b)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−1.0
−0.5
0.0
0.5
1.0
change in WSdmax
change in dPT950

Summary


(a)
change in dPT1000
dPT1000
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0


(b)
change in dPT 950
dPT950
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0