Future Climate Change Scenarios over Korea Using a Multi-Nested Downscaling System

Song-You Hong[1], Kyo-Sun Sunny Lim[1], Nan-Kyoung Moon[2], and Jong-Won Kim[2]

[1]Department of Atmospheric Sciences and Global Environment Laboratory, Yonsei University, Seoul, Korea

[2]Korea Environment Institute, Seoul, Korea

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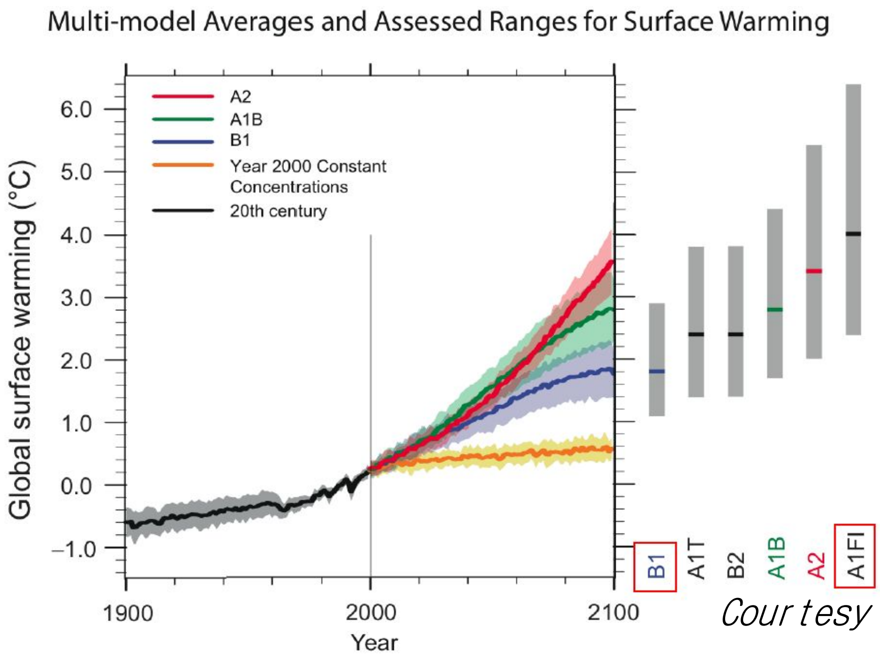
Introduction



Courtesy of Solomon et al. (2007)

According to the latest Intergovernmental Panel on Climate Change (IPCC) assessment report, all currently available global climate models agree that an increase in global mean temperature of 1.1 °C to 6.4 °C will occur during the 21st century.

Accurate projections of future regional-scale climates are needed to assess the possible societal impacts of climate change.

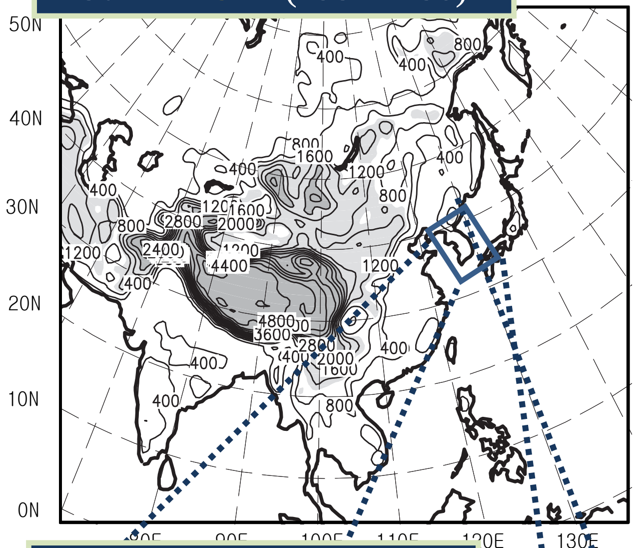
In order to derive application models that assess changes in ***air pollution*** and *river charge on local scales*, the high-resolution meteorological data (< 10 km) embedded in evolving global warming scenarios should be archived. → Down scaling by statistical methods or by nesting a regional climate model.

Purpose

Generate high-resolution climate change data for East Asia, centered over Korea, between the present (1995) and the mid-21st century (2055) using a multi-nested system.

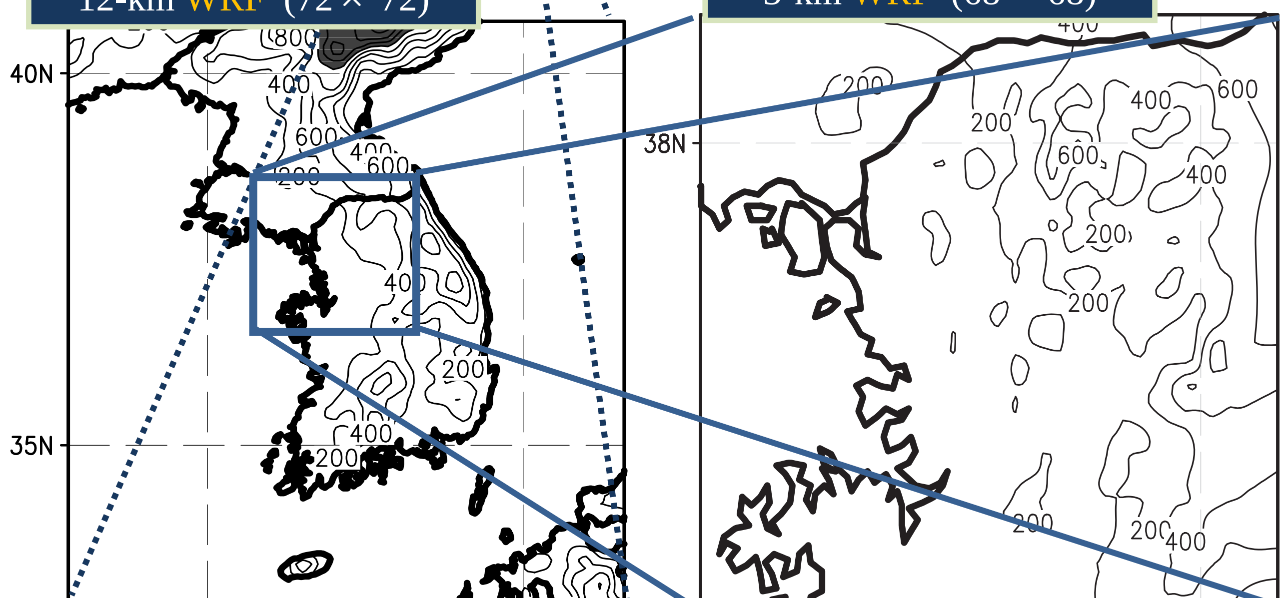
Experimental Setup

50-km RSM (193× 158)



12-km WRF (72× 72)

3-km WRF (68× 68)



Model :

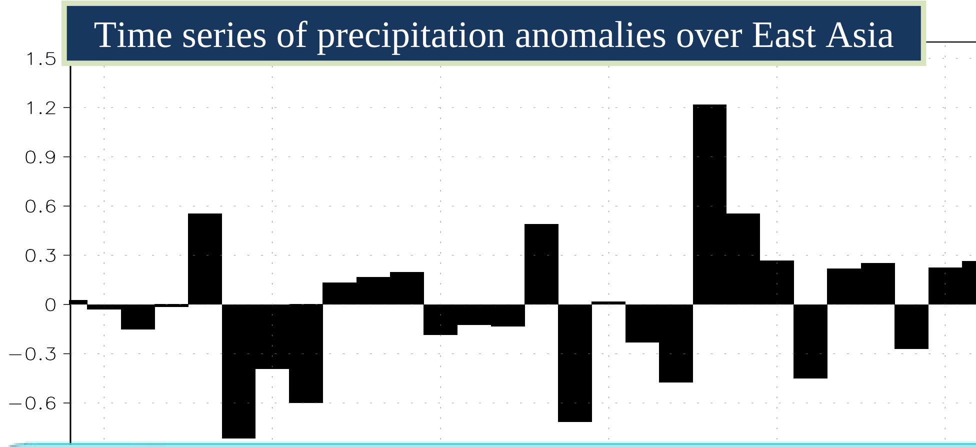
NCEP RSM (Juang et al. 1997)
NCAR WRF (Skamarock et al. 2008)

Global Data:

NCEP/DOE reanalysis (RA2) data: RA2_bdy
for investigation of the RSM’s capability in reprodu
the present climate
ECHAM5: ECHAM5_bdy
for generation of climate change scenario

Period : 3 months (JJA)

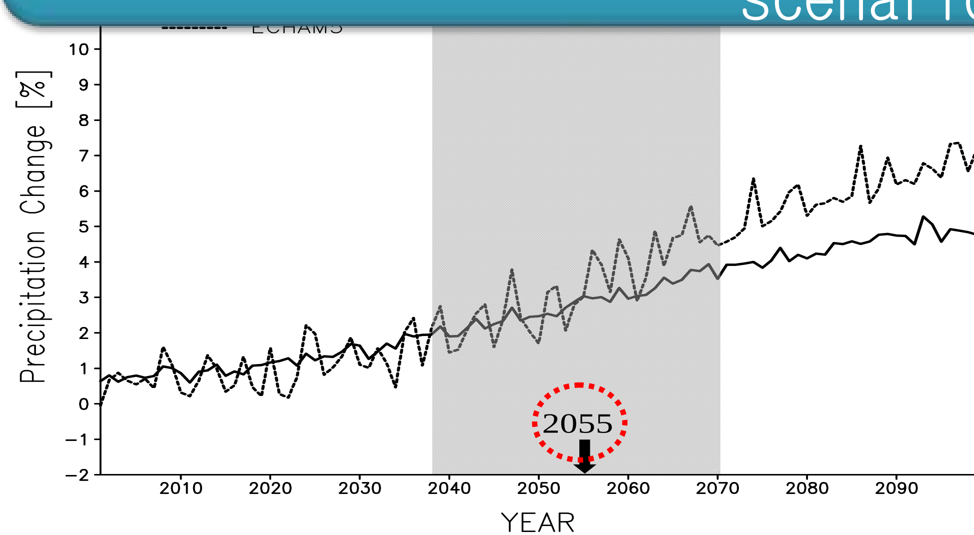
The Representative Year of the Present/Future Climate



1995

: *Normal summer* Over East Asia in terms of

The fundamental evaluation of possible systematic biases is a prerequisite to produce a reliable scenario.



2055

: ***Median between 2038 and 2070***

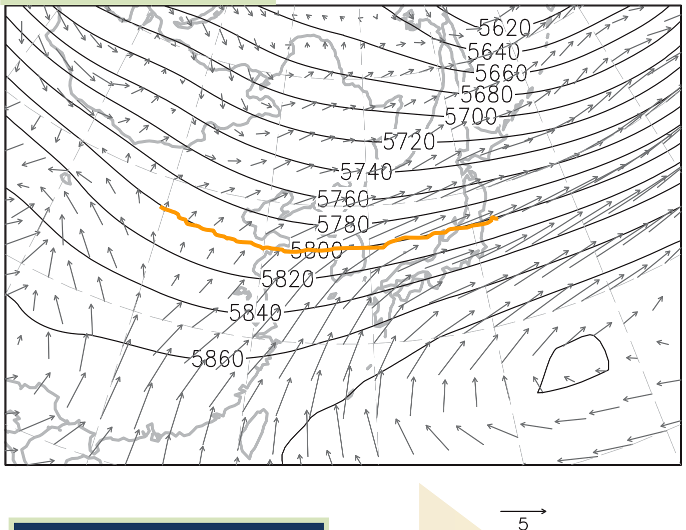
(the period of 2038-2080 is proposed for future climate simulation in RMIP phase Ⅲ)

Assessment of simulation accuracy for reconstructing present (1995) climate

-*Check the reproducibility of the EASM conditions in 1995.*
-*Evaluate the downscaled features forced by the ECHAM5 data.*

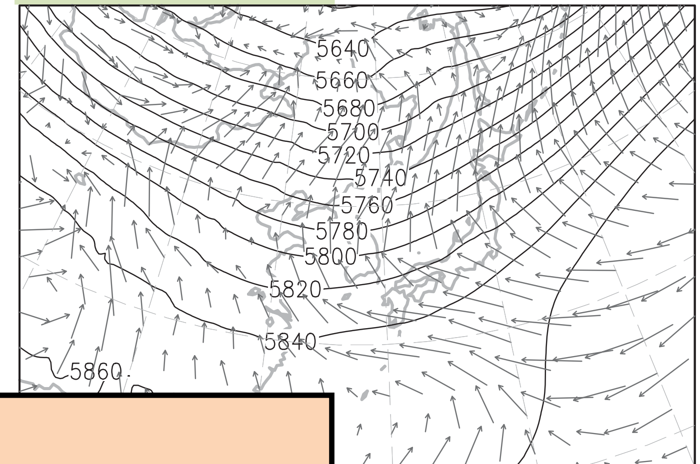
50-km RSM: 850-hPa winds and 500-hPa geopotential heights

RA2

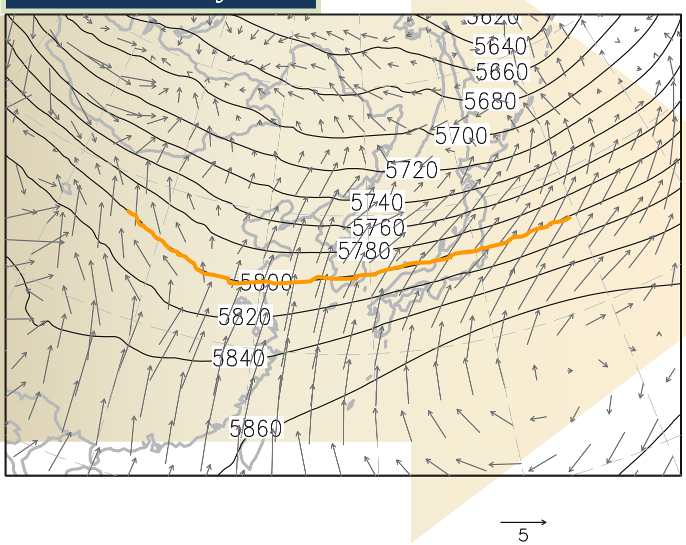


LLJ
Two major large scale circulation at 500 hPa

ECHAM5_bdy



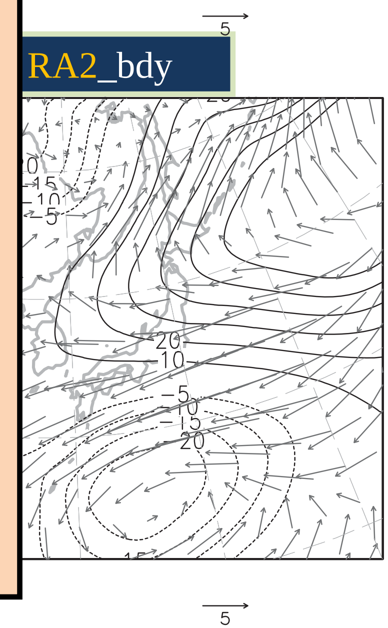
RA2_bdy



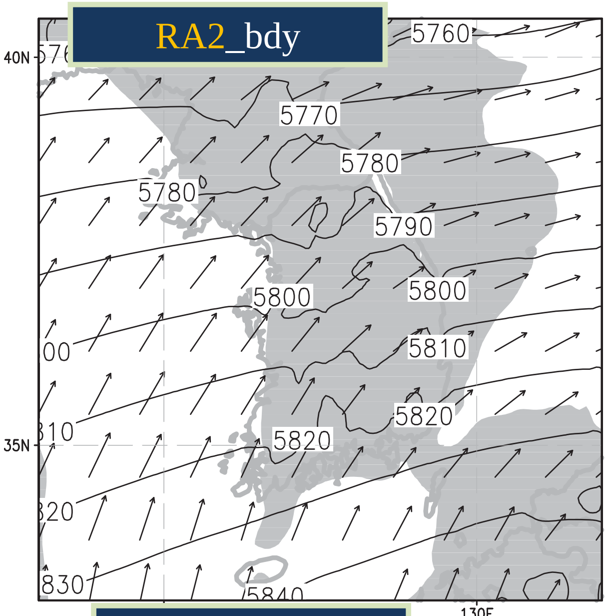
Similar with the RA2 with well reproduced 500 hPa circulation

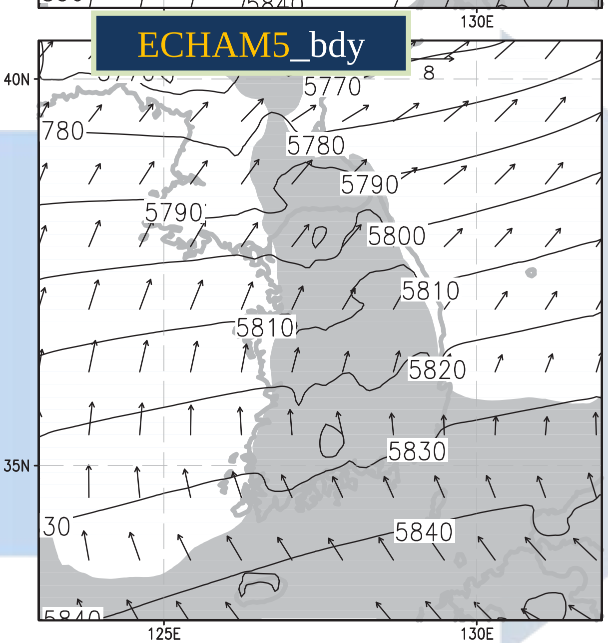
Weakening of the LLJ and intensity of the subtropical high → ***Weakened monsoon activity***

RA2_bdy

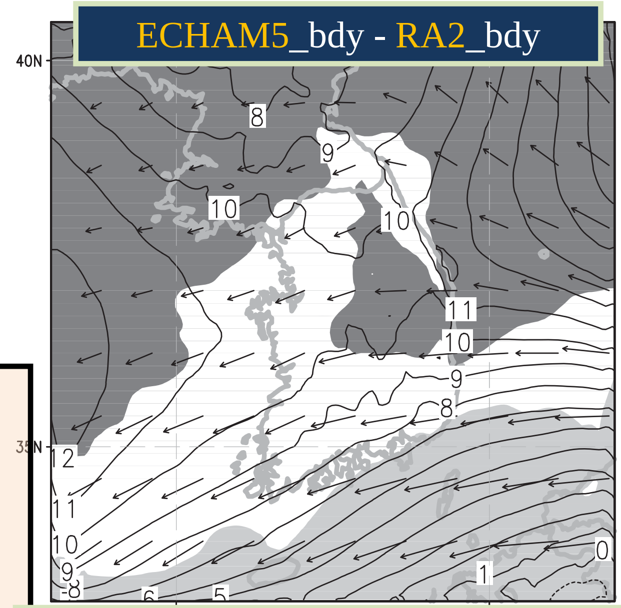


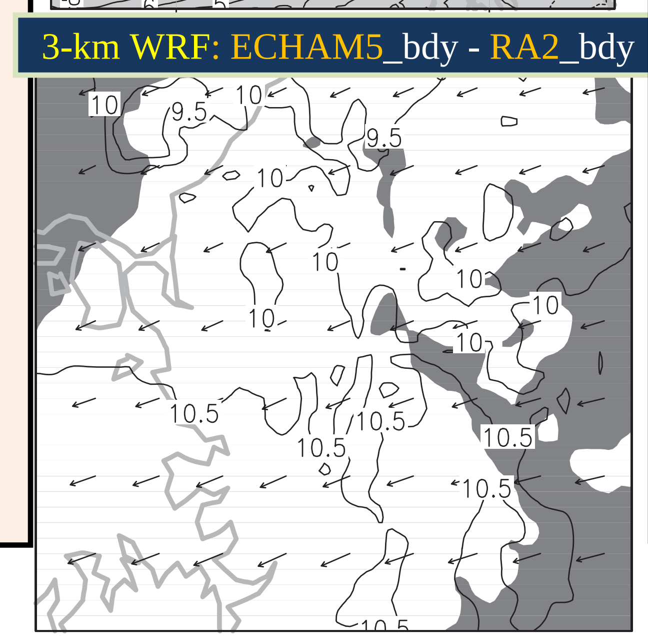
12-km (3-km) WRF: 850-hPa wind, qv, and 500-hPa geopotential heights





Consistent with the systematic bias of the 50-km RSM.





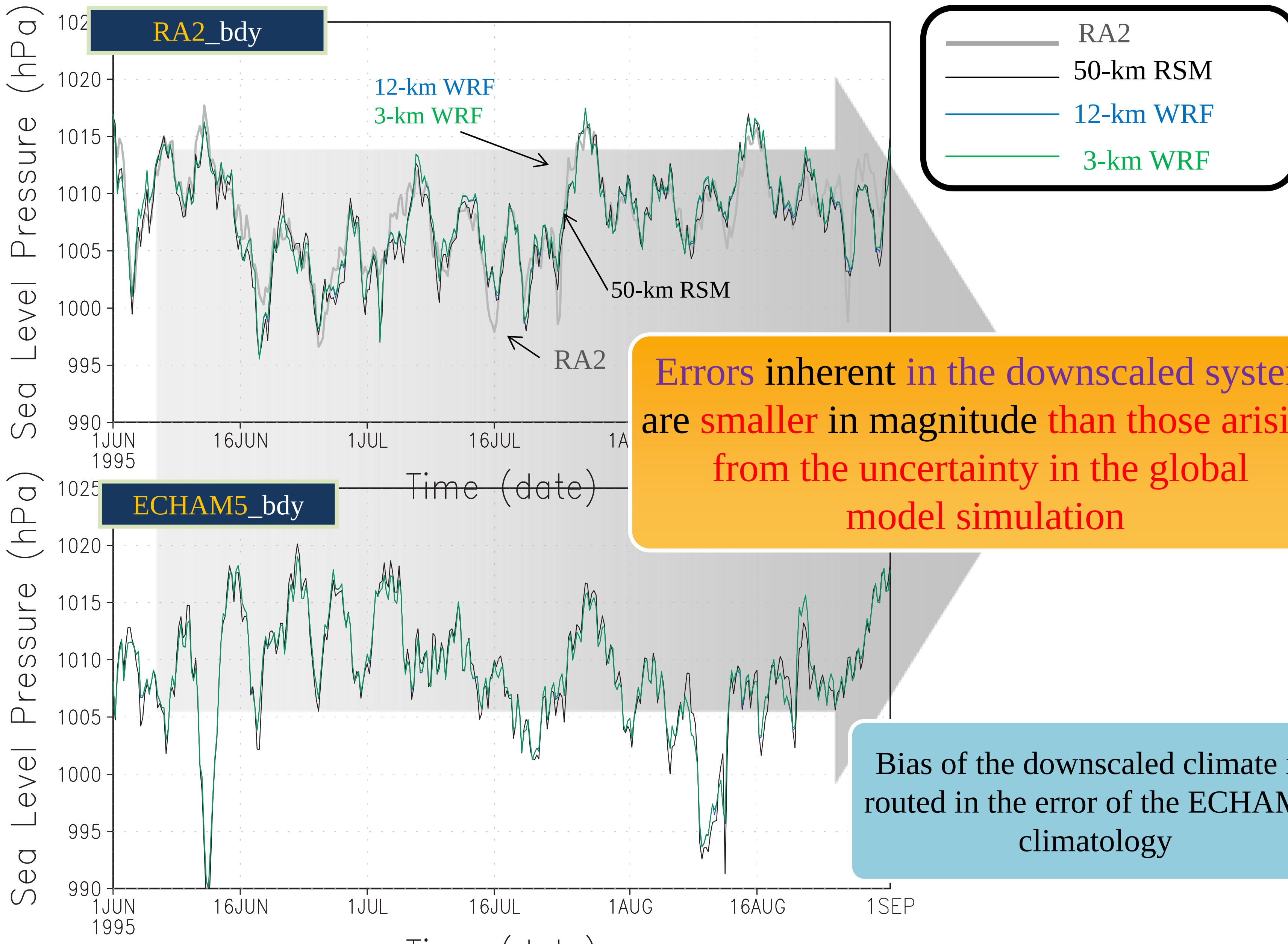
A more detailed distribution of the geopotential height because of the city-scale orographic effect

Statistics for the RSM and 12-km WRF simulations

Variable	Bias			RMSE		
	Land	Ocean	Whole	Land	Ocean	Whole
RA2_bdy						
Surface temperature (℃)	-1.03 (-0.40)			1.19 (0.91)		
Precipitation (mm day^{-1})	0.02 (1.34)	-0.88 (-1.02)	-0.54 (-0.01)	2.30 (4.43)	1.68 (2.20)	1.93 (2.97)
ECHAM_bdy						
Surface temperature (℃)	-1.89 (-0.46)			1.67 (0.99)		
Precipitation (mm day^{-1})	-0.25 (-0.51)	-0.73 (-2.51)	-0.55 (-1.61)	2.85 (3.43)	2.00 (3.40)	2.35 (3.41)

Simulations with the RA2 are in better agreement with the observation.

Time series of the domain-averaged sea level pressure



Errors inherent in the downscaled system are smaller in magnitude than those arising from the uncertainty in the global model simulation

Bias of the downscaled climate is routed in the error of the ECHAM5 climatology

Assessment of simulation accuracy for reconstructing present (1995) climate

❖We found that the RSM-WRF system can accurately reproduce large scale features associated with the EASM and the associated hydro-climate when it is nested by the RA2 data. In the case of the present climate simulation from the ECHAM5 data, monsoon activity was weakened.

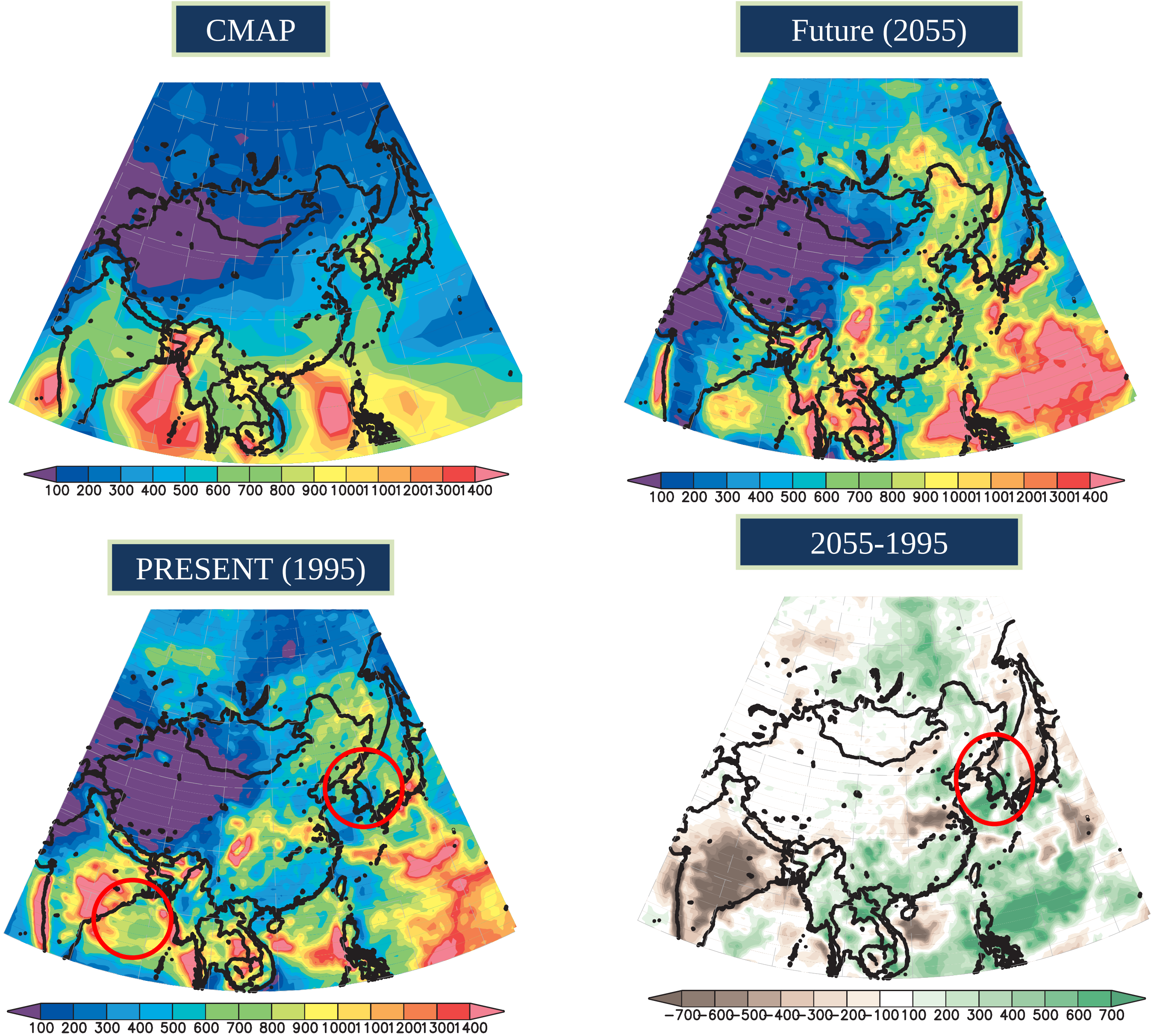
❖Simulations under high resolution showed consistent systematic bias of the 50-km RSM with detailed features and evolution of synoptic scale features was preserved.

→ ***These aspects enable us to ascertain credibility of the downscaled scenarios produced by the multi-nested system designed in this study!!.***

Future Climate Scenarios

- *Changes in hydro-climate and monsoonal circulations between the present and future summers*

50-km RSM: JJA (from June to August) precipitation

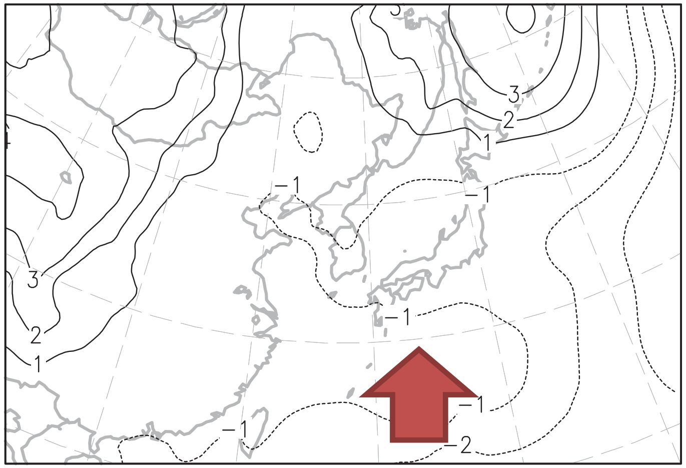


The location of major precipitation bands remains unchanged.

The increase: over much of the Asian continent including South Korea and Philippines
The decrease: over Indian region, North Korea, Northern Japan, Yangtze river basin.

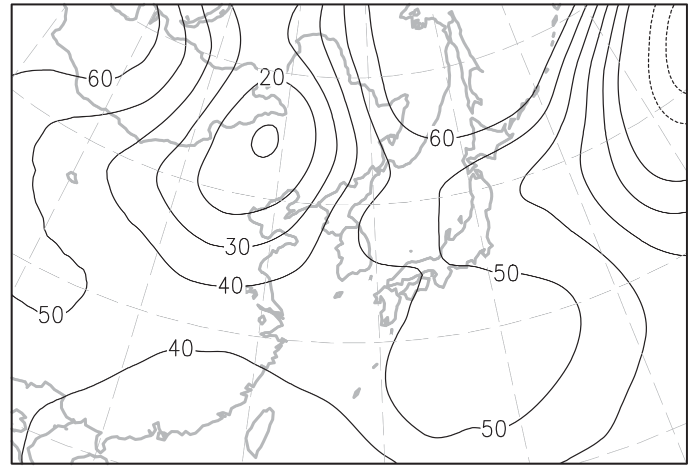
50-km RSM: Changes in Basic Fields (2055-1995)

Sea Level Pressure



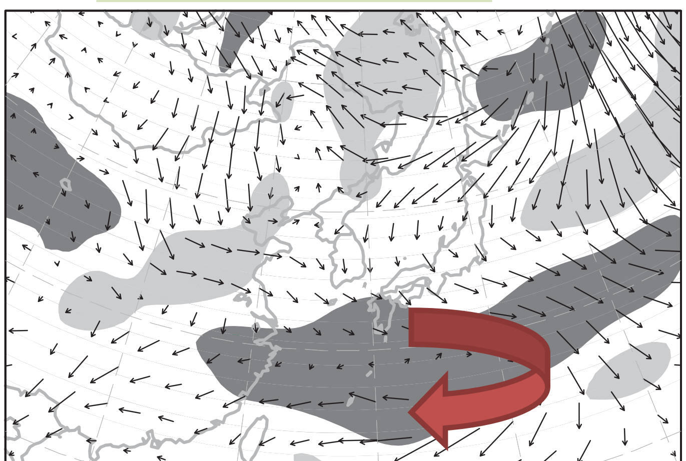
Enhanced precipitation results in the lowering sea level pressure.

500-hPa geopotential height

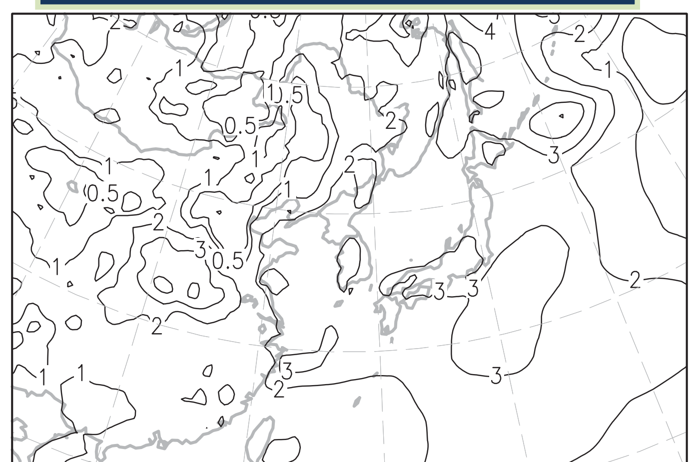


Increase of geopotential height due to the warming climate, indicating strengthened EASM

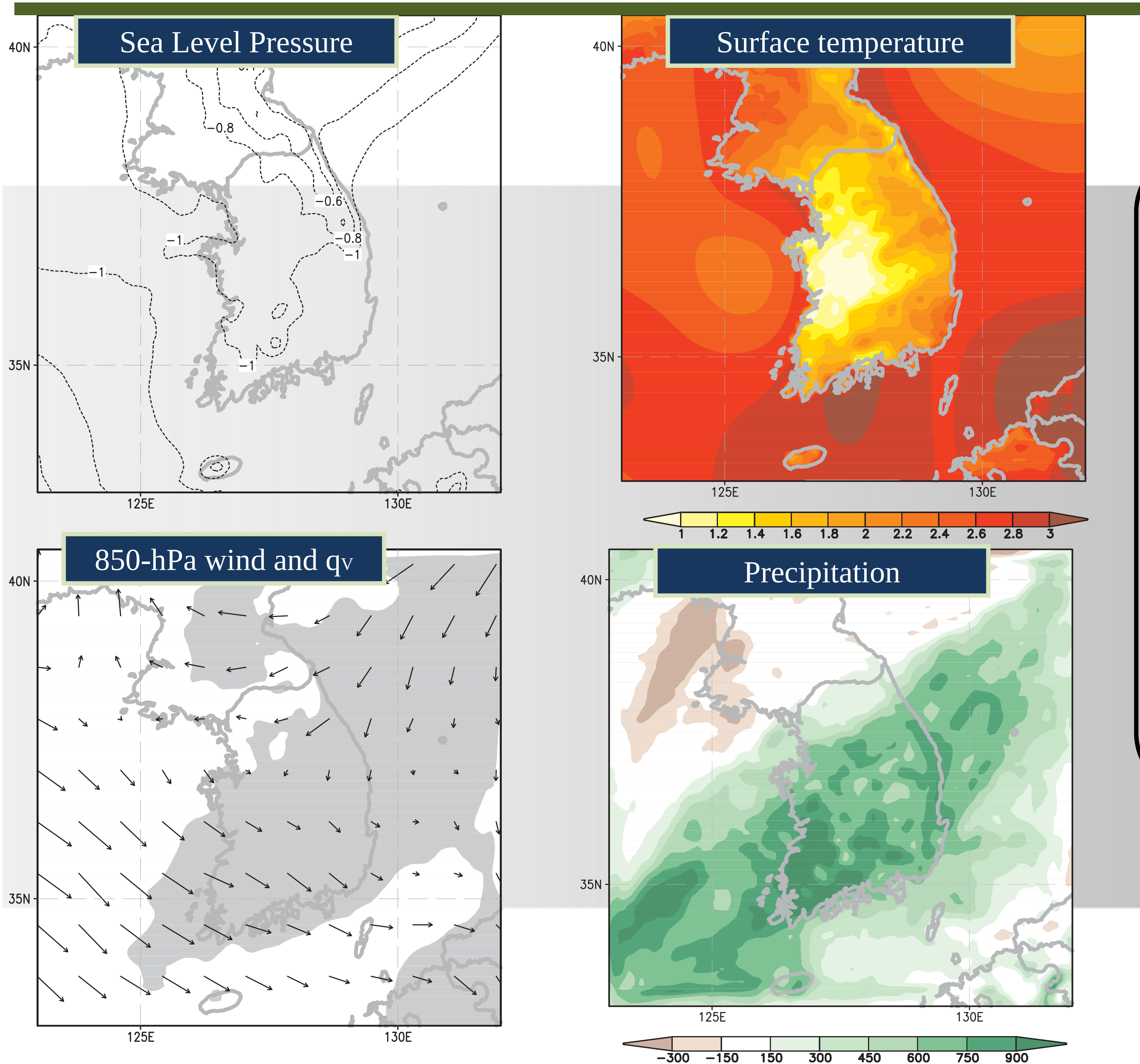
850-hPa wind and qv



Surface temperature



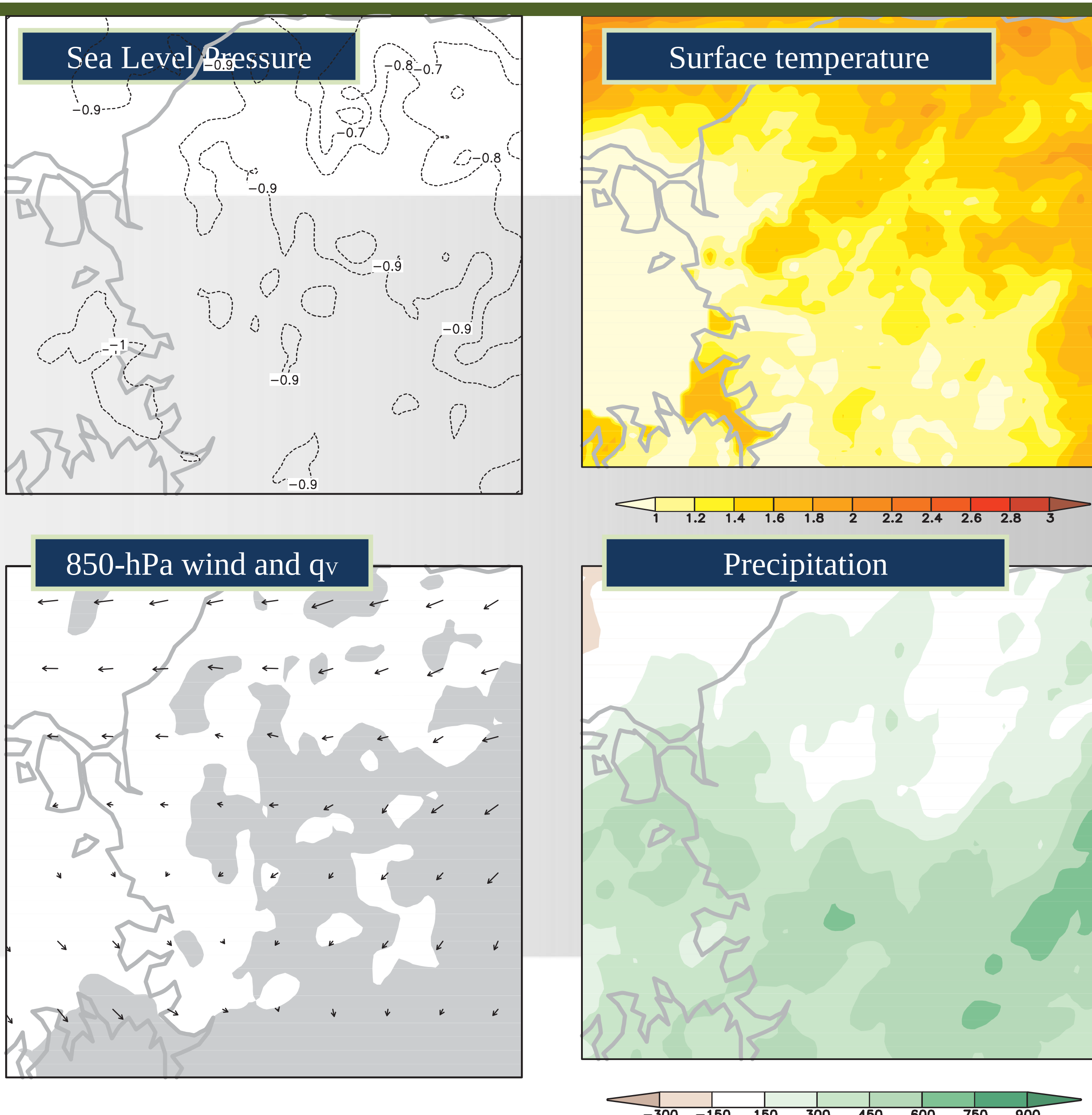
12-km WRF: Changes in Basic Fields (2055-1995)



The Changing trend is in the same direction, compared to the 50-km RSM simulation.

However, more detailed regional features are revealed in the 12-km WRF simulation.

3-km WRF: Changes in Basic Fields (2055-1995)



Similar to results in the 12-km simulations, but with more detailed features in response to the high-resolution orography.

Future Climate Scenarios

❖Changes in summer monsoon circulations between 1995 and 2055 include the lowering sea level pressure and overall increase of 500 hPa geopotential height , accompanied by a increase in precipitation.

❖12-km and 3-km WRF results show scenarios similar to those in 50-km RSM simulation, but with further detailed regional features in response to the high-resolution orography.

→ *It is not possible to validate the scenario at a city scale, but we assume that the downscaled scenarios do not suffer from a discernible systematic error.*

Concluding Remarks

We have examined the possibility of constructing a cloud-resolving future summer climate change scenario for the Korean peninsula using a multi-nested downscaling system.

- The dynamic frame of the RSM inherently suppress the large-scale bias through the perturbation method as well as the spectral nudging method; however, new efforts need to be made toward the mathematical refinement of lateral boundary conditions.
- Although this pilot study reveals the possibility of a cloud-resolving scale scenario, our results should be expanded with multi-year climatology for both present and future climates.
- Air-pollution assessments using the community multi-scale air quality (CMAQ) model are currently being conducted and will be reported soon.

Thanks for your attention!