D3831, EGU2020-15161

2020 EGU General Assembly (CL4.12: regional climate modeling, including CORDEX)

Evaluation of MM5 and HadGEM3-RA hindcast in the CORDEX East Asia Phase Ⅱ: near-surface air temperature

Seok-Woo Shin[1], Dong-Hyun Cha[1], Taehyung Kim[1], Gayoung Kim[1], Changyoung Park[1], Minkyu Lee[1], Young-Hwa Byun[2], and Hyun-suk Kang[3]

1 High-impact weather prediction lab.

2 Innovative meteorological research department

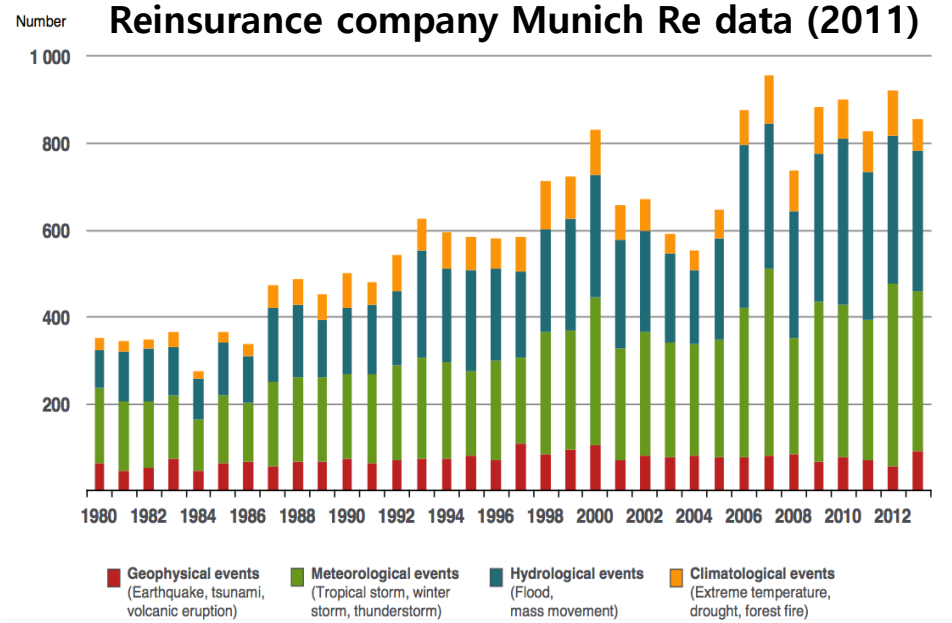
3 Numerical model development division

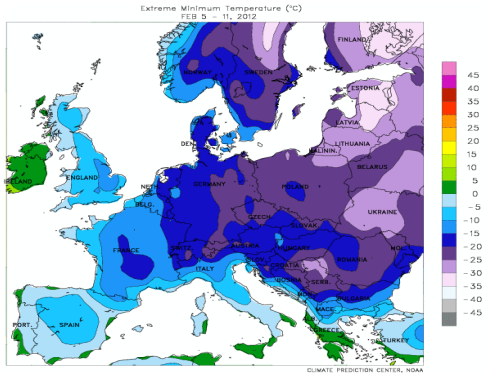
1

Contents

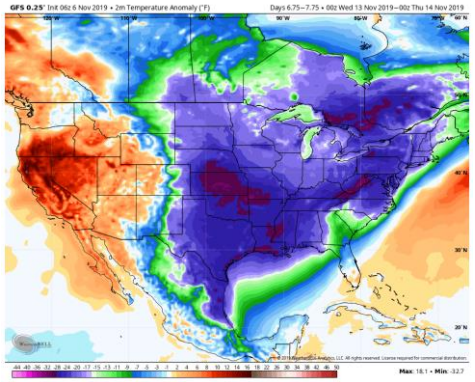
Introduction and research background

✓ Extreme temperature can have a devastating impact on the ecological environment (i.e., human health and crops) and the socioeconomic system.





Early 2012 European cold wave (CPC, NOAA)

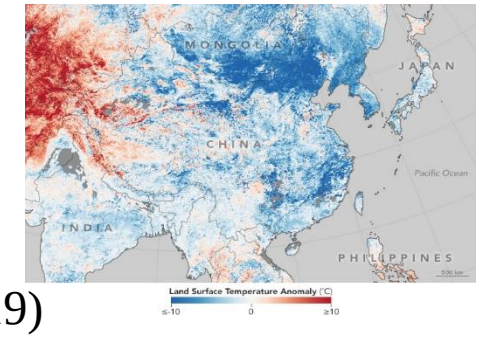


6 Nov 2019 Arctic blasts surge south (GFS 0.25degre)

✓ The frequency of annual disasters is indeed rising.

(Drought)

(Bush fire related to heat wave, 2019)



January 2016 East Asia cold wave (MODIS dat on NASA's Terra satellite)

Introduction and research background

✓ High-resolution models are especially useful tools to study the effects of human activities on regional and local climates (Gutowski *et al.*, 2016).

✓ The World Climate Research Programme (WCRP) established in 2009 the Task Force for Regional Climate Downscaling (TFRCD), which created the Coordinated Regional Climate Downscaling Experiment (CORDEX) initiative to generate regional climate change projections for all terrestrial regions of the global within the timeline of the Fifth Assessment Report (AR5) and beyond.

✓ CORDEX-East Asia is the East-Asian branch of the CORDEX initiative and National Institute of Meteorological Science (NIMS)/ Korea Meteorological Administration (KMA) organized the three RCM projects for the projection of regional climate over **1) CORDEX-East Asia (50km: 2010-2011), 2) Korean Peninsula (12.5km: 2012-2014), and 3) CORDEX-East Asia (25km: 2015-present).**

✓ To adapt to and cope with the rapidly changing climate, it is essential to understand the present climate and to estimate the future change in terms of temperature.

Research objective

We evaluate the characteristics of near-surface air temperature (SAT) simulated by two regional climate models (i.e., MM5 and HadGEM3-RA) over East Asia, focusing on the mean and extreme values.

Experimental setup, data, and methodology

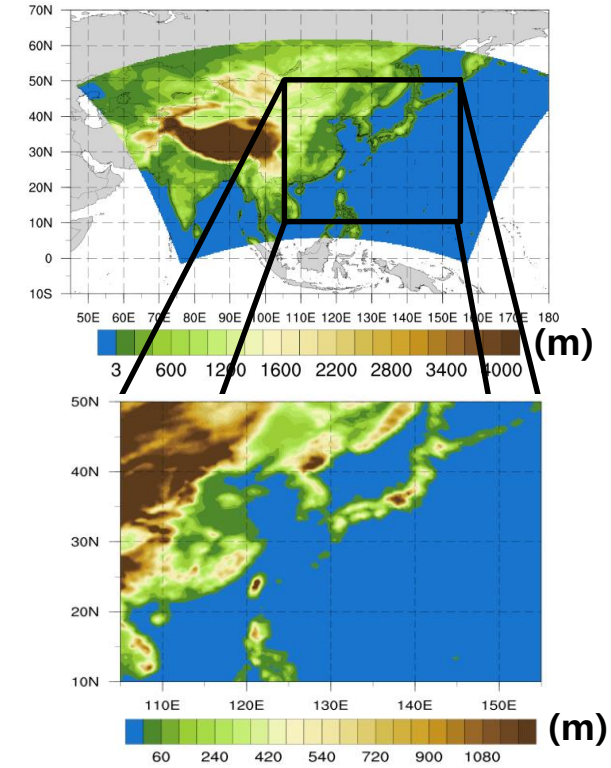
Configurations of RCMs used

CORDEX-EA Ⅱ (25km: 2015-present) | **CORDEX-EA Ⅰ (50km: 2010-2011)**

	HadGEM3RA	SNURCM (MM5)
Institution	Korea Meteorological Administration	Ulsan National Institute of Science and Technology (Seoul National Univ.)
Number of grids (Lat. × Lon.)	251×396 (183×220)	260×405 (197×233)
Horizontal resolution	~25 km (~50 km)	
Vertical coordination (top)	63 hybrid height (38 hybrid height)	24 sigma (24 sigma)
Experiment Period And forcing data	Evaluation data forced by **ERA-Interim**: 1989–2008	
Radiation	General 2-stream	CCM2 package
Microphysics (cloud)	Single moment bulk scheme	Reisner II
Convection	Revised mass flux	Kain-Fritch II
Non-local PBL	Nonlocal mixing scheme for unstable layers (Lock *et al.*, 2000)	YSU
Land surface model	JULES (Best *et al.*, 2011; Clack *et al.*, 2011) (MOSES II)	CLM3
Spectral nudging	No	Yes
Reference	Davies *et al.* (2005)	Lee *et al.* (2004)

Domain and analysis region

(lat.: 10.0°E-50.0°E, Lon.: 75.0°E-145.0°E)



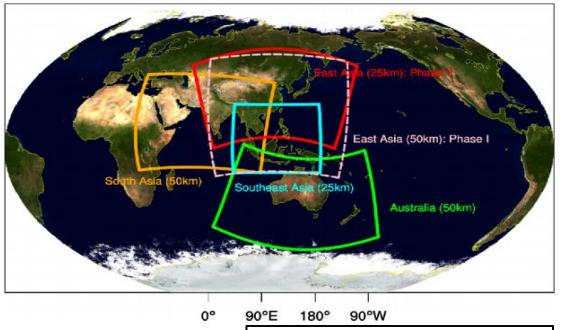


Fig. 1. CORDEX domains Asia-Pacific Region.

Kang *et al.*, 2016

Experimental setup, data, and methodology

Analysis variables

Acronym	Full name	Unit
SAT	Near surface air temperature	K
tasmax	Daily maximum near-surface air temperature	K
tasmin	Daily minimum near-surface air temperature	K
gph	Geopotential height	m
Ua	Zonal wind	$m\ s^{-1}$
Va	Meridional wind	$m\ s^{-1}$
psl	Mean sea level pressure	hPa
prc	Convective precipitation	$mm\ d^{-1}$
rsds	Surface downwelling shortwave radiation	$W\ m^{-2}$
rsus	Surface upwelling shortwave radiation	$W\ m^{-2}$
rlds	Surface downwelling longwave radiation	$W\ m^{-2}$
rlus	Surface upwelling longwave radiation	$W\ m^{-2}$

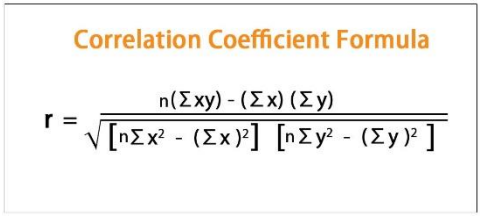
Statistics to assess model performance in hindcast data

Bias: $MB = \frac{1}{n}\sum_{i=1}^{n}(S_i - O_i);$

RMSE: root-mean-square error

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}}.$$

TCC: temporal correlation coefficient



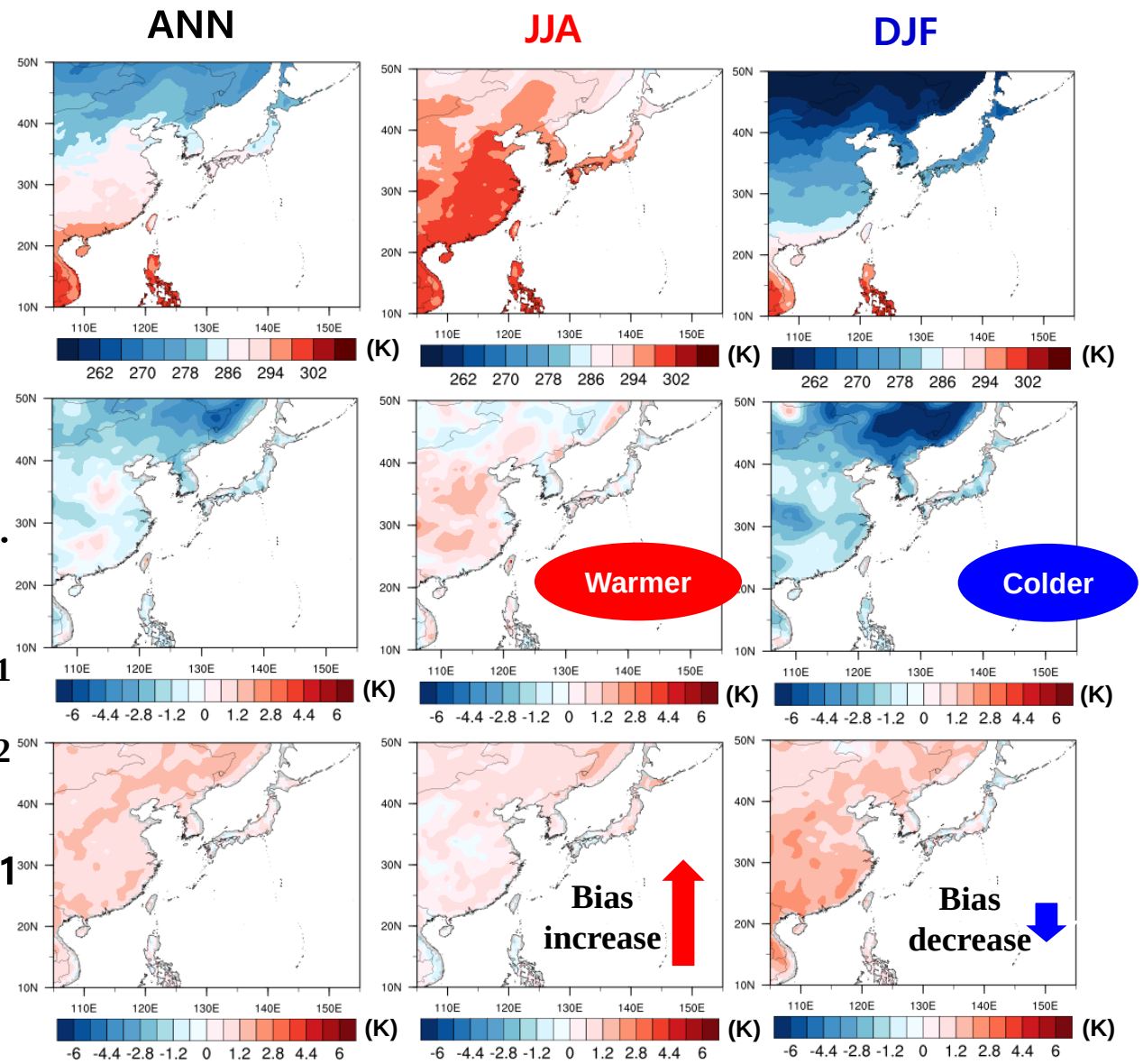
***Validation data:**
APHRODITE (Yatagai *et al.*, 2012)
ERA-Interim (Dee *et al.*, 2011)
ISCCP (Bishop, 1994; Seager, 1994)

Variables used in ETCCDI

ID	Name	Definition	Unit
TXx	Hottest day	Seasonal maximum value of daily maximum temperature	ºC
TNn	Coldest night	Seasonal minimum value of daily minimum temperature	ºC
ETR	Extreme temperature range	TXx minus TNn	ºC

Result 1: climatological mean

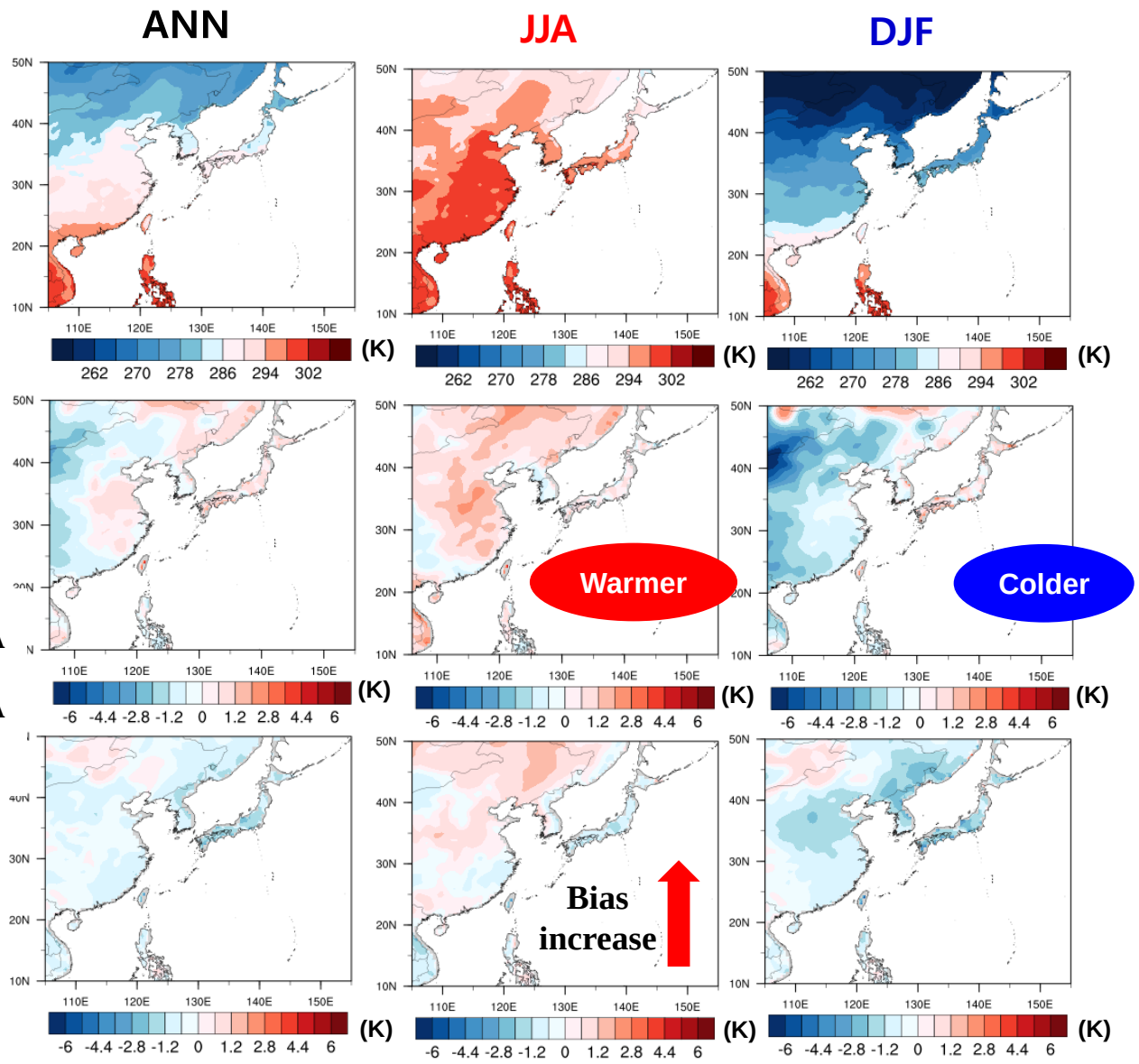
Spatial distribution of SAT averaged for 1989-2008 (20 years) and their difference



- The limitation of MM5 by the inaccuracies in the land use and terrain information as well as limitations of model treatments (e.g., PBL and land-surface schemes) at a fine grid scale (Miao *et al.*, 2007; Zhang *et al.*, 2011)

Result 1: climatological mean

Spatial distribution of SAT averaged for 1989-2008 (20 years) and their difference

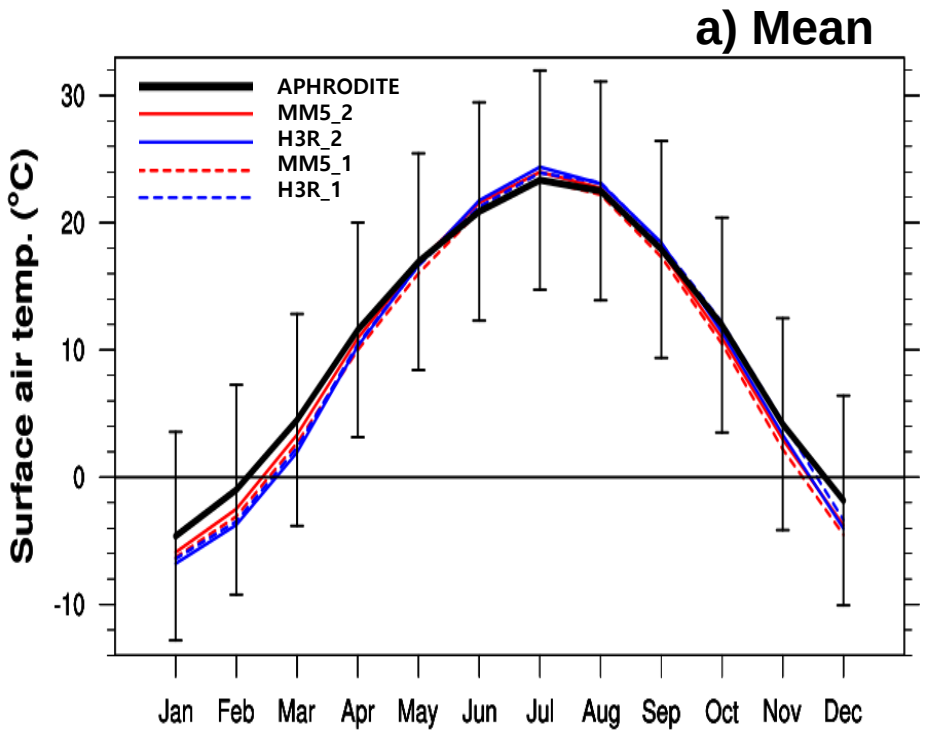


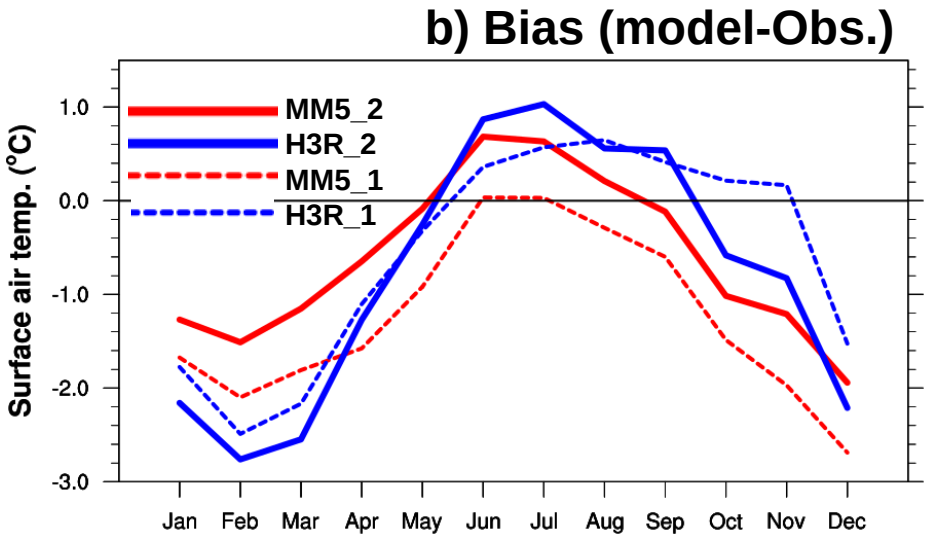
*H3R_1: HadGEM3-RA in CORDEX Phase 1
*H3R_2: HadGEM3-RA in CORDEX Phase 2

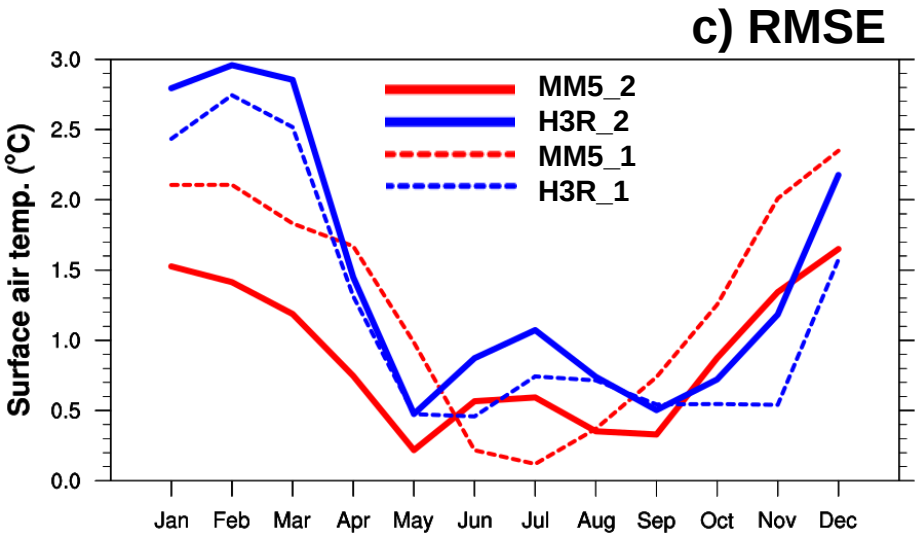
- The limitation of HadGEM3 having cold bias over East Asia (Kim *et al.*, 2016; Suh *et al.*, 2016; Christianson 2016; Ciavarella *et al.*, 2018)

Result 1: climatological mean

Statistics of SAT for 1989-2008 (20 years) over East Asian region

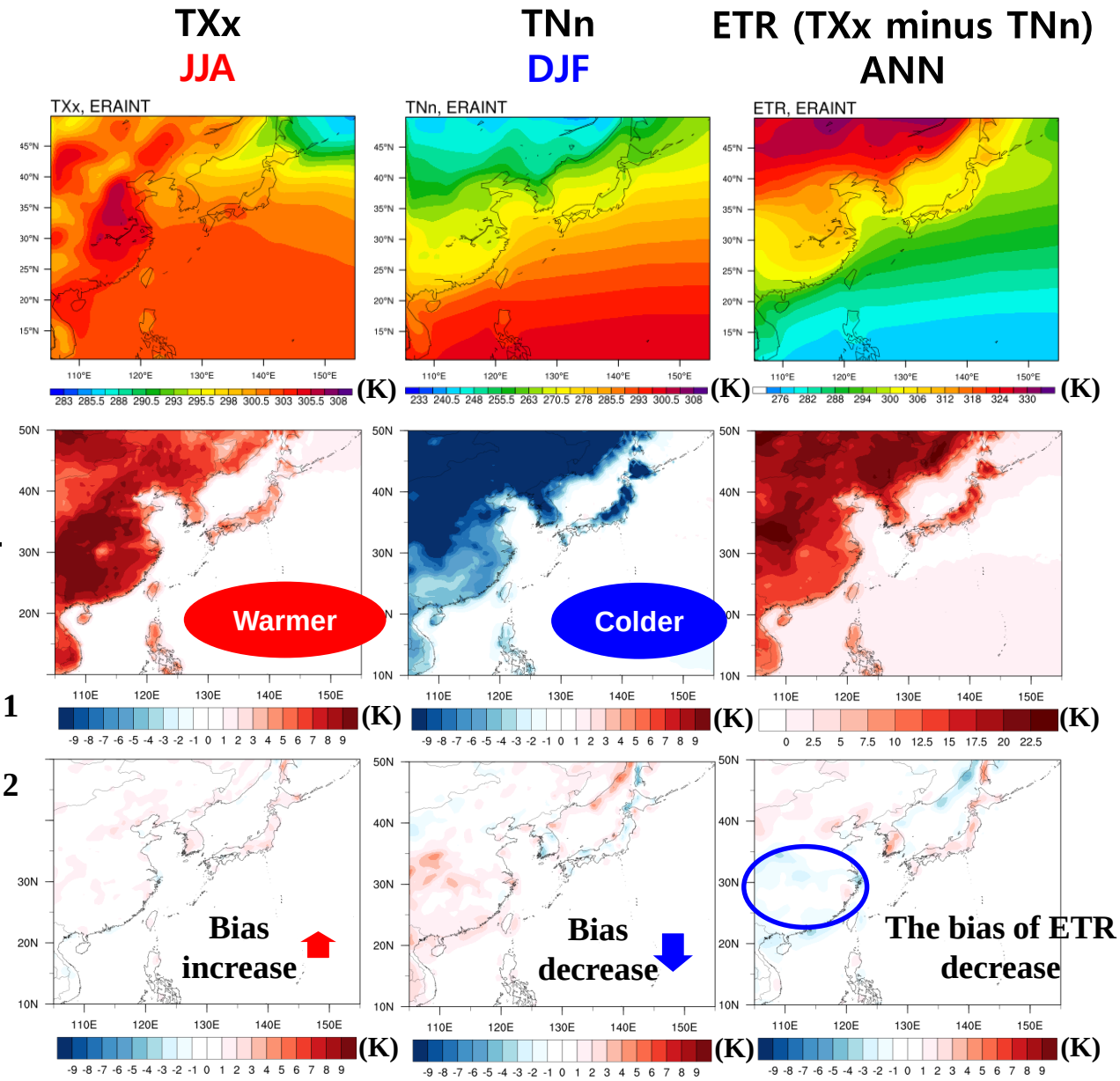






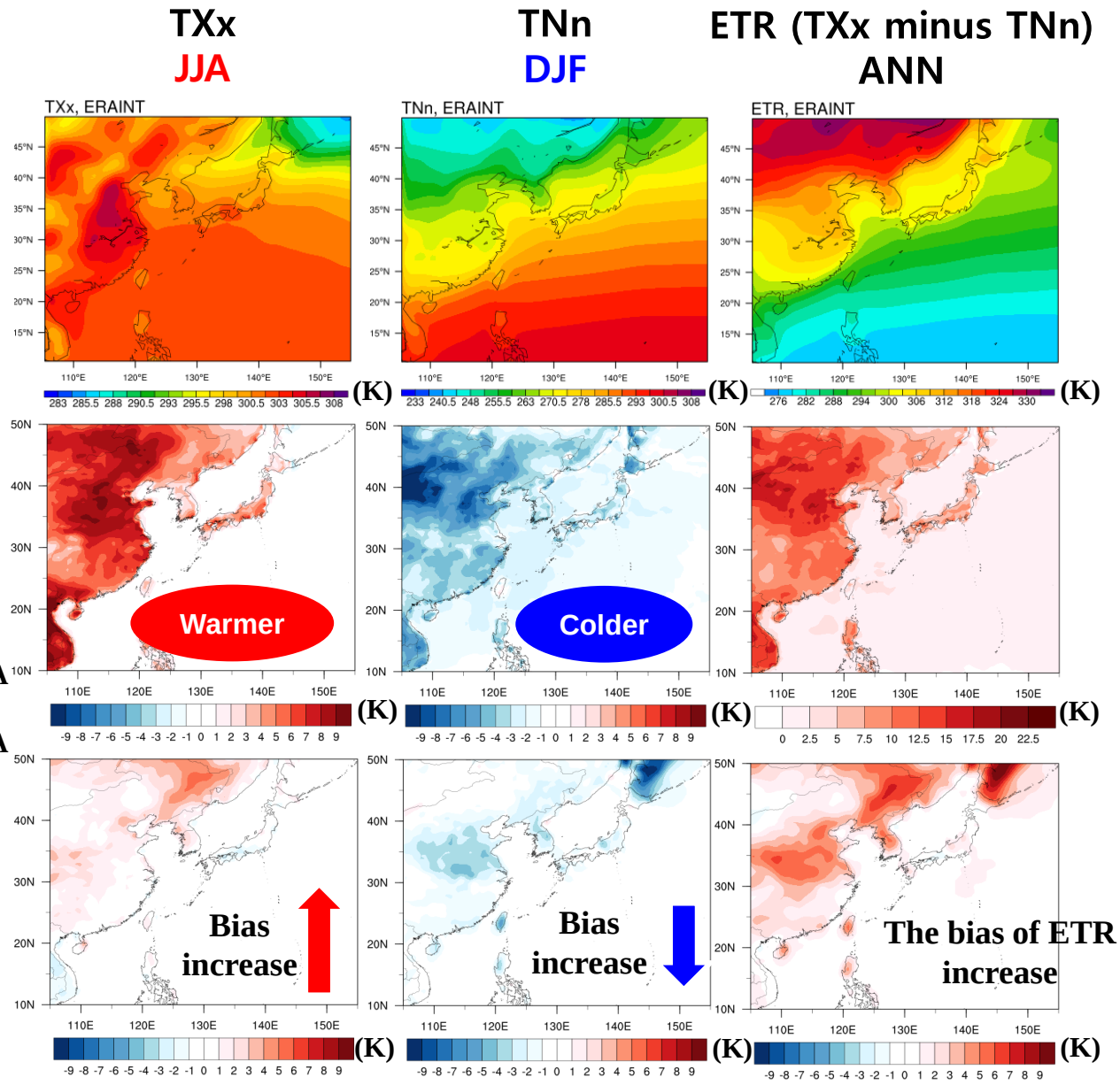
- The annual cycle simulated by RCM over East Asia and shown in previous studies (Kim *et al.*, 2016; Suh *et al.*, 2016; Chen *et al.*, 2019; Yu *et al.*, 2020).
- The cold biases of MM5 are reduced from phase 1 to phase 2, except for those in summer.
- The warm or cold biases of HadGEM3-RA are not apparently improved changing phase 1 to phase 2.
- A wide range of SAT of H3R is larger than that of MM5 at the result of RMSE.

Result 2: extreme



- The spatial distribution of SAT extreme is significantly related to that of climatological mean of SAT. (Zhang *et al.*, 2009)
- The bias results of MM5 are reduced from phase 1 to phase 2, except for TXx.

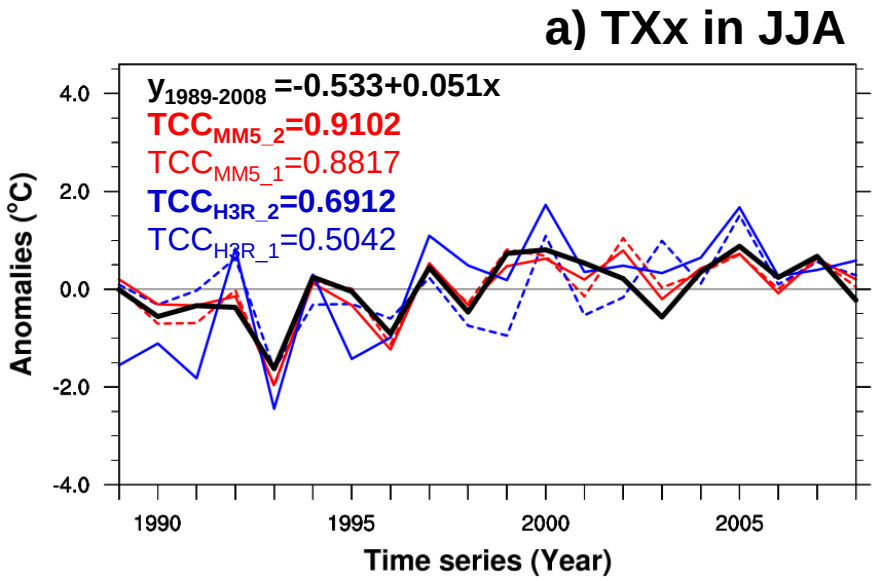
Result 2: extreme

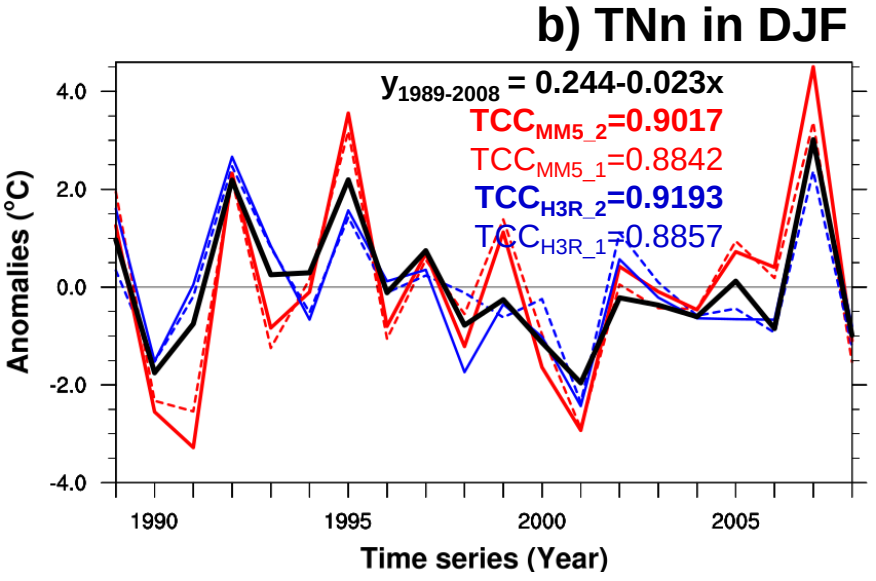


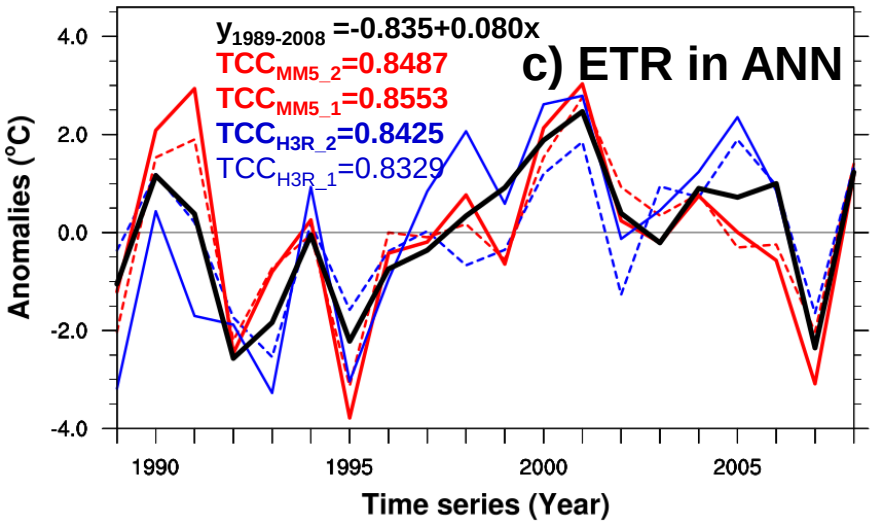
- The spatial distribution of SAT extreme is significantly related to that of climatological mean of SAT. (Zhang *et al.*, 2009)
- The bias results of H3R are increased from phase 1 to phase 2, particularly, more than those of MM5.

Result 2: extreme

Interannual variation of TXx anomalies for JJA, TNn anomalies for DJF, and ETR anomalies for ANN over East Asian region







***Temporal Correlation Coefficient: TCC (Yu *et al.*, 2020)**

ERAINT
MM5_2
H3R_2
MM5_1
H3R_1

Linear regression equation (without error)

$$\hat{Y} = bX + a$$

$\hat{Y}$: predicted values of Y; b = slope = rate of predicted T/F for Y scores for each unit increase in X; a: Y-intercept = level of Y when X is 0

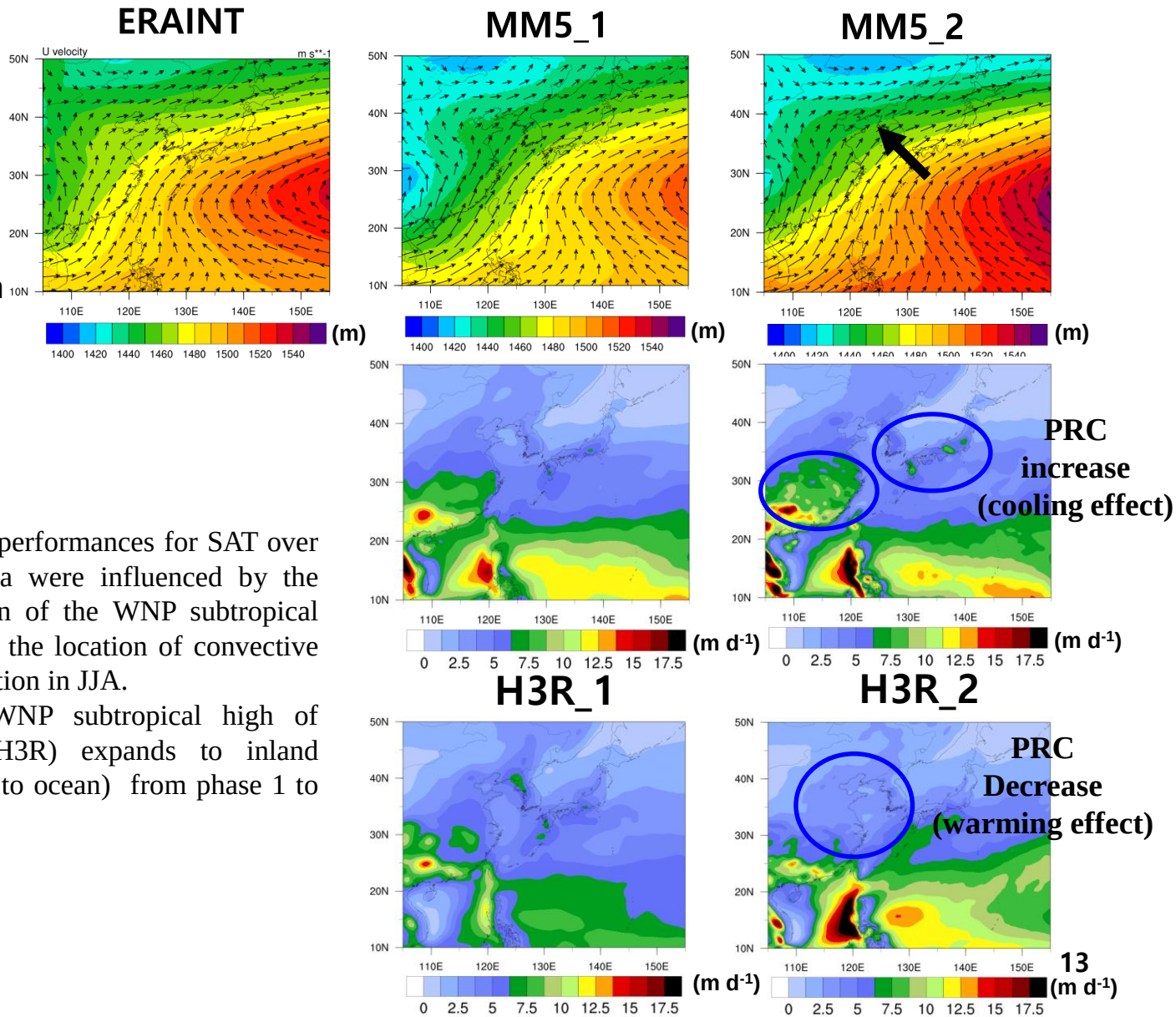
- The interannual variations of TXx and TNn are apparently improved from phase 1 to phase 2, except for those of ETR using MM5.
- The results of TXx in JJA simulated by MM5 using Spectral Nudging (SN) method are better than those by H3R not using SN method.

Result 3: additional analysis of sources related to SAT

Spatial distribution of the atmospheric field associated with SAT in JJA over East Asian region

Ua850 (vector)
Va850 (vector)
GPH850 (shading)

The definition of the Western North Pacific (WNP) subtropical high: Du *et al.*, 2017



PRC

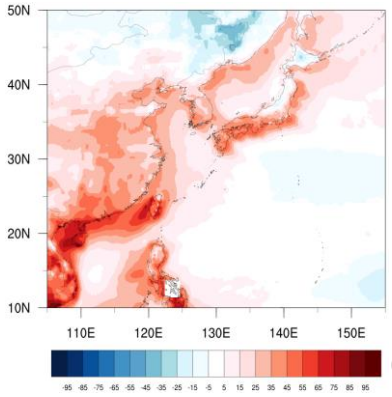
- Model performances for SAT over East Asia were influenced by the expansion of the WNP subtropical high and the location of convective precipitation in JJA.
- The WNP subtropical high of MM5 (H3R) expands to inland (reduces to ocean) from phase 1 to phase 2.

PRC

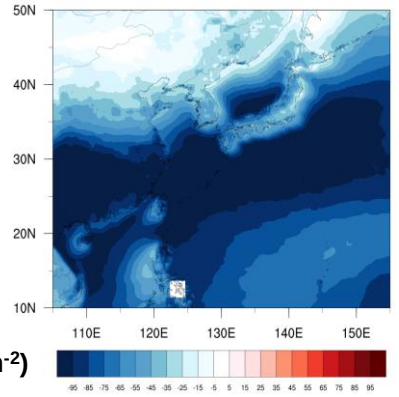
Result 3: additional analysis of sources related to SAT

Spatial distribution of the atmospheric field associated with SAT in DJF over East Asian region

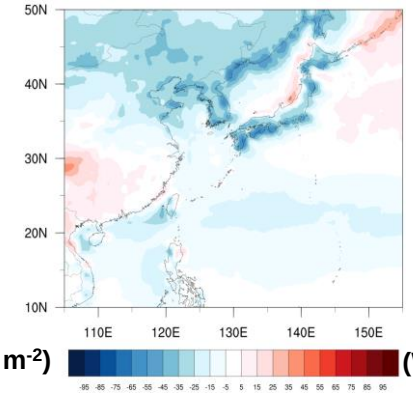
rsds: MM5_2-ISCCP



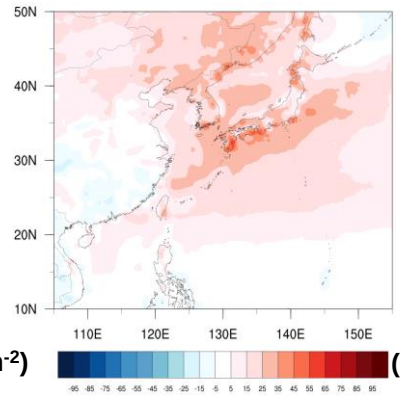
rsus: -(MM5_2-ISCCP)



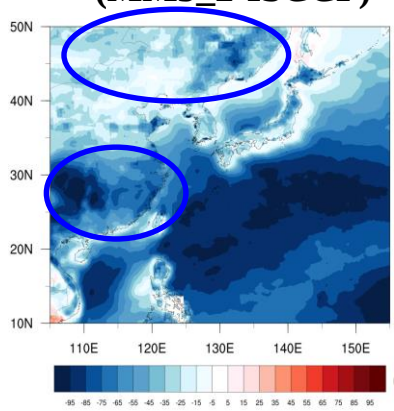
rlds: MM5_2-ISCCP



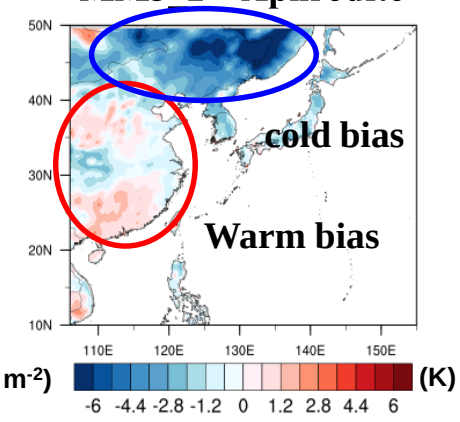
rlus: -(MM5_2-ISCCP)



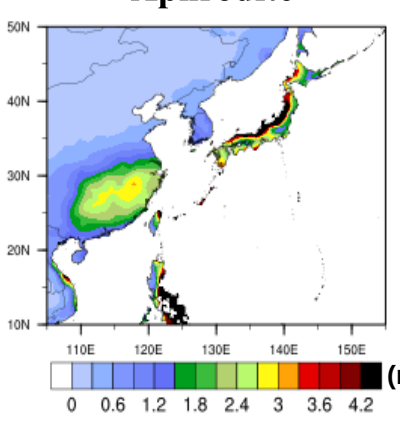
Net radiation=rsds+rsus+rlds+rlus (MM5_2-ISCCP)



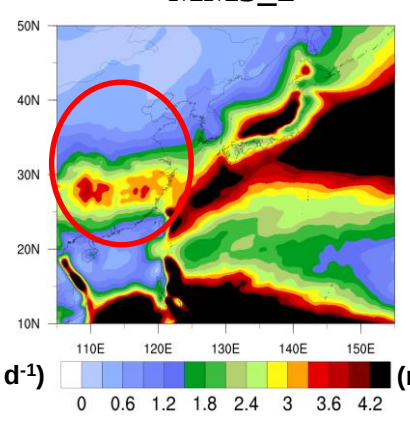
tas MM5_2 – Aphrodite



Precipitation Aphrodite



Precipitation MM5_2



- The biases of SAT between MM5_2 and observation data are associated with precipitation and net radiation of shortwave and longwave in DJF over East Asian region.

Summary and future plans

- ✓ In this study, we evaluate the characteristics of near-surface air temperature (SAT) simulated by two regional climate models (i.e., MM5 and HadGEM3-RA) over East Asia, focusing on the mean and extreme values.
- ✓ In the results of the CORDEX-East Asia phase I, the mean and extreme values of SAT for DJF (JJA) tend to be colder (warmer) than observation data over the East Asian region.
- ✓ In those of CORDEX-East Asia phase II, the mean and extreme values of SAT for DJF and JJA have warmer than those of the CORDEX-East Asia phase I except for those of HadGEM3-RA for DJF.
- ✓ Furthermore, the Extreme Temperature Range (ETR, maximum value of Tmax - minimum value of Tmin) of CORDEX-East Asia phase I data, which are significantly different from those of observation data, are reduced in that of CORDEX-East Asia phase II.
- ✓ Consequently, the high-resolution regional climate models play a role in the improvement of the cold bias having the relatively low-resolution ones.
- ✓ To understand the reasons for the improved and weak points of regional climate models, we investigated the atmospheric field (i.e., flow, air mass, precipitation, and radiation) influencing near-surface air temperature.
- ✓ Model performances for SAT over East Asia were influenced by the expansion of the western North Pacific subtropical high and the location of convective precipitation in JJA
- ✓ The biases of SAT between MM5_2 and observation data are associated with precipitation and net radiation of shortwave and longwave in DJF.
- ✓ We need the additional research understanding the source of SAT to improve the performance of RCMs.

Thank you for your attention!

Acknowledgments

This study was funded by the Korea Meteorological Administration Research and Development Program under KMI2018-01211.