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Evaluation of CORDEX experiment for East Asia with HadGEM3-RA

Suhee Park, Hyun-Suk Kang, and ChunHo Cho

National Institute of Meteorological Research (NIMR)/KMA

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Introduction

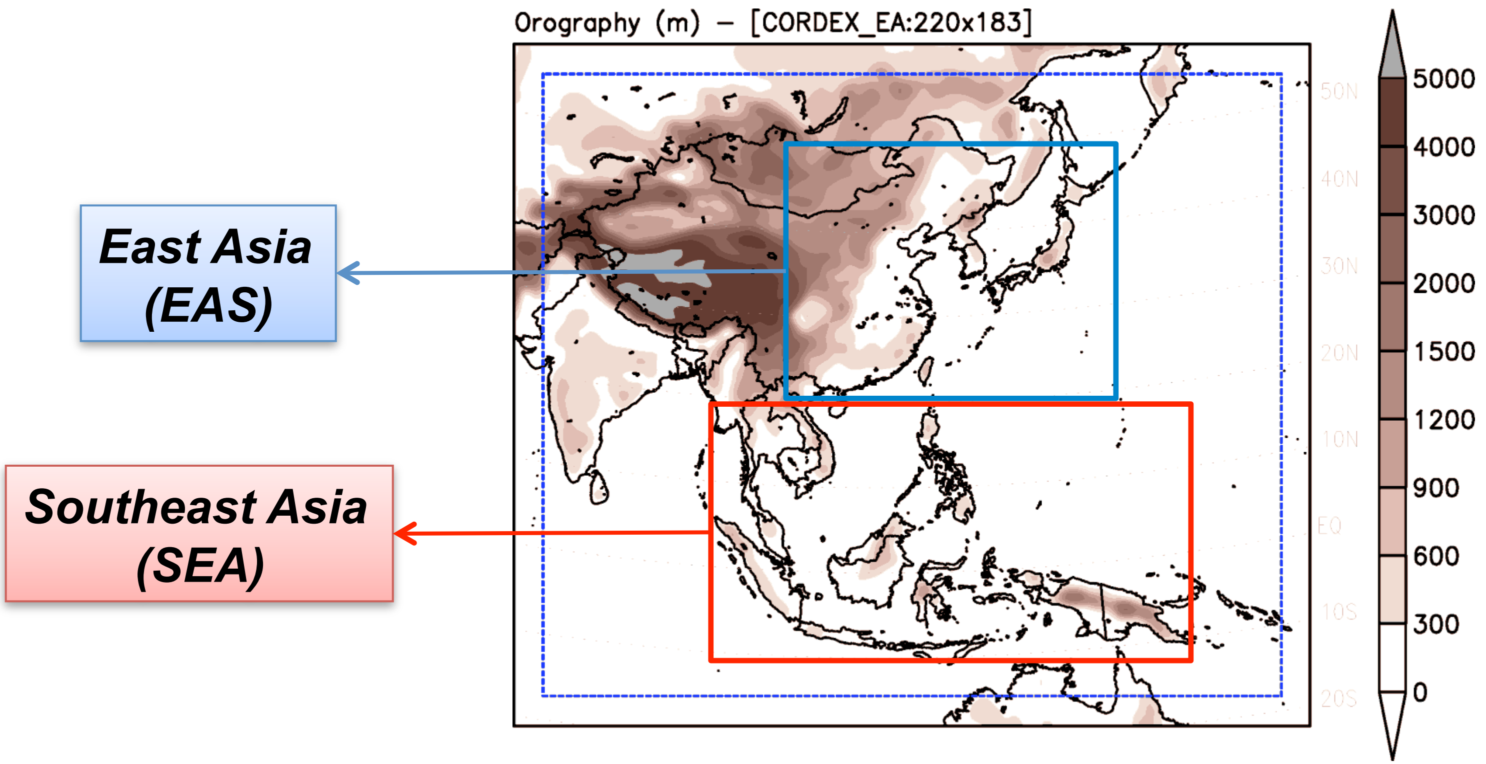
- UM-based regional climate modeling in KMA
  - KMA is using the UM-regional model for dynamical downscaling over the East Asian region according to the collaboration agreement between Korea Meteo rological Administration (KMA) and Met Office (2008).
  - HadGEM3-RA (vn7.6) is being used as a main tool of dynamical downscaling for both CORDEX (50-km) domain over the East Asian region and high resolu tion (12.5 -km) domain around the Korean peninsula.

- Status and Plan for the CORDEX project
  - ERA-Interim forcing experiment (1989~2008): Done
    - Met Office Hadley Centre kindly provided the ERA-Interim LBC data and various pat ch code for regional climate run.
  - HadGEM2-AO's historical run forcing experiment (1950~2005)
  - HadGEM2-AO's RCP 3/4.5/6/8.5 run forcing experiment (2006~2100)

- Goal of this talk
  - To evaluate the dynamical downscaling ability of HadGEM3-RA over the East Asian region based on the ERA-Interim forcing experiment

Experiment Design: CORDEX-East Asia domain

- Model domain : Region 7 - East Asia in CORDEX domains
  - RotPole (295.22; 77.61), TLC (319.08; 46.20), Nx=203, Ny=167, resolution=0.44 deg



- CORDEX-EA domain and orography (m) with buffer zone.

- Lateral boundary condition: ERA-Interim data
- Simulation period: 1989 ~ 2008 (20 years)

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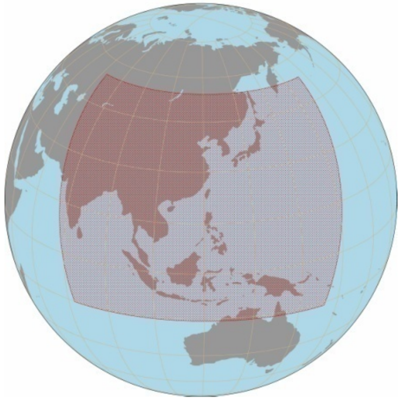
Model description

❖ Regional climate model: HadGEM3-RA



➢ A regional atmospheric model based on the global atmospheric model, HadGEM3, of the Met Office Hadley Centre

▪In this study, a proto-type configuration of HadGEM3-RA was used.

		Description
Dynamics		Non-hydrostatic, Arakawa-C grid (horizontal) and Charney-Phillips grid (vertical), semi-Lagrangian advection, conservative monotone treatment of tracers, semi-implicit time integration (Davies et al. 2005)
Physics	**Radiation**	General 2-stream radiation (Edwards and Slingo 1996; Cusack et al. 1999a)
	Boundary layer	Nonlocal mixing scheme for unstable layers (Lock et al. 2000). Local number scheme for stable layers (Smith 1990)
	Microphysics	Mixed phase scheme including prognostic ice content; solves physical equations for microphysical processes using particle size information (Wilson and Ballard 1999)
	Convection	Revised mass flux scheme from Gregory and Rowntree (1990) including triggering of deep and shallow cumulus convection based on the boundary layer scheme and parameterized entrainment/detrainment rates for shallow convection (Grant and Brown 1999)
	Gravity wave drag	Orographic scheme including flow blocking (Webster et al. 2003)
	Land surface	MOSES-II (Essery et al. 2003); nine surface tile types plus coastal tiling

Evaluation results 1

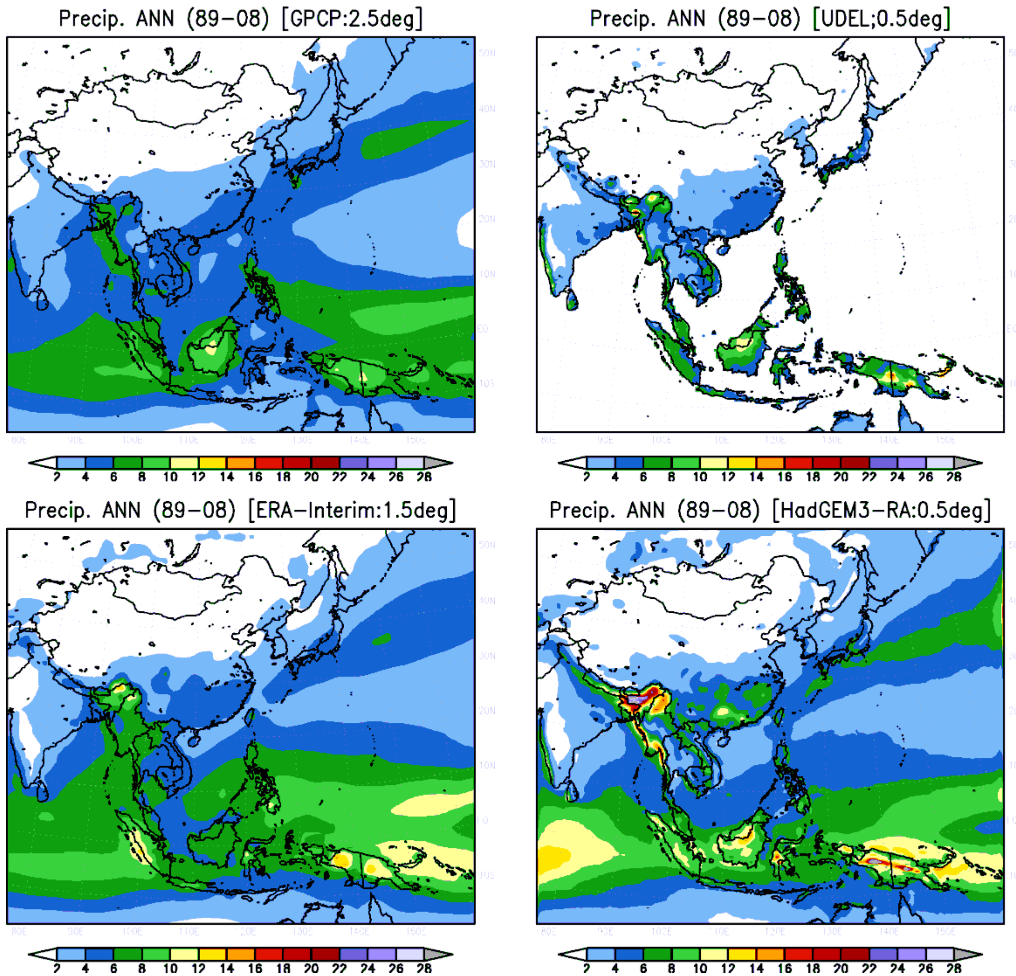
- Mean surface climate

Performance: Precipitation

❖ 20-yr mean annual precipitation (1989~2008)

Observation
GPCP

Observation
UDEL



ERA-Interim

HadGEM3-RA

▪GPCP: Global Precipitation Climatology Project; monthly, 2.5x2.5
▪UDEL: the University of Delaware precipitation (v.2.01); monthly, 0.5x0.5

- The precipitation distributions of both ERA-Interim and HadGEM3-RA are similar to observation.
- HadGEM3-RA could resolve small-scale features.

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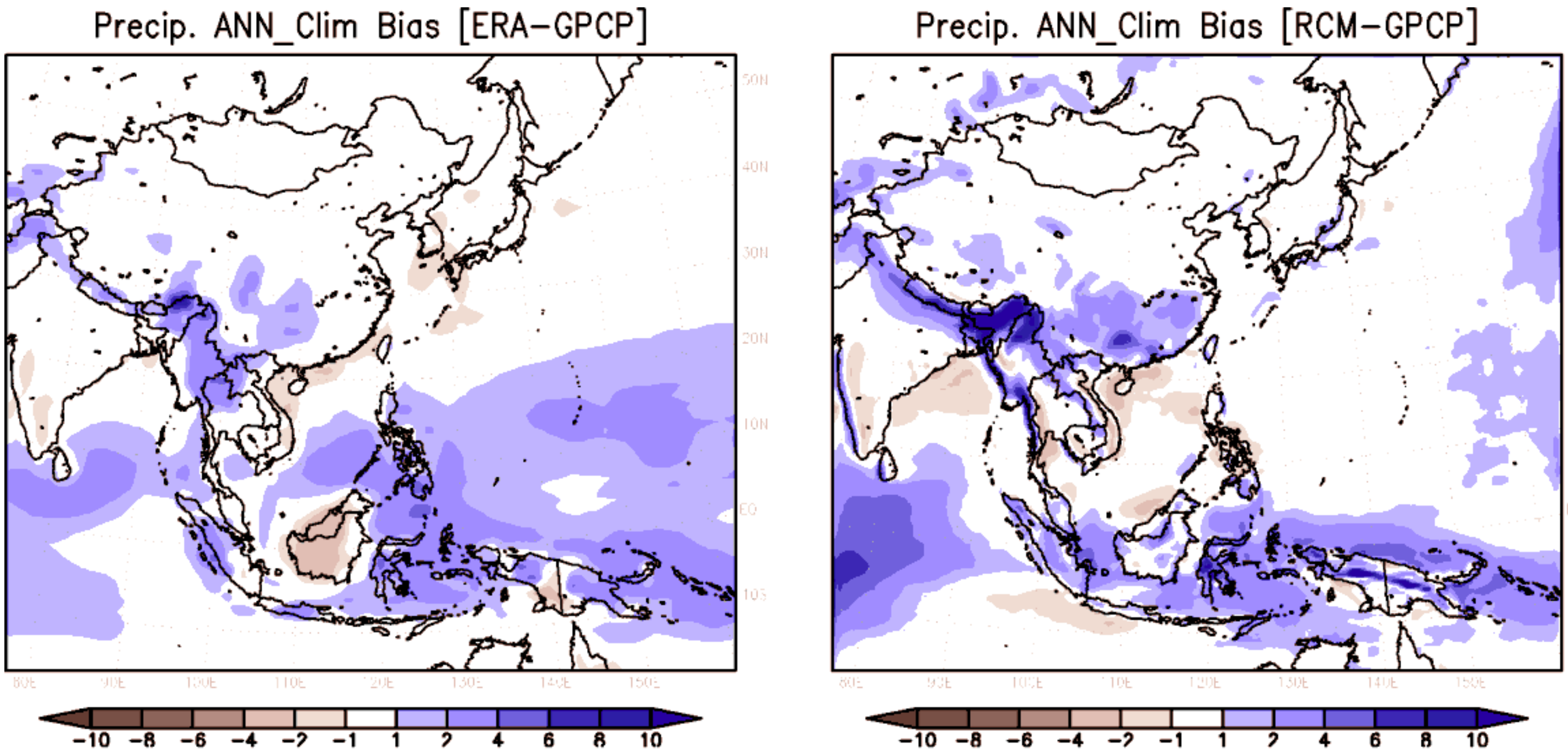
Performance: Precipitation bias

❖ Difference of 20-yr mean annual precipitation from observation

ERA - GPCP

RCM - GPCP

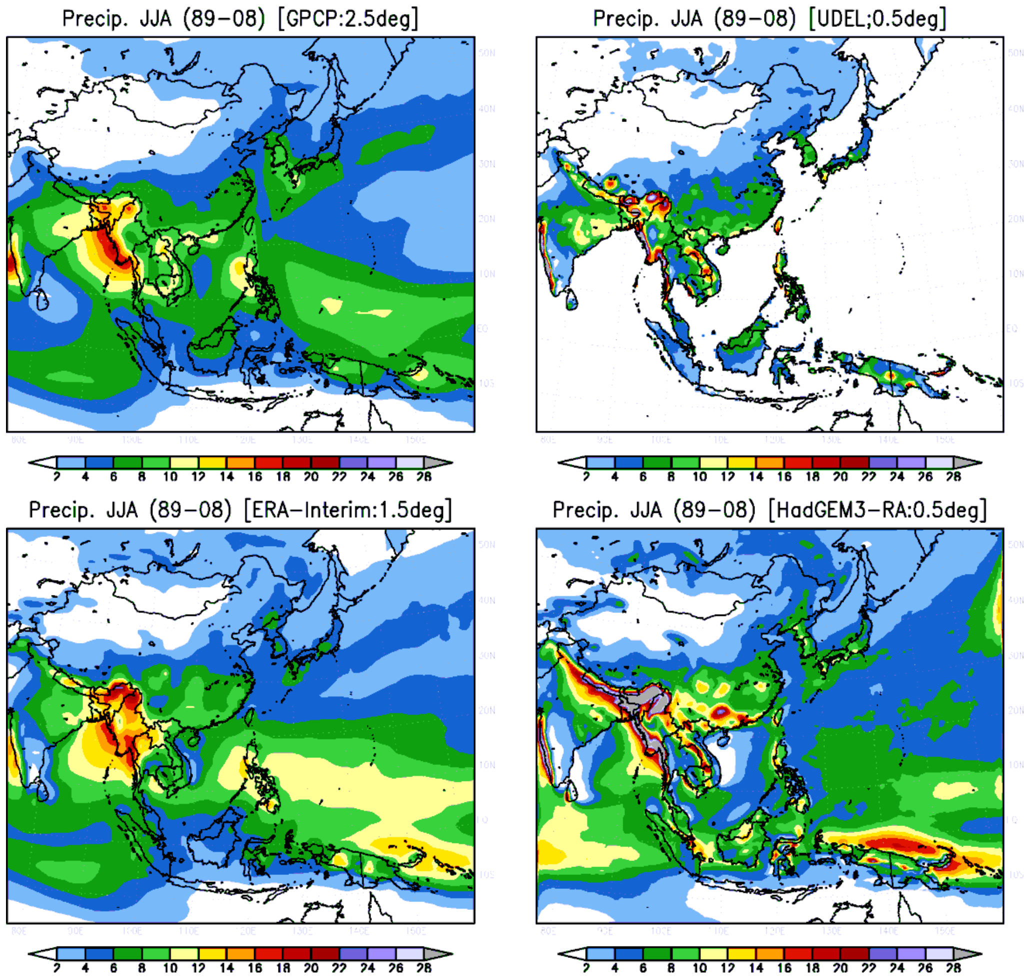


Performance: Precipitation

❖ 20-yr mean summer precipitation (JJA 1989~2008)

Observation GPCP

Observation UDEL



ERA-Interim

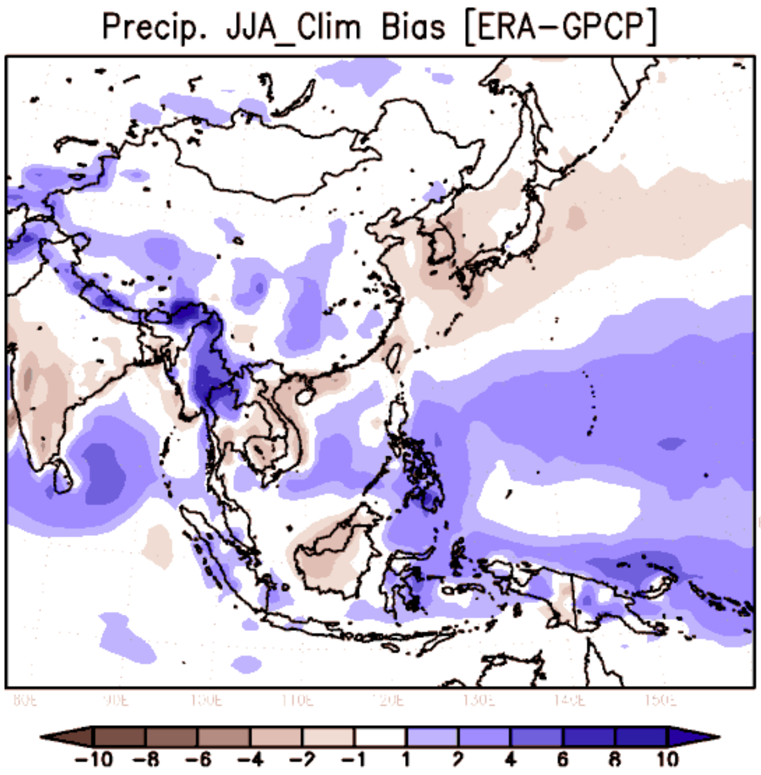
HadGEM3-RA

- The precipitation distributions of both ERA-Interim and HadGEM3-RA are similar to observation.
- It is clear that the HadGEM3-RA could produce small-scale information, especially around coastal regions.

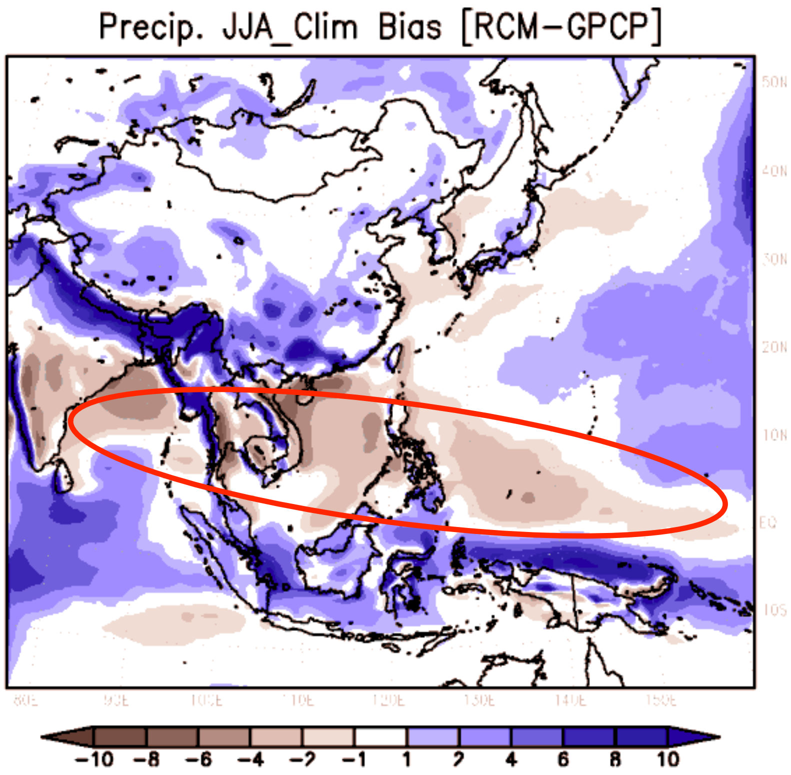
Performance: Precipitation

❖ Difference of 20-yr mean summer precipitation from observation

ERA - GPCP



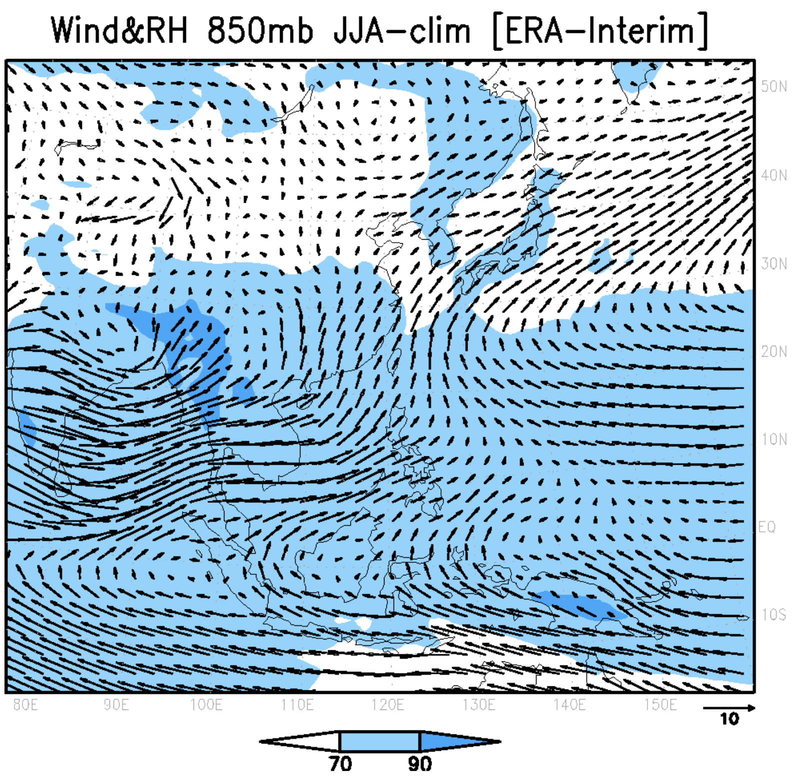
RCM - GPCP



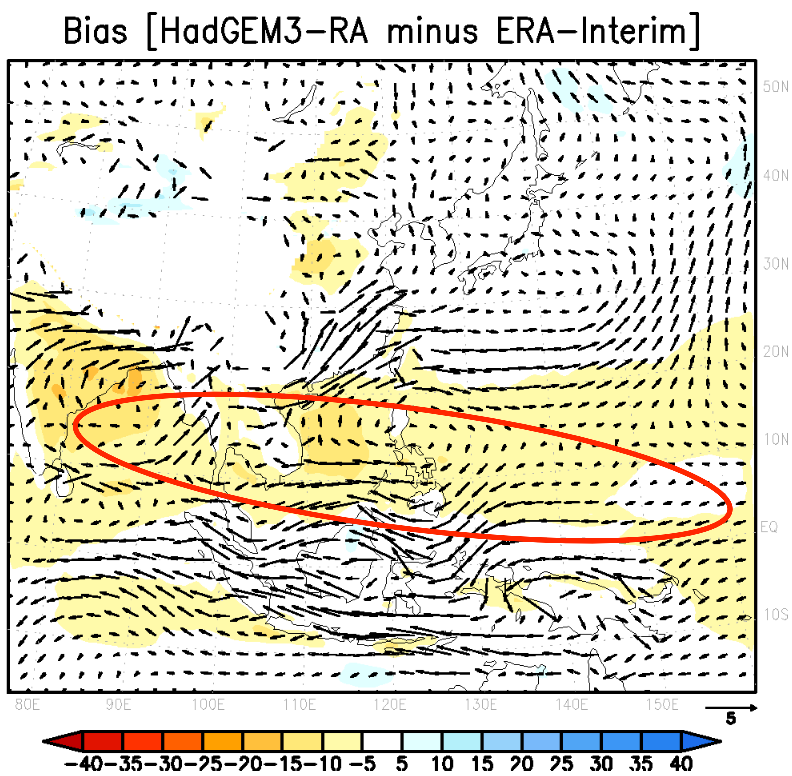
Low level circulation

❖ 20-yr mean summer 850-hPa wind and humidity (JJA 1989~2008)

Observation



Bias

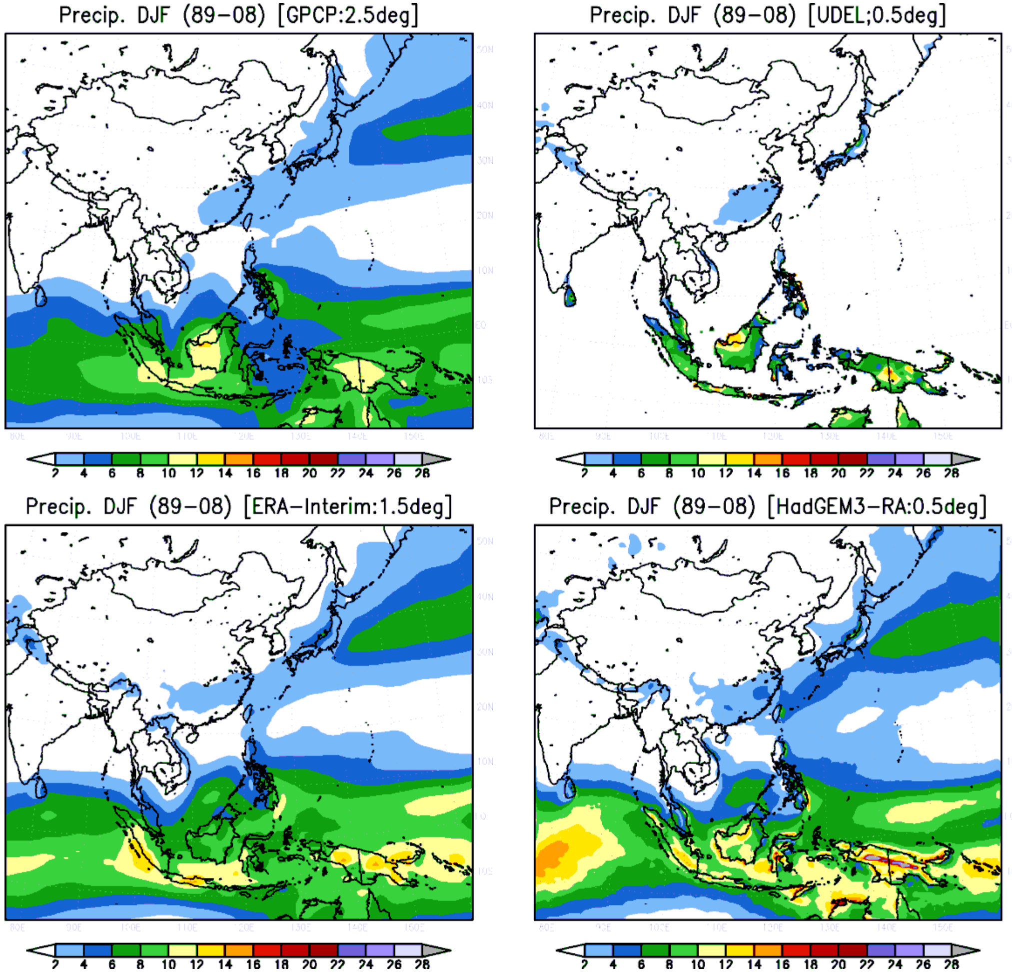


Performance: Precipitation

❖ 20-yr mean winter precipitation (DJF 1989~2008)

Observation GPCP

Observation UDEL



ERA-Interim

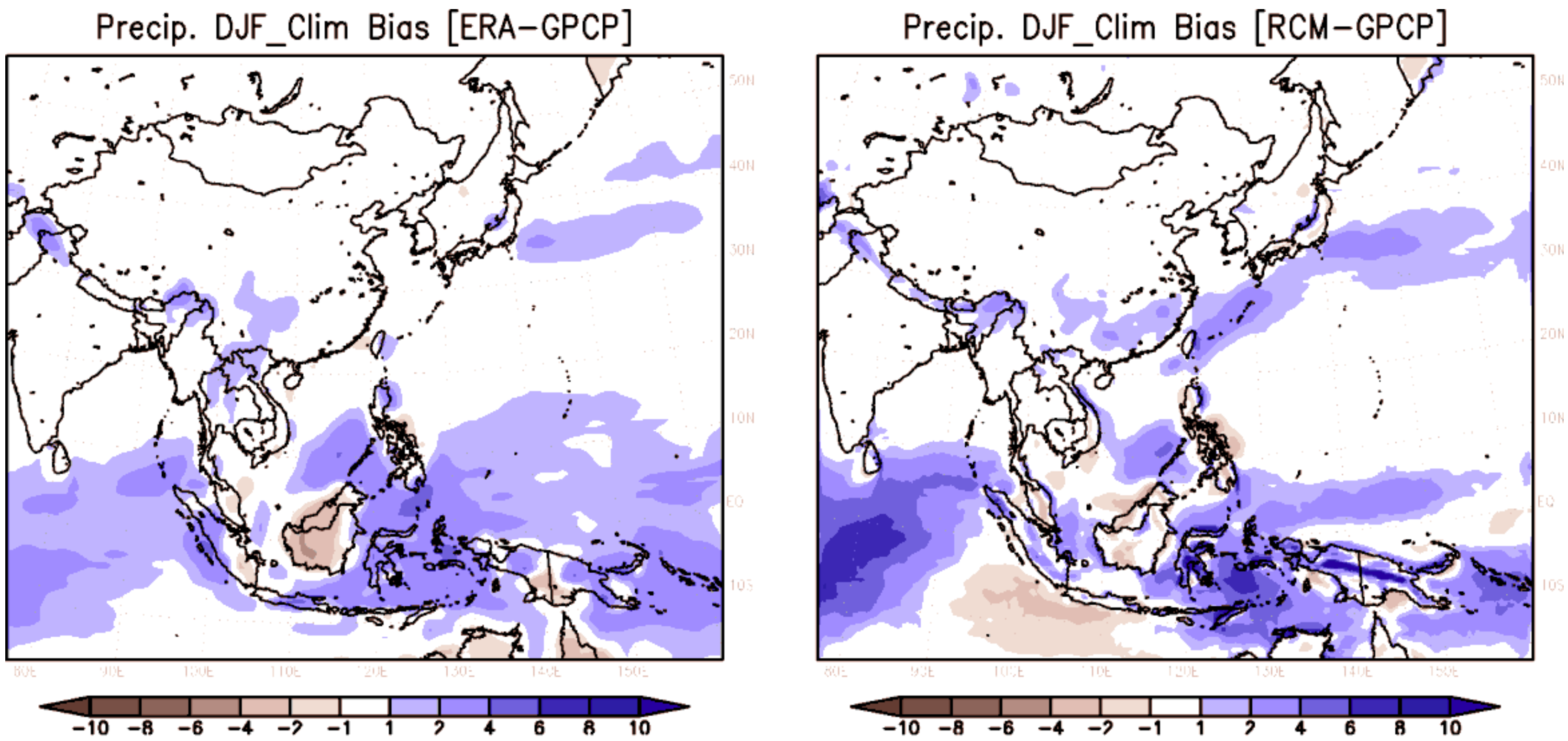
HadGEM3-RA

Performance: Precipitation

❖ Difference of 20-yr mean winter precipitation from observation

ERA - GPCP

RCM - GPCP



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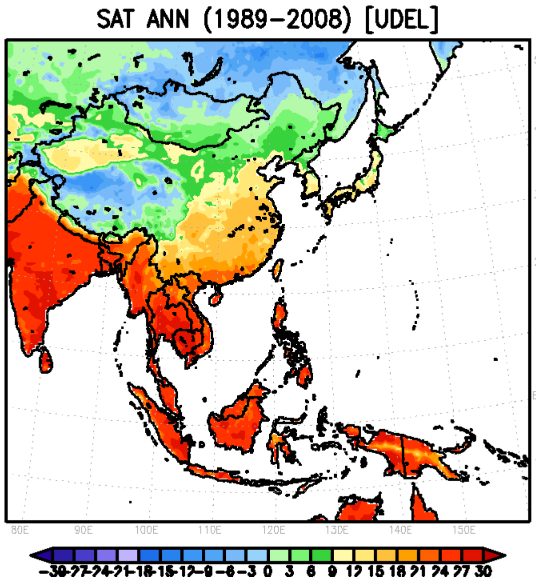
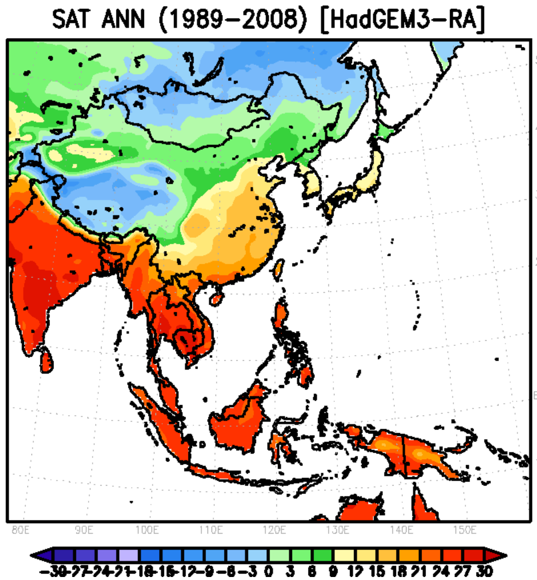
Performance: Surface Air temperature

❖ 20-yrs mean annual surface air temperature (1989~2008)

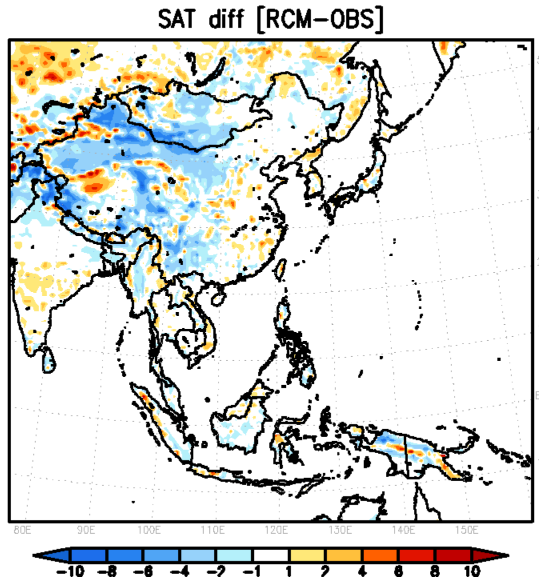
Observation



HadGEM3-RA



Bias



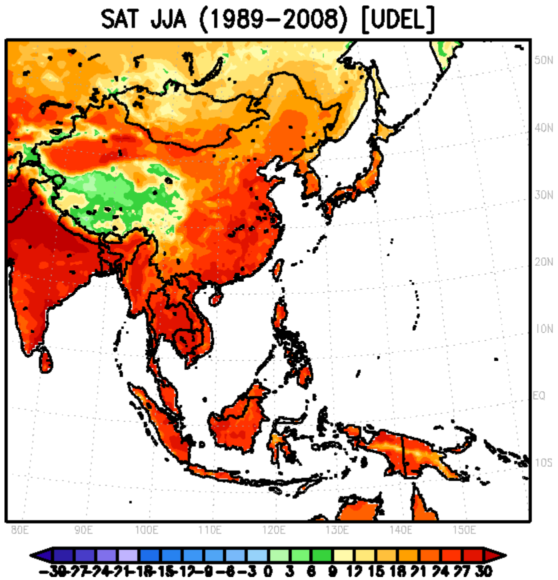
▪Observation: the University of Delaware precipitation and temperature (v.2.01); monthly, 0.5x0.5

- ➢ The HadGEM3-RA could reproduce the climatological distribution of mean annual temperature.
- ➢ It is clear that the HadGEM3-RA could resolve small-scale features related with topography.

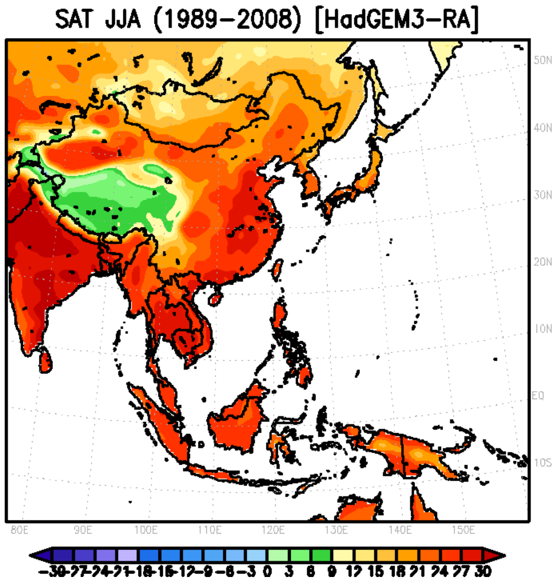
Performance: Surface Air temperature

❖ 20-yr mean summer surface air temperature (JJA 1989~2008)

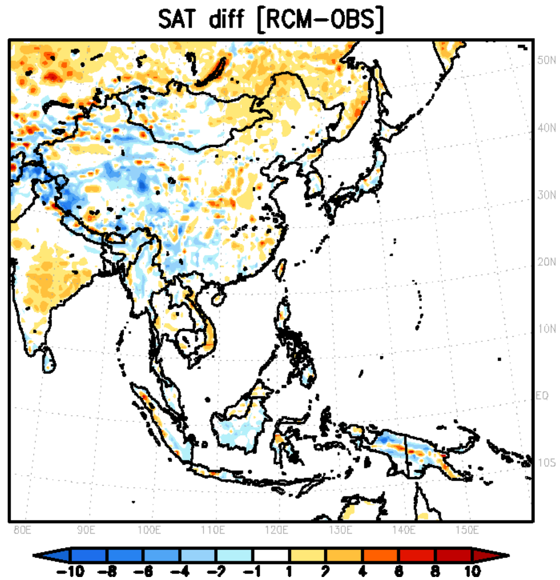
Observation



HadGEM3-RA



Bias



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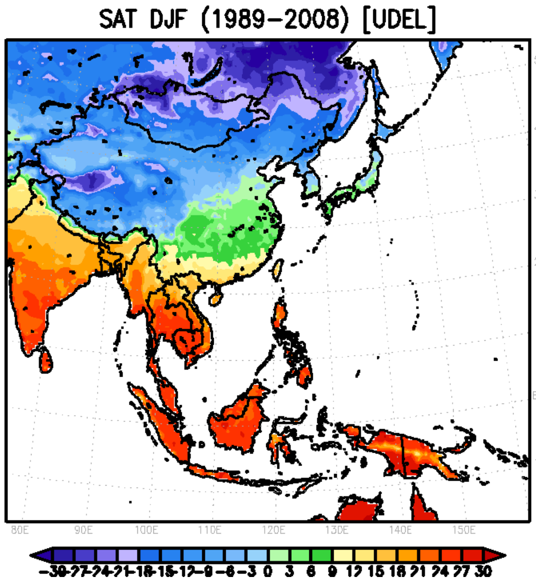
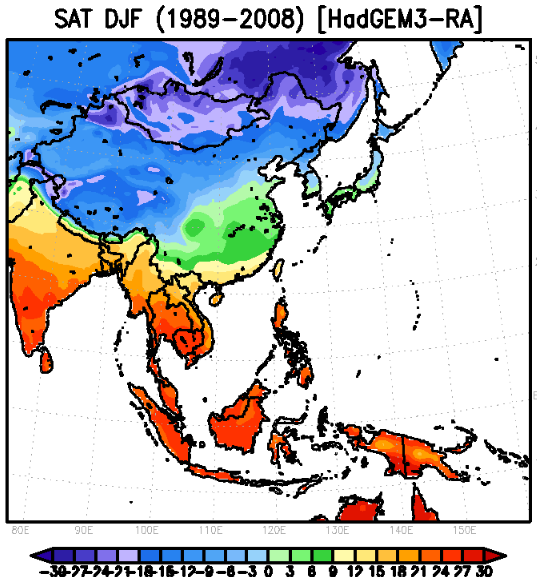
Performance: Surface Air temperature

❖ 20-yr mean winter surface air temperature (DJF 1989~2008)

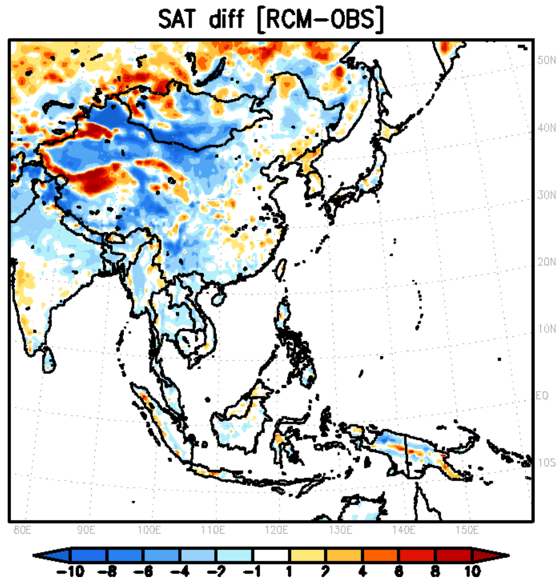
Observation



HadGEM3-RA



Bias



Statistics: Precipitation & Temperature (Land)

❖ Mean of observation and hadGEM3-RA, bias, Root-mean-squared error (RMSE) and pattern correlation coefficient of precipitation and temperature.♪

Variables		Mean (UDEL)	Mean (Model)	Bias	RMSE	Pattern Corr.
Precip. (mm/day)	ANN	2.56	3.61	1.05	1.24	0.835
	JJA	4.23	5.90	1.67	2.32	0.759
	DJF	1.48	1.91	0.43	0.64	0.883
Temp. (deg C)	ANN	10.8	10.1	-0.6	1.6	0.982
	JJA	20.6	20.6	0.0	1.4	0.958
	DJF	-0.5	-1.5	-1.0	2.4	0.983

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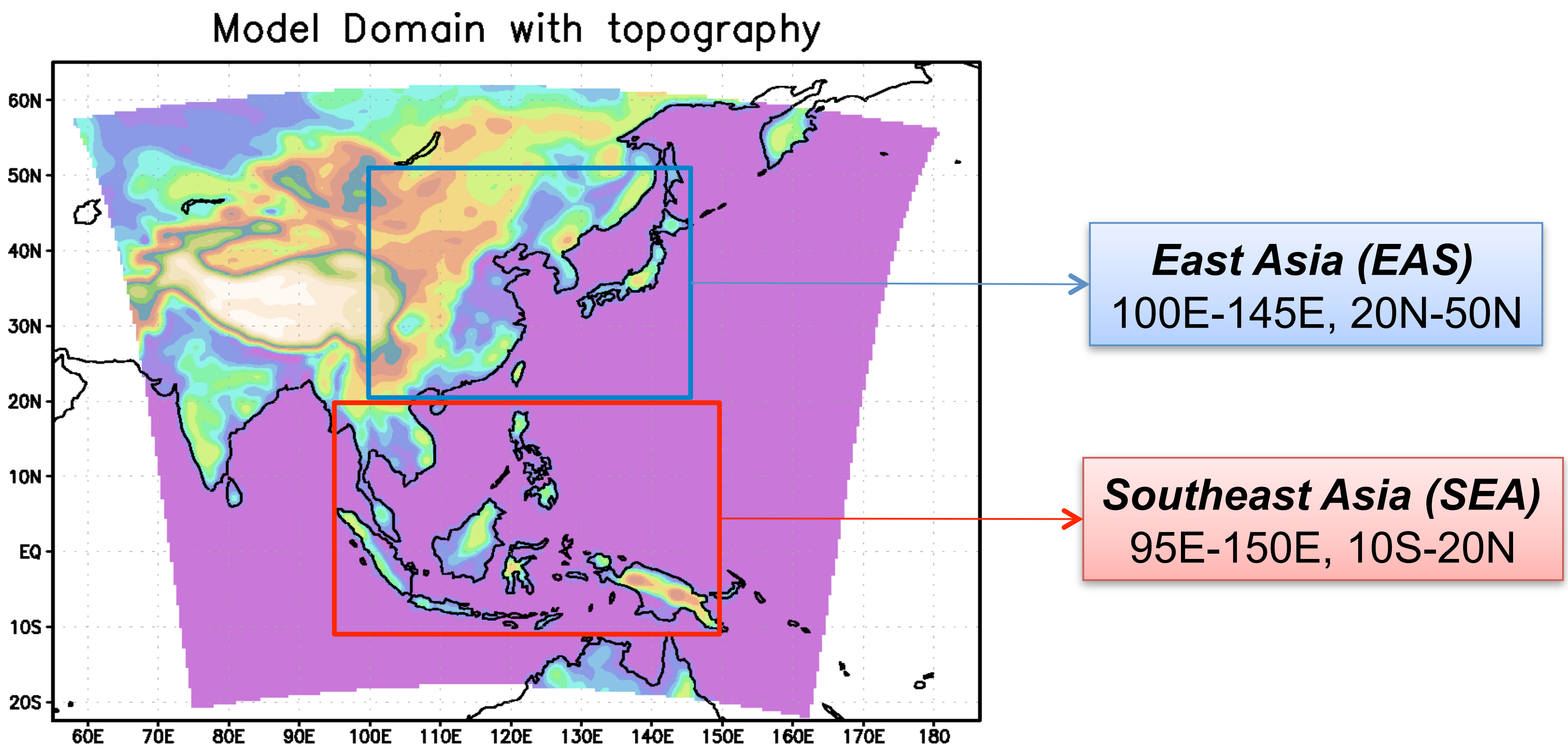
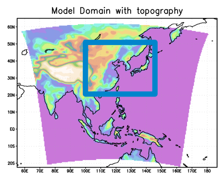
Sub-domains for annual cycle analysis

❖ Two sub-domains: EAS and SEA

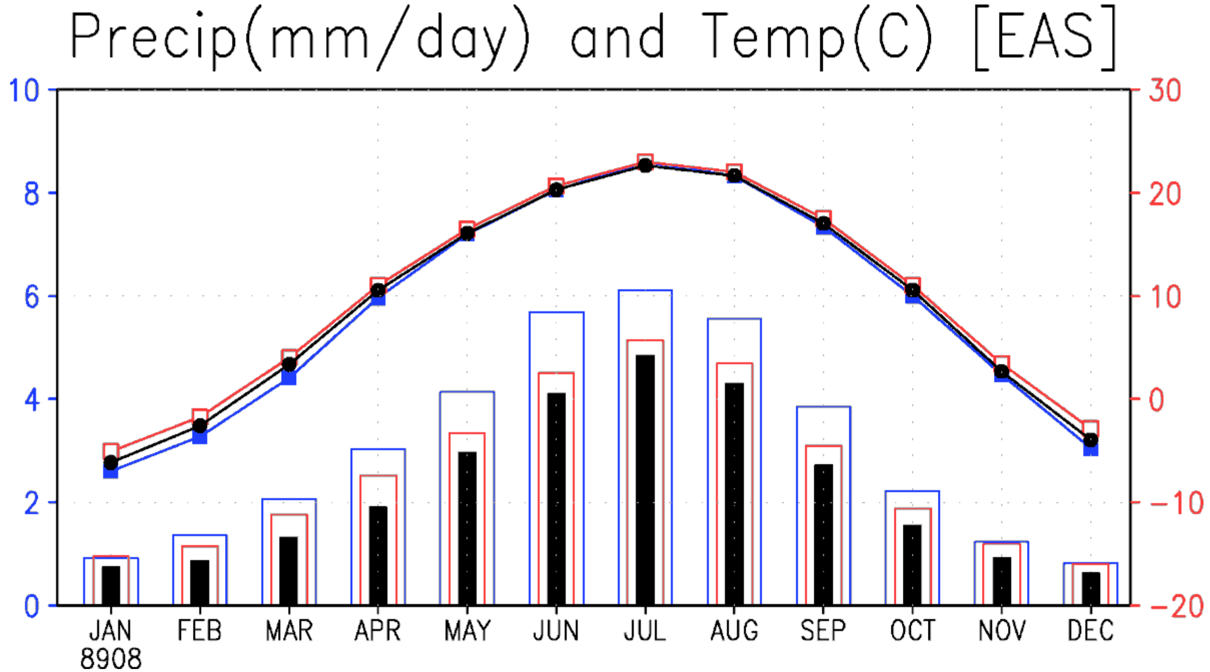


Performance: Annual cycle

❖ 20-yr mean annual cycle of domain-averaged precipitation and surfac e air temperature (1989~2008): East Asia♪



Precip.

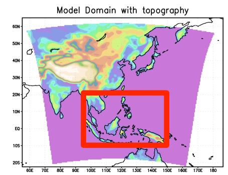


SAT

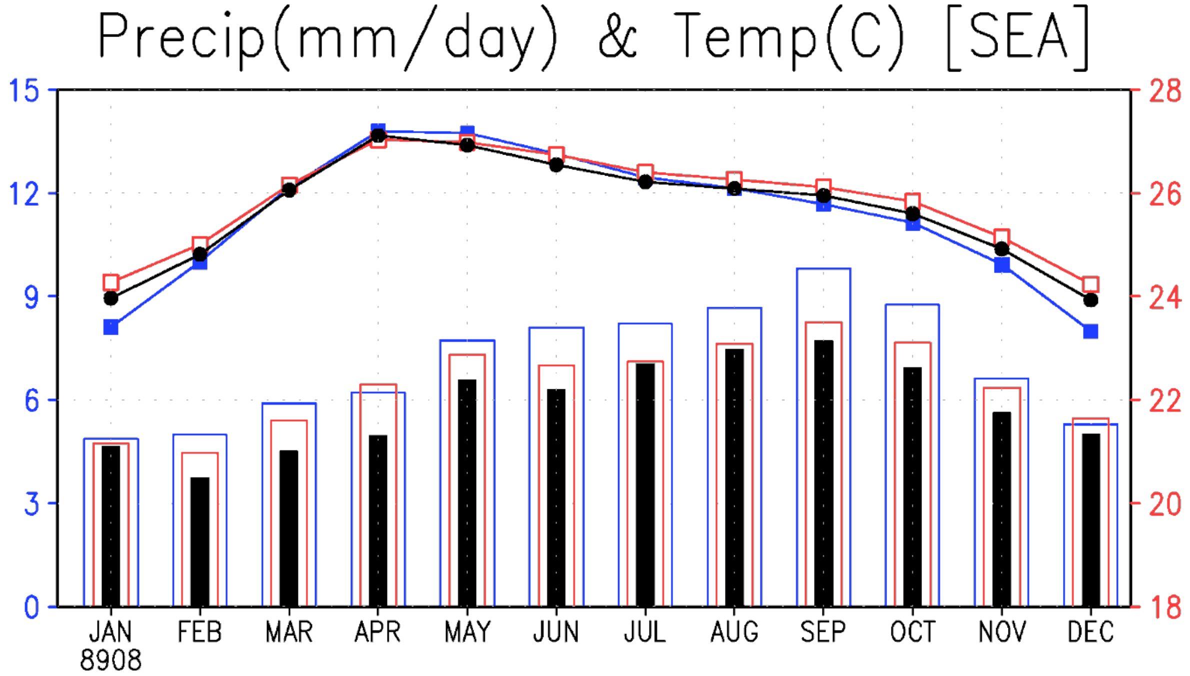
- Black: observation (UDEL)
- Red: ERA-Interim
- Blue: HadGEM3-RA

Performance: Annual cycle

❖ 20-yr mean annual cycle of domain-averaged precipitation and surface air temperature (1989~2008): Southeast Asia♪



Precip.



SAT

- Black: observation (UDEL)
- Red: ERA-Interim
- Blue: HadGEM3-RA

Evaluation results 2

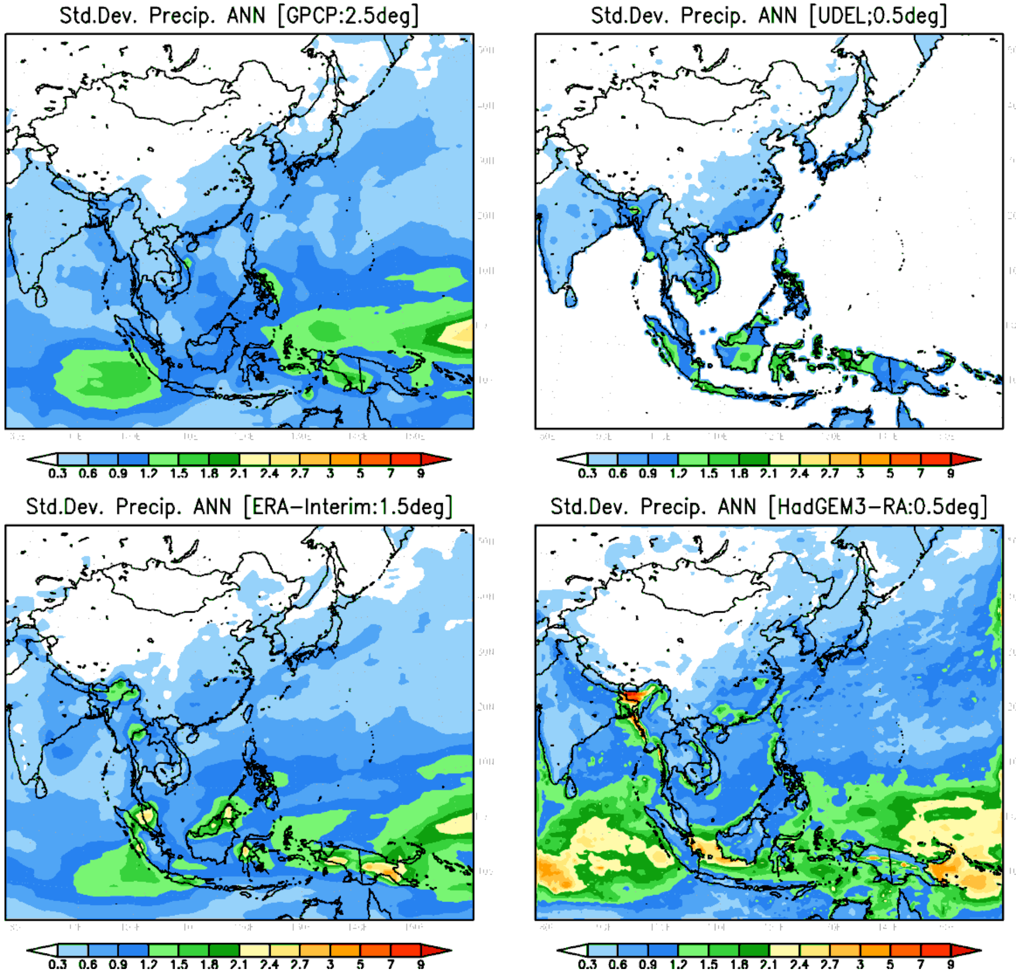
- Climate variability (Inter-annual variability)

Inter-annual variance: Precipitation

❖ Standard deviation of annual mean precipitation

Observation
GPCP

Observation
UDEL



ERA-Interim

HadGEM3-RA

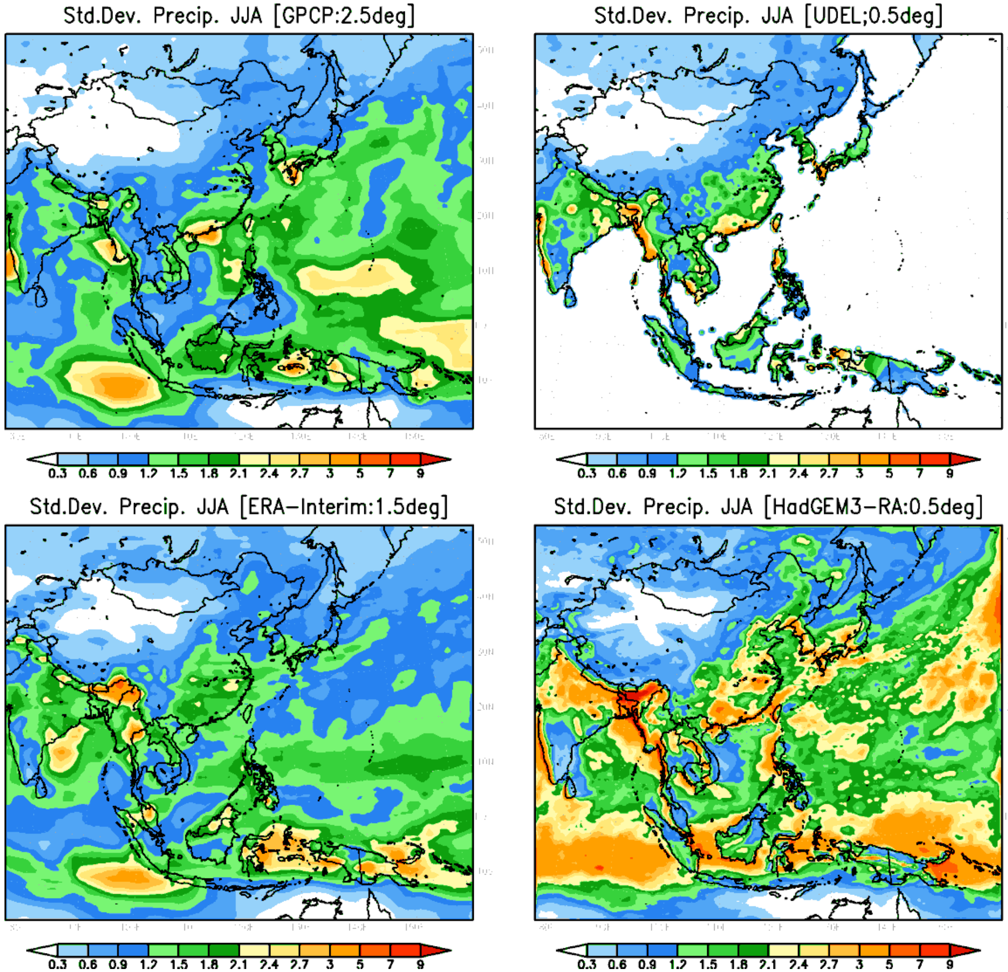
➢ Although HadGEM3-RA has stronger inter-annual variance, general pattern is reproduced well.

Inter-annual variance: Precipitation

❖ Standard deviation of summer mean precipitation

Observation
GPCP

Observation
UDEL



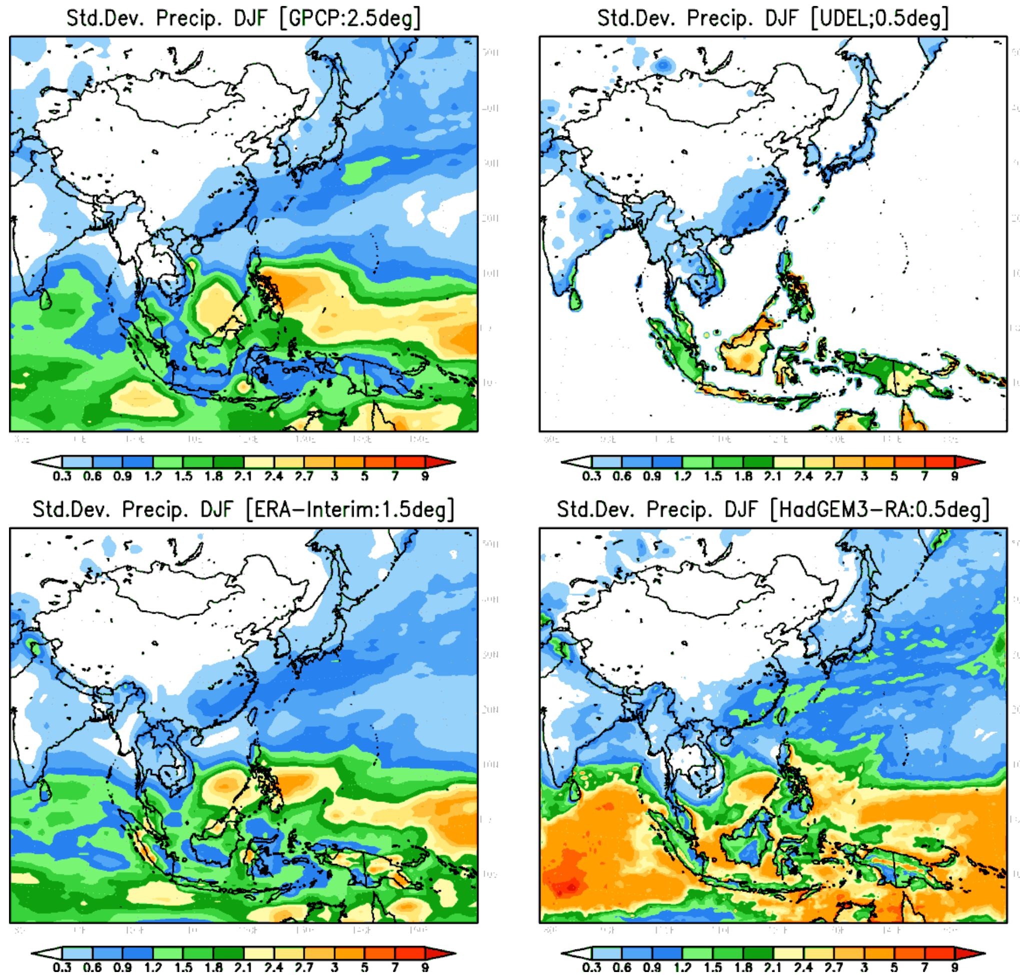
ERA-Interim

HadGEM3-RA

Inter-annual variance: Precipitation

❖ Standard deviation of winter mean precipitation

Observation
GPCP



Observation
UDEL

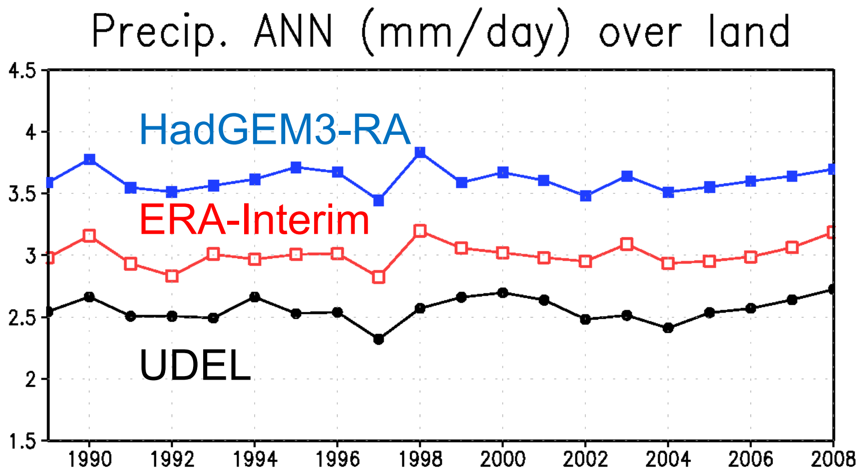
ERA-Interim

HadGEM3-RA

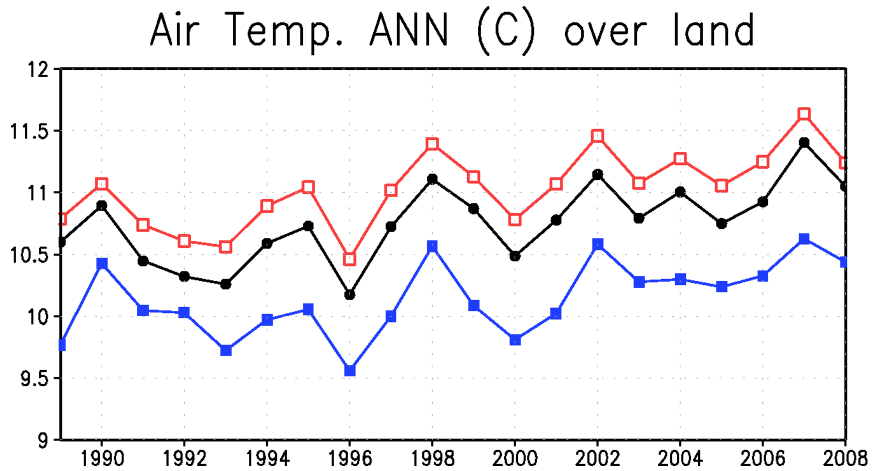
Inter-annual variation: Precipitation and SAT

❖ Annual mean precipitation and temperature averaged over land

Precipitation



Temperature



PRP	ERA	RCM
COR	0.647	0.618

- Black line with closed circle: Observation
- Red line with open square: ERA-Interim
- Blue line with closed square: HadGEM3-RA

SAT	ERA	RCM
COR	0.991	0.903

➢ Although HadGEM3-RA has wet and cold biases, model show good inter-annual variation.

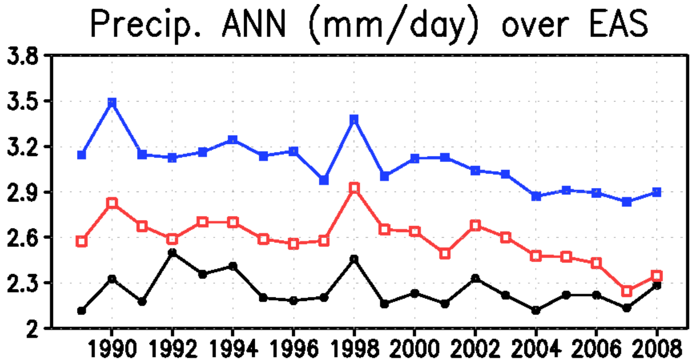
Inter-annual variation: Precipitation and SAT

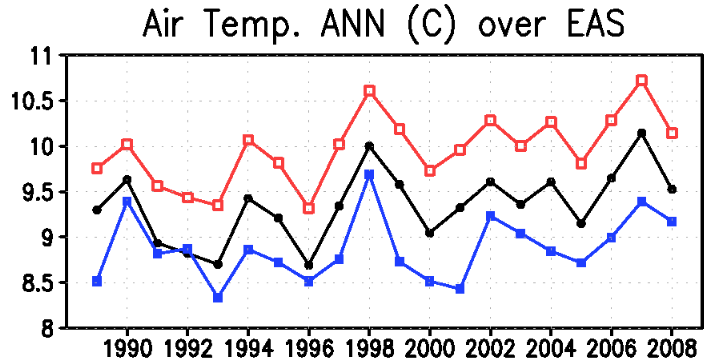
❖ Annual precipitation and temperature averaged over sub-regions

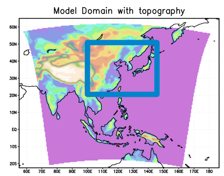
Precipitation

Temperature

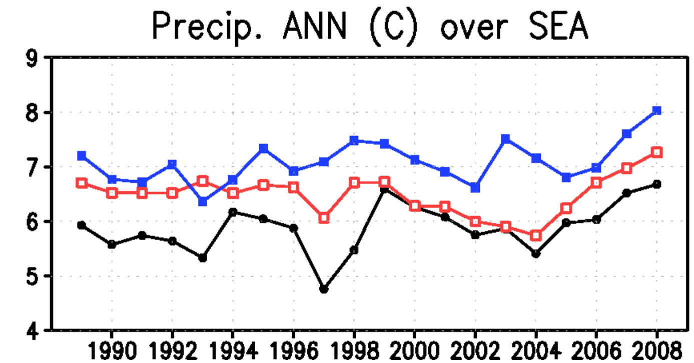
EAS

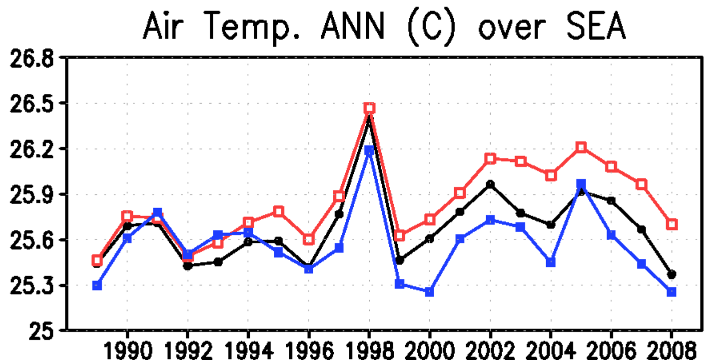


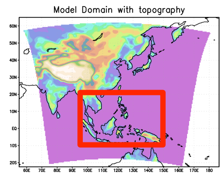




SEA







Precip	ERA	RCM
COR - EAS	0.545	0.513
COR - SEA	0.714	0.613

Air Temperature	ERA	RCM
COR - EAS	0.983	0.766
COR - SEA	0.851	0.918

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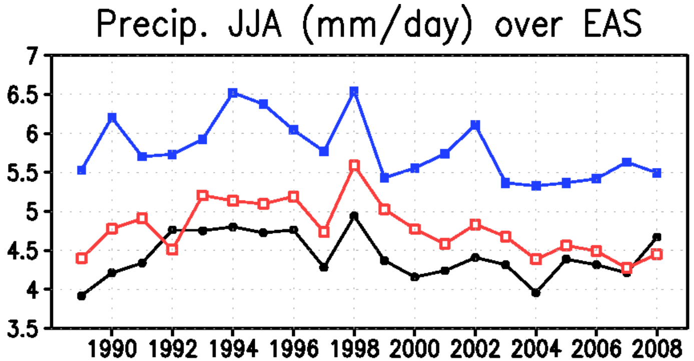
Inter-annual variation: Precipitation and SAT

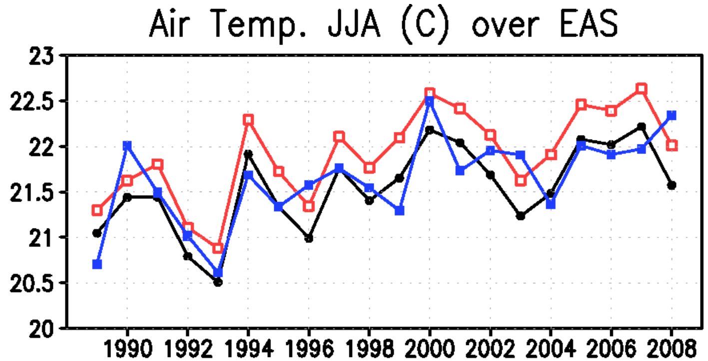
❖ Summer precipitation and temperature averaged over sub-regions

Precipitation

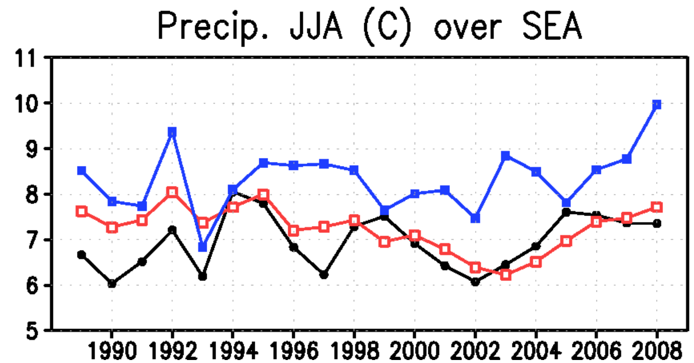
Temperature

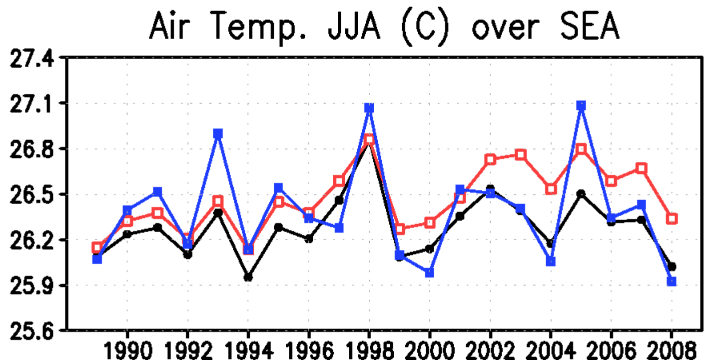
EAS





SEA





Precip	ERA	RCM
COR - EAS	0.688	0.632
COR - SEA	0.765	0.619

Air Temperature	ERA	RCM
COR - EAS	0.993	0.742
COR - SEA	0.793	0.871

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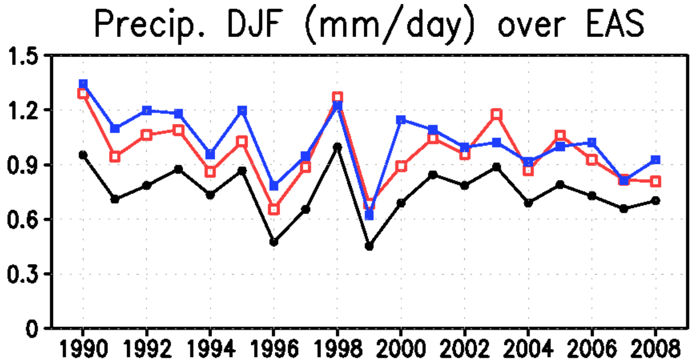
Inter-annual variation: Precipitation and SAT

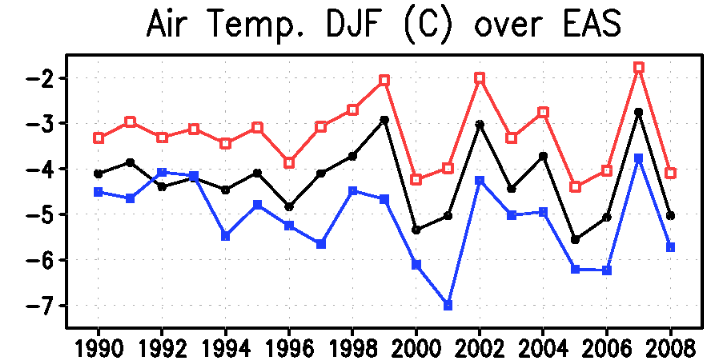
❖ Winter precipitation and temperature averaged over sub-regions

Precipitation

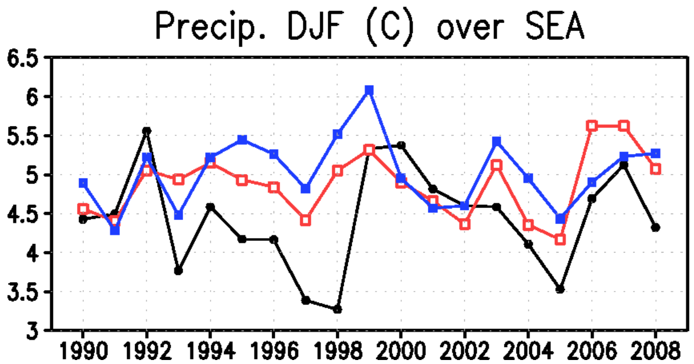
Temperature

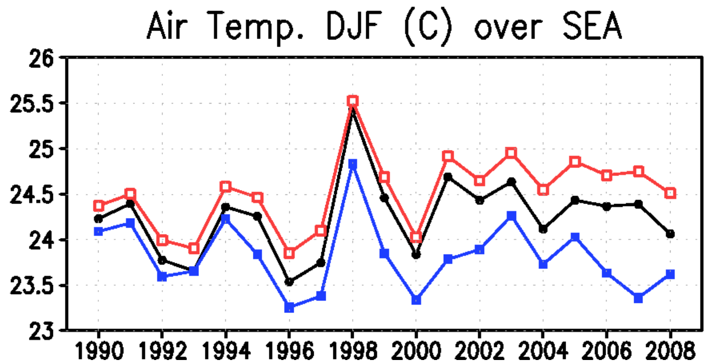
EAS





SEA





Precip	ERA	RCM
COR - EAS	0.950	0.856
COR - SEA	0.464	0.376

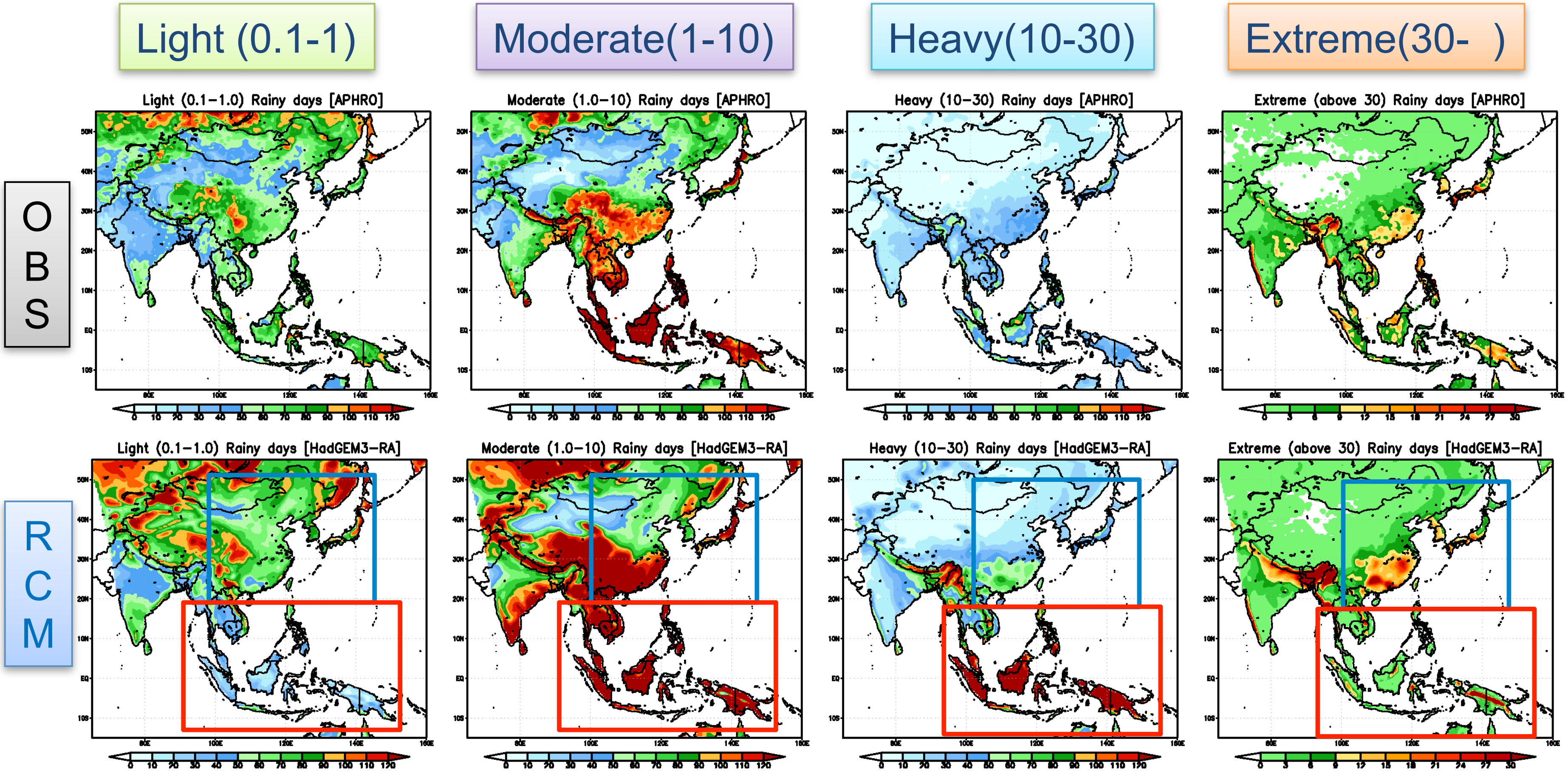
Air Temperature	ERA	RCM
COR - EAS	0.994	0.777
COR - SEA	0.935	0.925

Evaluation results 3

- Climate extreme (Daily precipitation)

Daily precipitation intensity

❖ Number of rainy day based on daily precipitation intensity



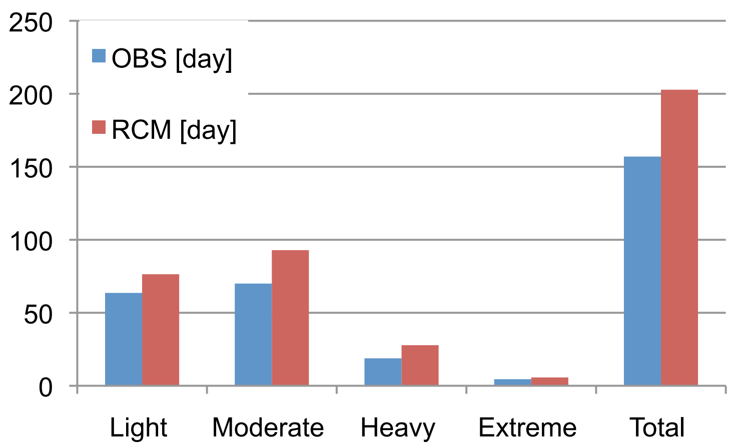
▪ Observation: APHRODITE's Water Resources (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources); daily, 0.5x0.5 (and 0.25x0.25)

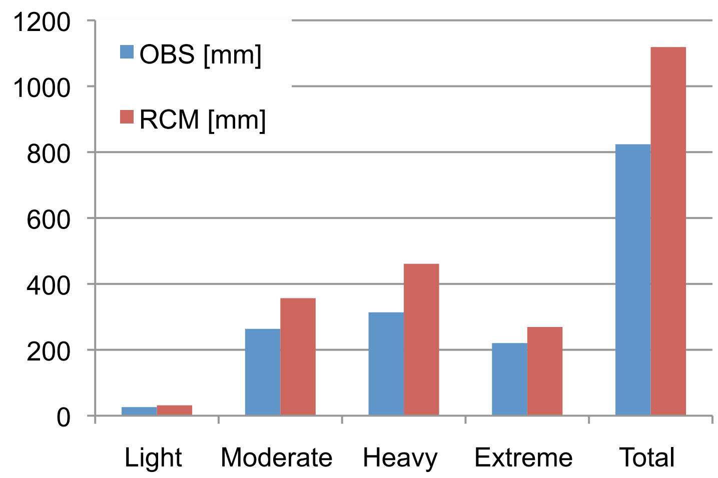
➢ In EAS sub-region, rainy days at all intensity are overestimated.
➢ In SEA sub-region, rainy days at light and extreme intensities are underestimated.

Daily precipitation intensity and amount

❖ Sub-region: East Asia

		Light (0.1-1)	Moderate (1-10)	Heavy (10-30)	Extreme (30-)	Total
Number of day	OBS	63.6	70.0	18.8	4.5	157.0
	RCM	76.4	92.9	27.8	5.7	202.8
Total Amount	OBS	26.1	263.6	313.8	220.4	823.9
	RCM	31.6	356.7	461.1	269.3	1118.8

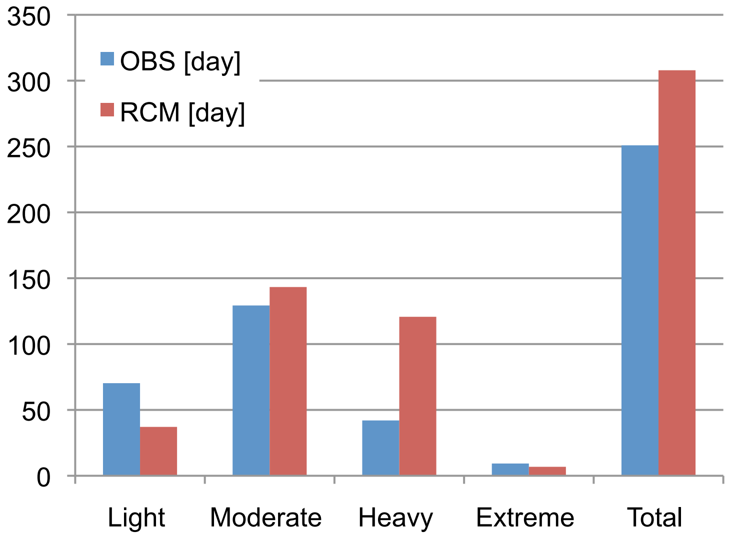


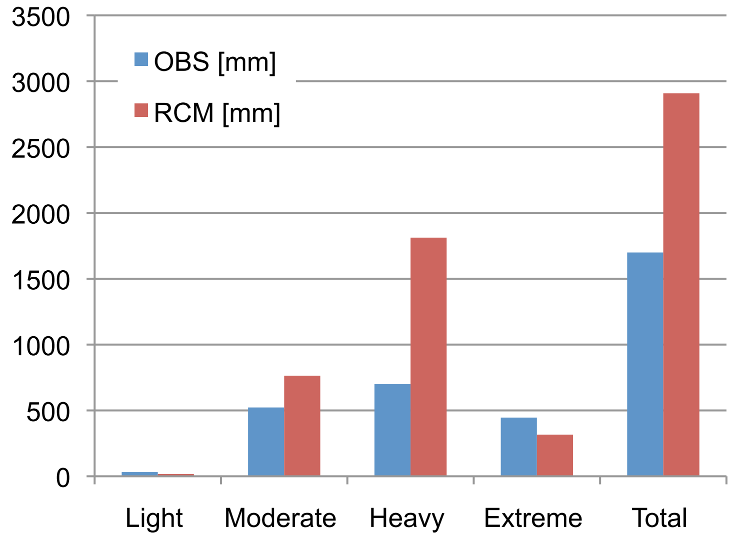


Daily precipitation intensity and amount

❖ Sub-region: Southeast Asia

		Light (0.1-1)	Moderate (1-10)	Heavy (10-30)	Extreme (30-)	Total
Number of day	OBS	70.3	129.3	42.0	9.3	250.9
	RCM	37.1	143.3	120.7	6.8	307.9
Total Amount	OBS	31.7	522.5	699.3	445.6	1699.0
	RCM	17.0	763.4	1811.7	316.0	2908.0

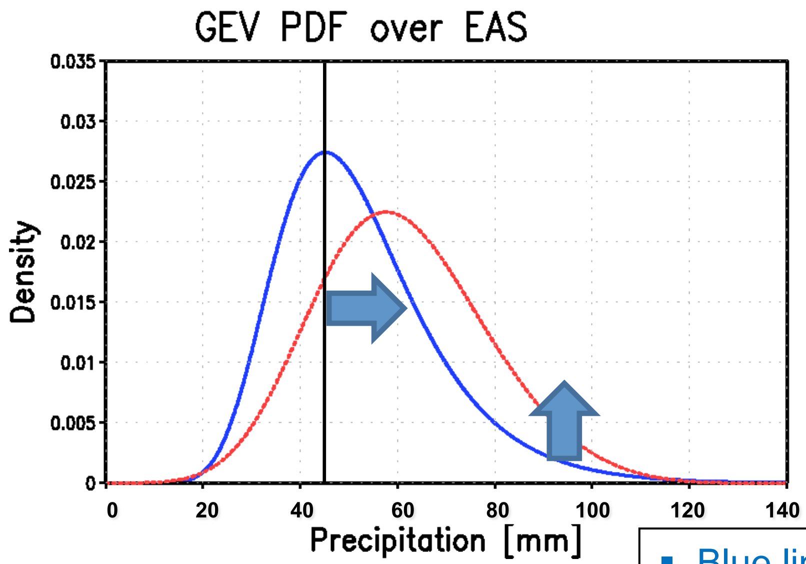




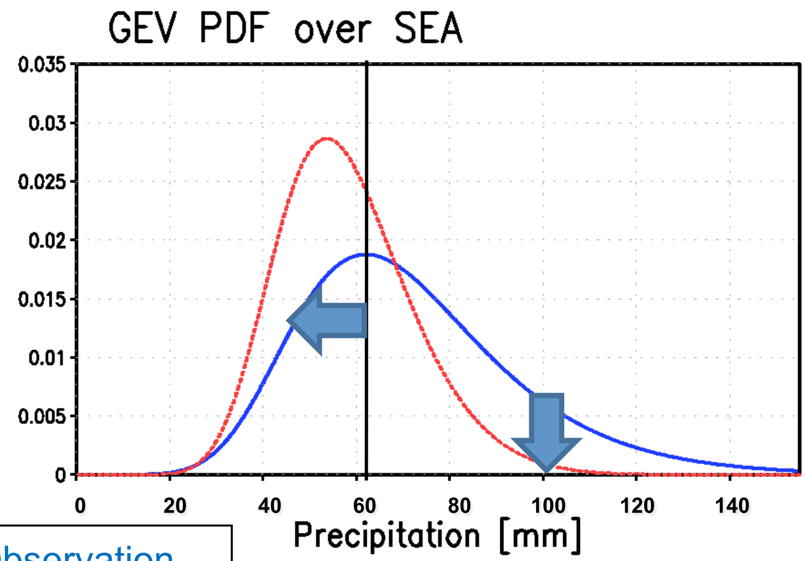
GEV analysis : Probability density function

❖ GEV analysis: Fitting time series of annual maximum daily precipitati on to generalized extreme value (GEV) distribution

East Asia



Southeast Asia



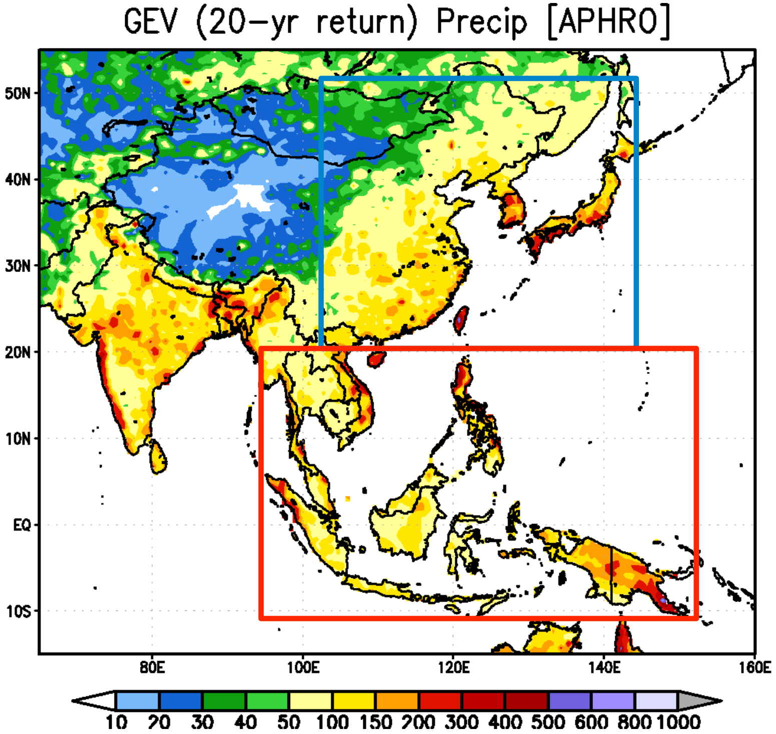
- Blue line: Observation
- Red line: HadGEM3-RA

- In EAS sub-region, PDF of model extreme shifted to strong intensity and variance.
- In SEA sub-region, PDF of model extreme shifted to weak intensity and variance.

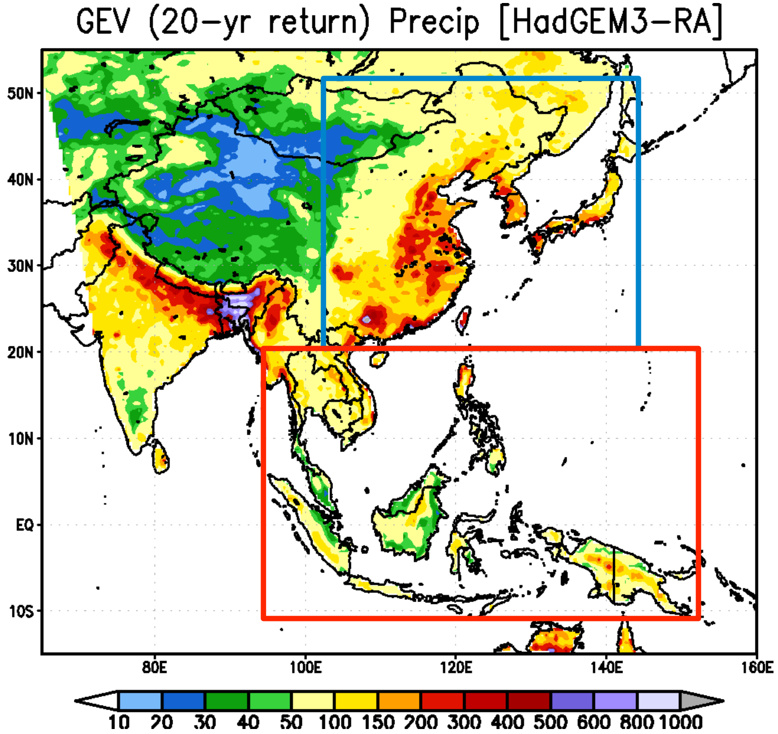
GEV analysis : 20-year return value precipitation

❖ GEV analysis: 20-year return value of maximum daily precipitation

Observation



HadGEM3-RA



- In EAS sub-region, 20-yr return value precipitation tends to overestimated.
- In SEA sub-region, 20-yr return value precipitation tends to underestimated.

Summary and concluding remarks

- ❖ Twenty-year integrations on CORDEX-EA domain (50km) forced by the ERA-Interim data have been conducted by the HadGEM3-RA of proto-type.
- ❖ The model performance of mean climate, annual cycle, inter-annual variability and climate extreme are evaluated.
- ❖ Results reveals that the HadGEM3-RA has the dynamical downscaling ability for the CORDEX-East Asia domain.
- ❖ Meanwhile, HadGEM3-RA show generally wet and cold biases. Therefore, we will test the final version of HadGEM3 with new configuration in model physics options.

nimr
National Institute of Meteorological Research

Thank you very much!