Multi-RCM Simulations and Bias Assessment for CORDEX-East Asia

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Outline

- Introduction
- What We've Done
  - Optimal Physics Configuration (Convection and Micro-physics)
  - Lateral Boundary Forcing (ERA-interim, NCEP/DOE RA2)
  - 20-year-long (1989-2008) Simulations with Multi-RCMs
- Summary

Backgrounds

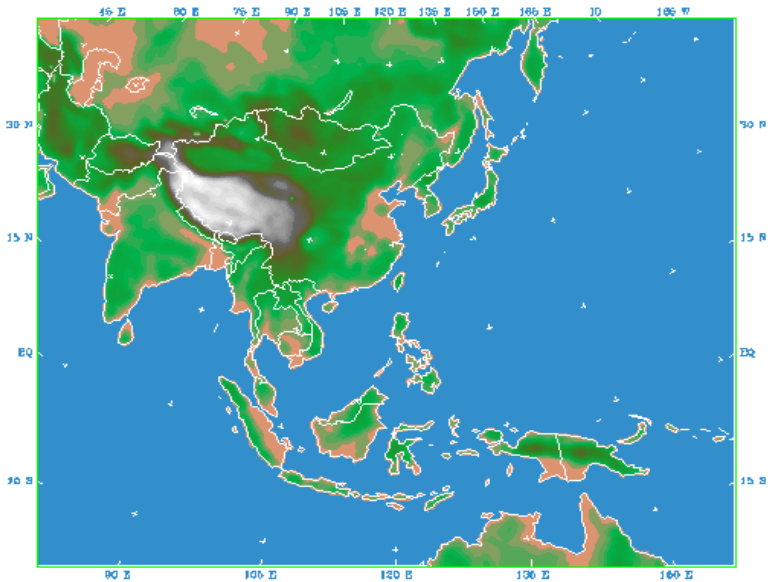
- Korea Meteorological Administration (KMA) is coordinating a collaborative program with domestic universities for CORDEX-East Asia – 4 RCMs and 1 SD are involved from three universities.

- The motivation, objective, and frameworks of this project are exactly same to the CORDEX for **not only the ESA-44 domain but also the Korea domain with higher resolution (0.11 deg)**

Time-line and Contents

	Year1 (2010)	Year2 (2011)	Year3 (2012)
	Evaluation Framework	Projection Framework	
Model	MM5, WRF, RegCM4, RSM		
Domain	East Asia (0.44 deg)	East Asia (0.44 deg), Korea (0.11 deg)	
Lateral BC	ERA-interim, NNRP2	HadGEM2-AO (or one more CMIP5 GCM if available)	
Simulation Period	1989-2008	1981-2010 2041-2070	2071-2100 2011-2040
RCP	N/A	8.5, 4.5	8.5, 4.5
Statistical Downscali ng	• Evaluation of PRI SM module • CCA based Transfe r function	• Application SD to t he projection • Bayesian method development	Uncertainty Assessm ent with Bayesian m ethod

Physics Configuration



CORDEX East Asia (50 km)
197 (Lat) X 233 (Lon)

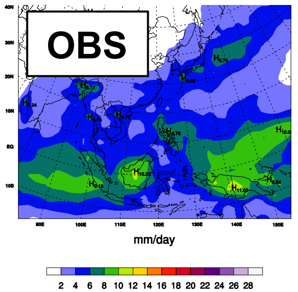
Period: Jan. ~ Dec. 1989

MM5

Vertical layers (top)	24 sigma layers (70 hPa)
Cumulus convection	Anthes-Kuo(AK)/ Grell(GR)/ Kain-Fritch (KF)/ Kain-Fritch2(KF2)
Explicit moisture	Simple Ice(SI)/ Reisner2(R2)
Radiation	CCM2 package
PBL	YSU
LSM	NCAR CLM3
Forcing & initial data	ERA-interim

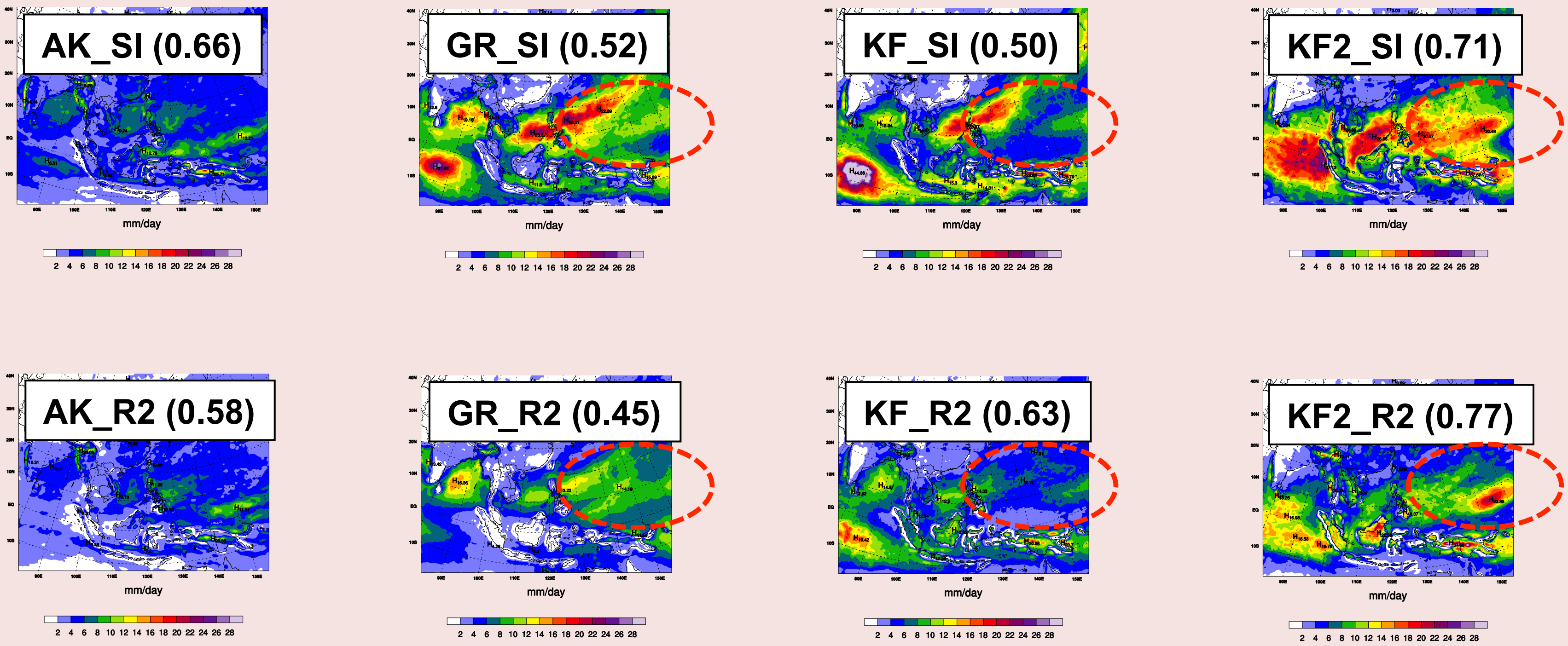
WRF

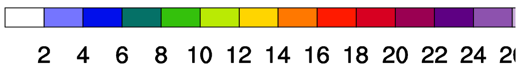
Vertical layers (top)	27 sigma layers (70 hPa)
Cumulus convection	Betts-Miller(BM)/ Grell-Devenyi(GD)/ Kain-Fritch2(KF2)
Explicit moisture	WSM3/ WSM6
Radiation	RRTM/Dudhia
PBL	YSU
LSM	Unified Noah
Forcing & initial data	ERA-interim



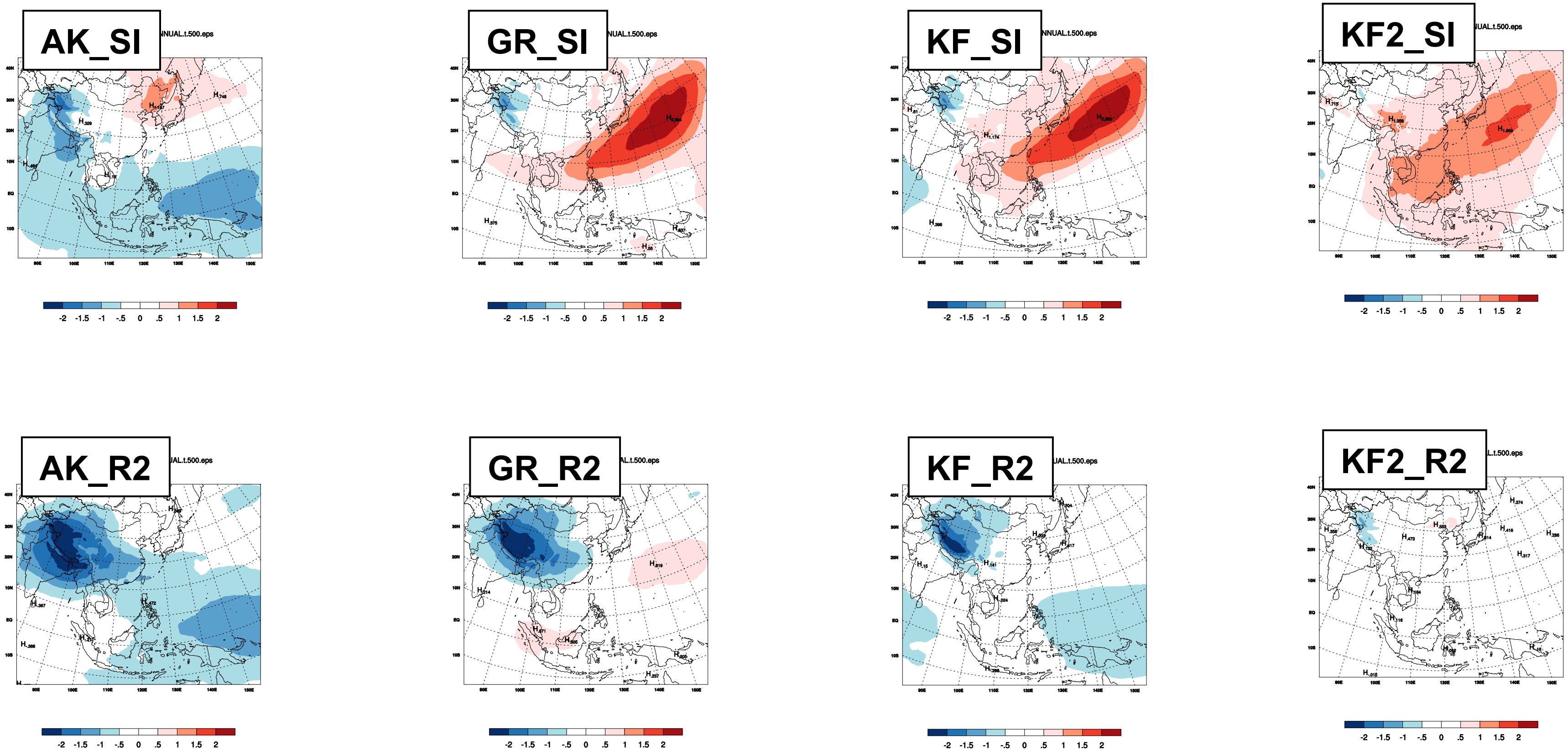
Annual Precipitation (MM5)

(Spatial Corr.)





500 hPa Temp. Bias (MM5)



Statistics of precipitation (MM5)

Model	OBS (mm day^{-1})	Simulated preci. (mm day^{-1})			BIAS (mm day^{-1})	RMSE (mm day^{-1})	S.C.
		Total	Conv.	Non-Conv.			
AK_SI	4.22	3.91	3.35	0.56	0.31	1.89	0.66
GR_SI		6.17	4.03	2.13	1.95	4.43	0.52
KF_SI		6.14	4.13	2.01	1.92	4.76	0.50
KF2_SI		6.88	4.69	2.19	2.66	4.92	0.71
AK_R2		3.37	2.92	0.44	0.85	2.16	0.58
GR_R2		4.35	3.50	0.85	0.13	2.83	0.45
KF_R2		4.61	3.71	0.90	0.39	2.36	0.63
KF2_R2		5.35	4.4	0.95	1.13	2.31	0.77

Statistics of precipitation (WRF)

Model	OBS (mm day^{-1})	Simulated preci. (mm day^{-1})			BIAS (mm day^{-1})	RMSE (mm day^{-1})	S.C.
		Total	Conv.	Non-Conv.			
BM_WSM3	4.22	5.20	4.01	1.19	0.99	3.32	0.71
GD_WSM3		4.01	3.55	0.46	-0.21	2.56	0.61
KF2_WSM3		5.60	4.82	0.78	1.38	2.76	0.79
BM_WSM6		6.46	3.70	2.76	2.24	5.46	0.70
GD_WSM6		4.66	4.14	0.53	0.45	2.78	0.67
KF2_WSM6		7.11	5.91	1.20	2.89	5.92	0.76

Sensitivity to Reanalysis Forcing

	ERA-interim	NCEP/DOE (RA2)
Horizontal Resolution	Triangular truncation of 255 waves (~80 km)	Triangular truncation of 62 waves (~200 km)
Vertical Resolution	Hybrid vertical 60 levels	28 sigma levels
Assimilation system	4DVAR (time window, 12 h)	3DVAR

- **Experiments**

WRF_INT
WRF_RA2

- **Simulation period**

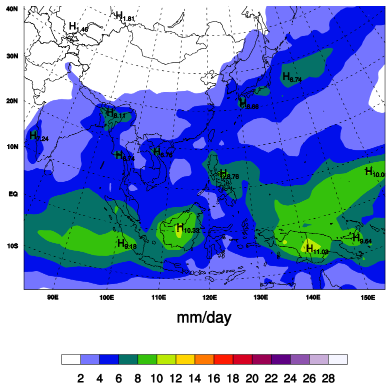
Jan. 1989 – Dec. 1989

WRF Configuration

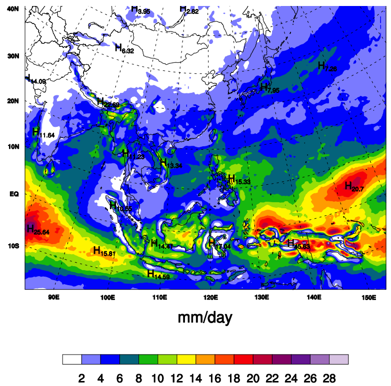
Vertical layers (top)	27 sigma layers (70 hPa)
Cumulus convection	Kain-Fritch2(KF2)
Explicit moisture	WSM3
Radiation	RRTM/Dudhia
PBL	YSU
LSM	Unified Noah
Forcing & initial data	ERA-Interim , NCEP/DOE RA2

Annual Precipitation

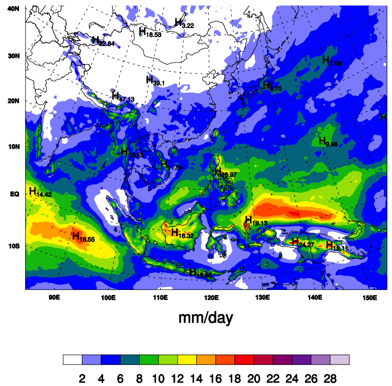
OBS (GPCP)

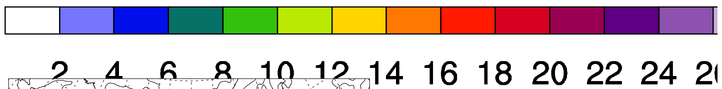


WRF_INT

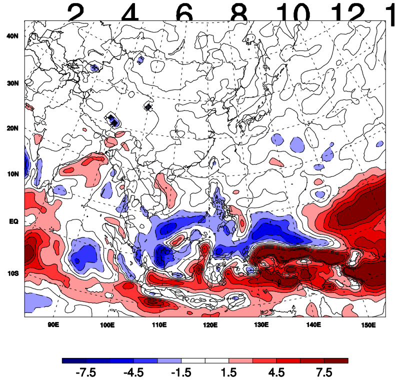


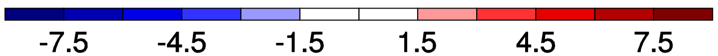
WRF_RA2





- **Difference (WRF_INT – WRF_RA2)**

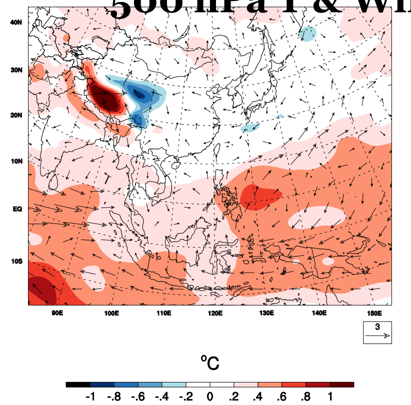




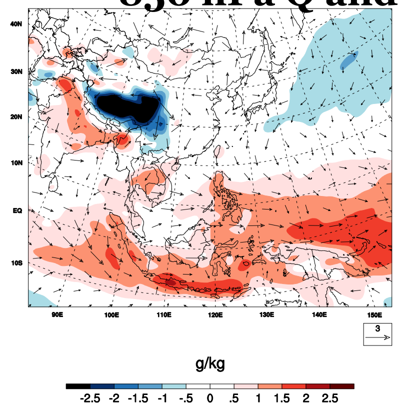
ERA-interim vs. NNRP2

ERA_interim – NNRP2

500 hPa T & Winds

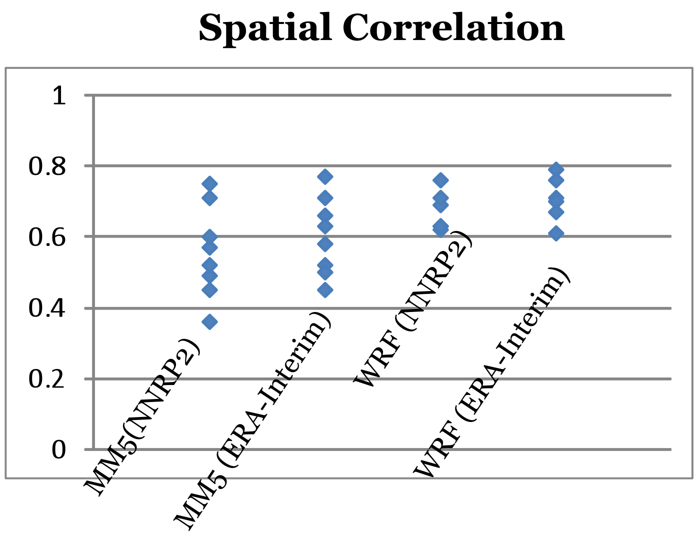


850 hPa Q and Winds



Statistics of Precipitation

Model	Reanalysis	Physics combination (CPS_EMS)	BIAS (mm day^{-1})	RMSE (mm day^{-1})	Spatial Correlation.
MM5	NNRP2	AK_SI	-0.70	2.17	0.57
		AK_R2	-1.17	2.44	0.49
		GR_SI	1.24	4.06	0.45
		GR_R2	-0.49	2.73	0.36
		KF_SI	0.83	3.30	0.52
		KF_R2	-0.31	2.08	0.60
		KF2_SI	1.54	3.49	0.71
		KF2_R2	0.69	2.55	0.75
	ERAIN	AK_SI	-0.31	1.89	0.66
		AK_R2	-0.85	2.16	0.58
		GR_SI	1.95	4.43	0.52
		GR_R2	0.13	2.83	0.45
		KF_SI	1.92	4.76	0.50
		KF_R2	0.39	2.36	0.63
		KF2_SI	2.66	4.92	0.71
		KF2_R2	1.13	2.81	0.77
WRF	NNRP2	BM_WSM3	0.35	2.86	0.62
		BM_WSM6	1.41	4.52	0.63
		GD_WSM3	-0.54	2.17	0.63
		GD_WSM6	0.06	2.19	0.69
		KF2_WSM3	0.70	2.39	0.76
		KF2_WSM6	2.06	4.92	0.71
	ERAIN	BM_WSM3	0.99	3.32	0.71
		BM_WSM6	2.24	5.46	0.70
		GD_WSM3	-0.21	2.56	0.61
		GD_WSM6	0.45	2.78	0.67
		KF2_WSM3	1.38	3.16	0.79
		KF2_WSM6	2.89	5.92	0.76



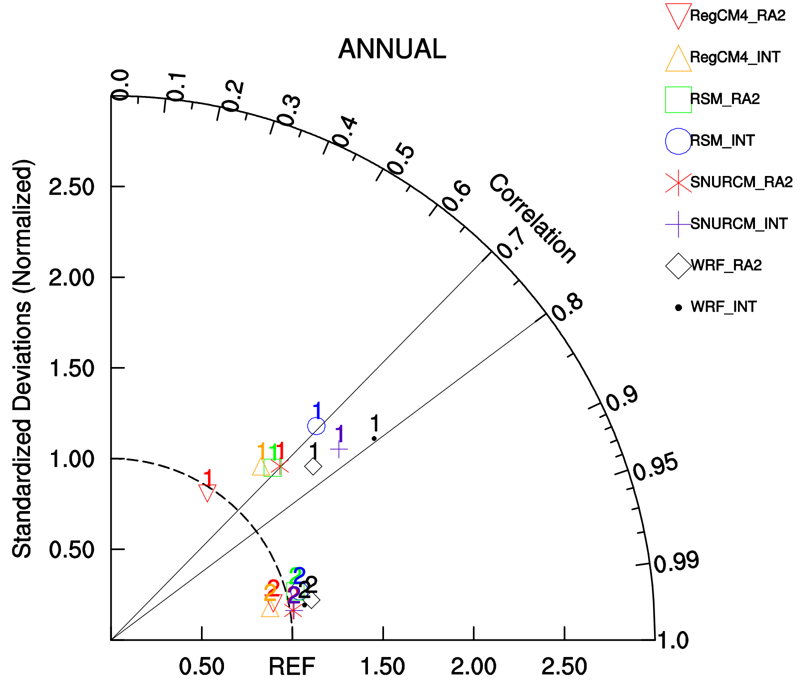
- Most skillful combinations of the physical parameterization schemes are **KF2_R2 for MM5** and **KF2_WSM3** for WRF.

- ERA-interim is better in terms of pattern correlation, but not for bias and RMS error.

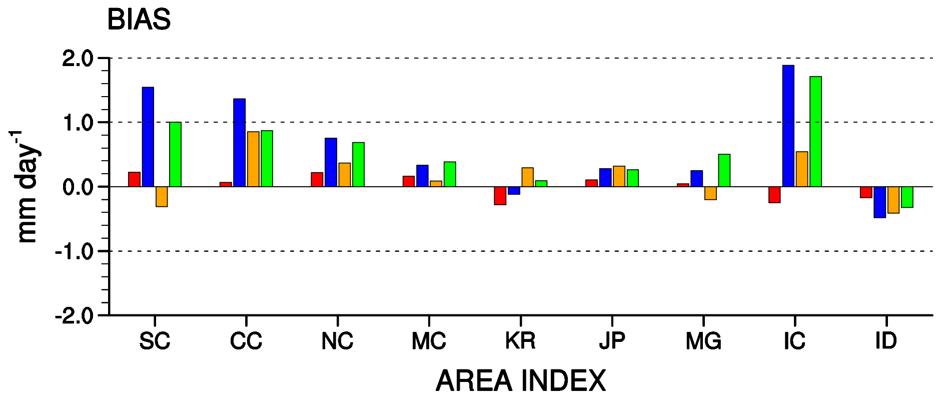
Configuration of RCMs for CORDEX-East Asia

	RegCM4	RSM	MM5	WRF
Dynamical core	Hydrostatic	Hydrostatic	Non-hydrostatic	Non-hydrostatic
Vertical levels	σ-18	σ-22	σ-24	σ-27
PBL	Holtslag	YSU	YSU	YSU
Deep Convection	Emanuel	SAS	KF2	KF2
Cloud micro physics	SUBEX	WSM1	Reisner2	WSM3
LSM	CLM	NOAH	CLM3	Unified NOAH
LW Radiation	CCM3	GFDL	CCM2	RRTM
SW Radiation	CCM3	GSFC	CCM2	Dudhia
Spectral nudging	Yes, but with different formula for each model			
LBC forcing	ERA-interim, NCEP/DOE RA2			

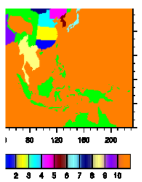
Taylor Diagram for Precip. & Sfc Temp.



Bias of Sub-regional Precipitation

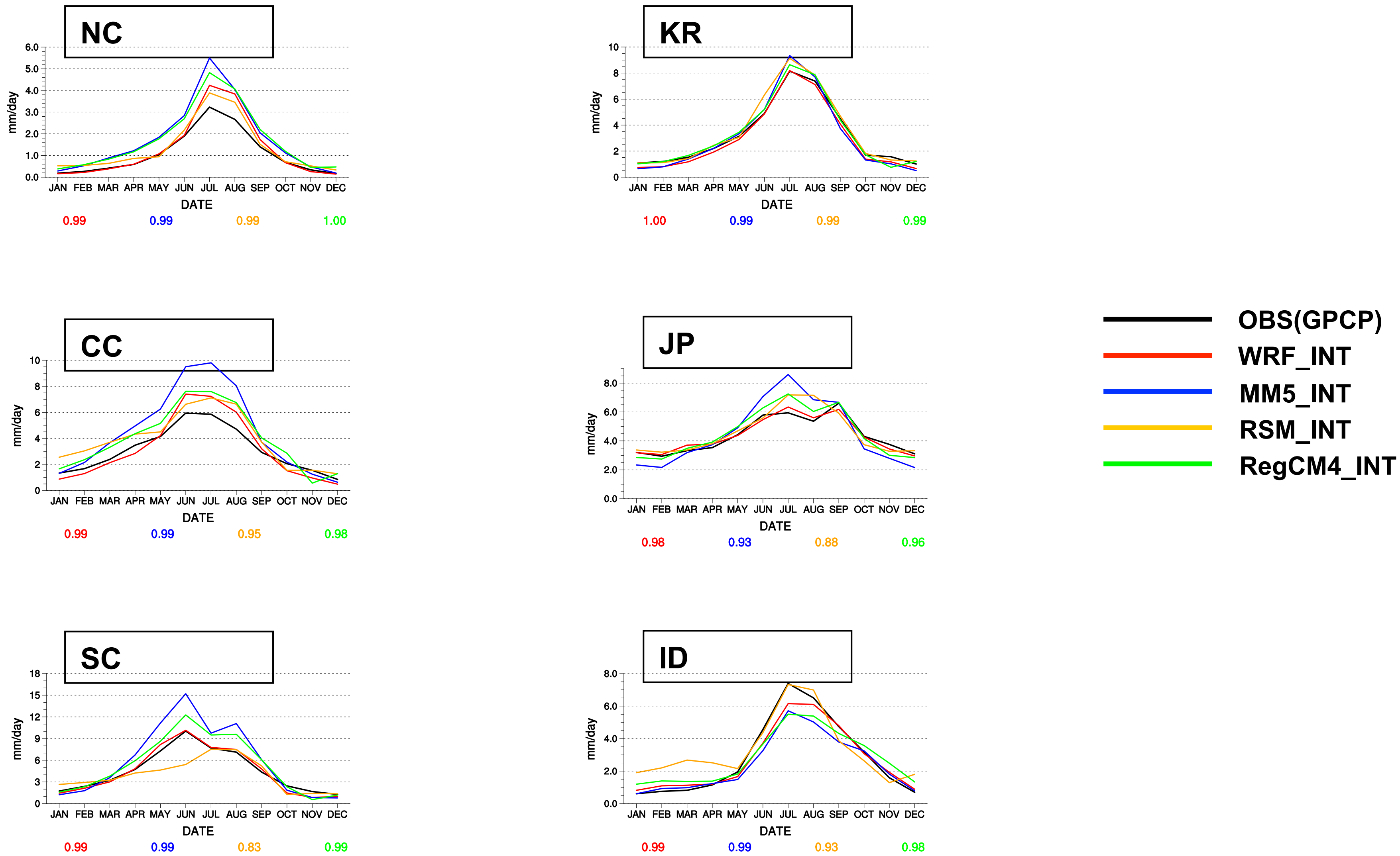


WRF_INT **RSM_INT**
MM5_INT **RegCM4_INT**

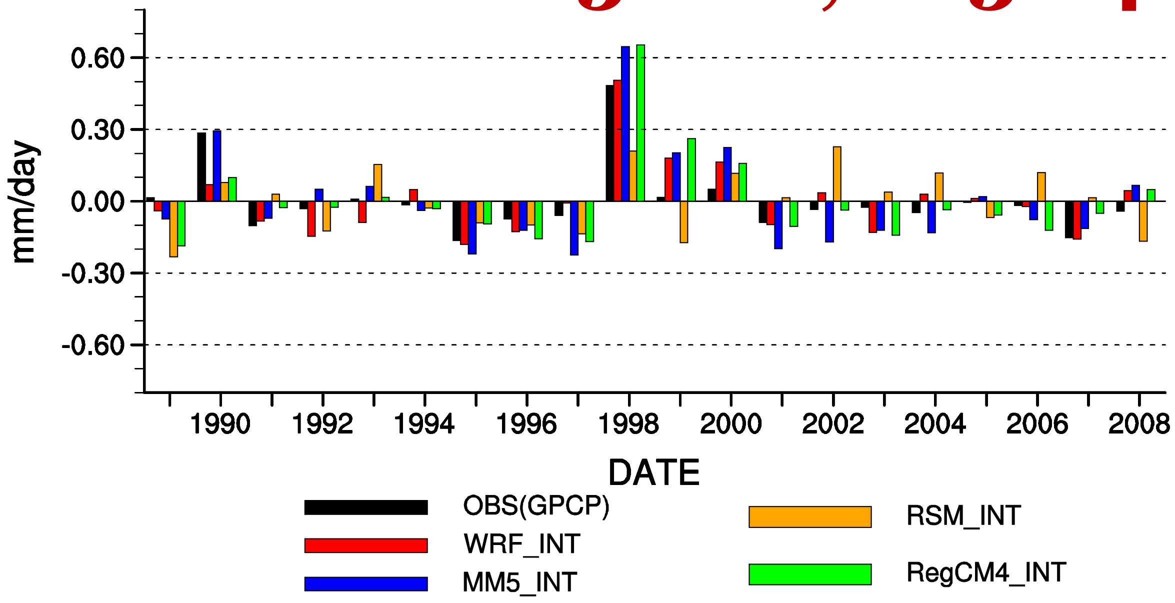


SC (Southern China)
CC (Central China)
NC (Northern China)
MC (Manchuria)
KR (Korea)
JP (Japan)
MG (Mongolia)
IC (Indochina)
ID (India)

Annual Cycle of Precipitation



Interannual Variability in East Asia (20-50°N , 105-140°E)



Correlations: RegCM4 (0.79), RSM (0.39), MM5 (0.89) , WRF (0.83)

Performance based Ensemble Averaging (PEA): A Modified REA

based on Giorgi and Mearns (2002)

Model Bias $$\Delta T_i = \frac{1}{N_p}\sum_{p=1}^{N_p}(T_{isp} - T_{op})$$

Simple Average Model Bias $$\Delta \overline{T} = \frac{1}{N_M}\sum_{i=1}^{N_M}\Delta T_i$$

Modified Reliability Ensemble Averaging $$\Delta \widetilde{T} = \frac{\sum_{i=1}^{N_M} MR_i \Delta T_i}{\sum_{i=1}^{N_M} MR_i}$$

Modified Reliability Factor

$$MR_i = \frac{1.0}{[Abs(Bias_i) + 1.0]} \times \frac{1.0}{(RMSE_i + 1.0)} \times Abs(Corr._i)$$

N_p : Number of point

N_i : Number of Model

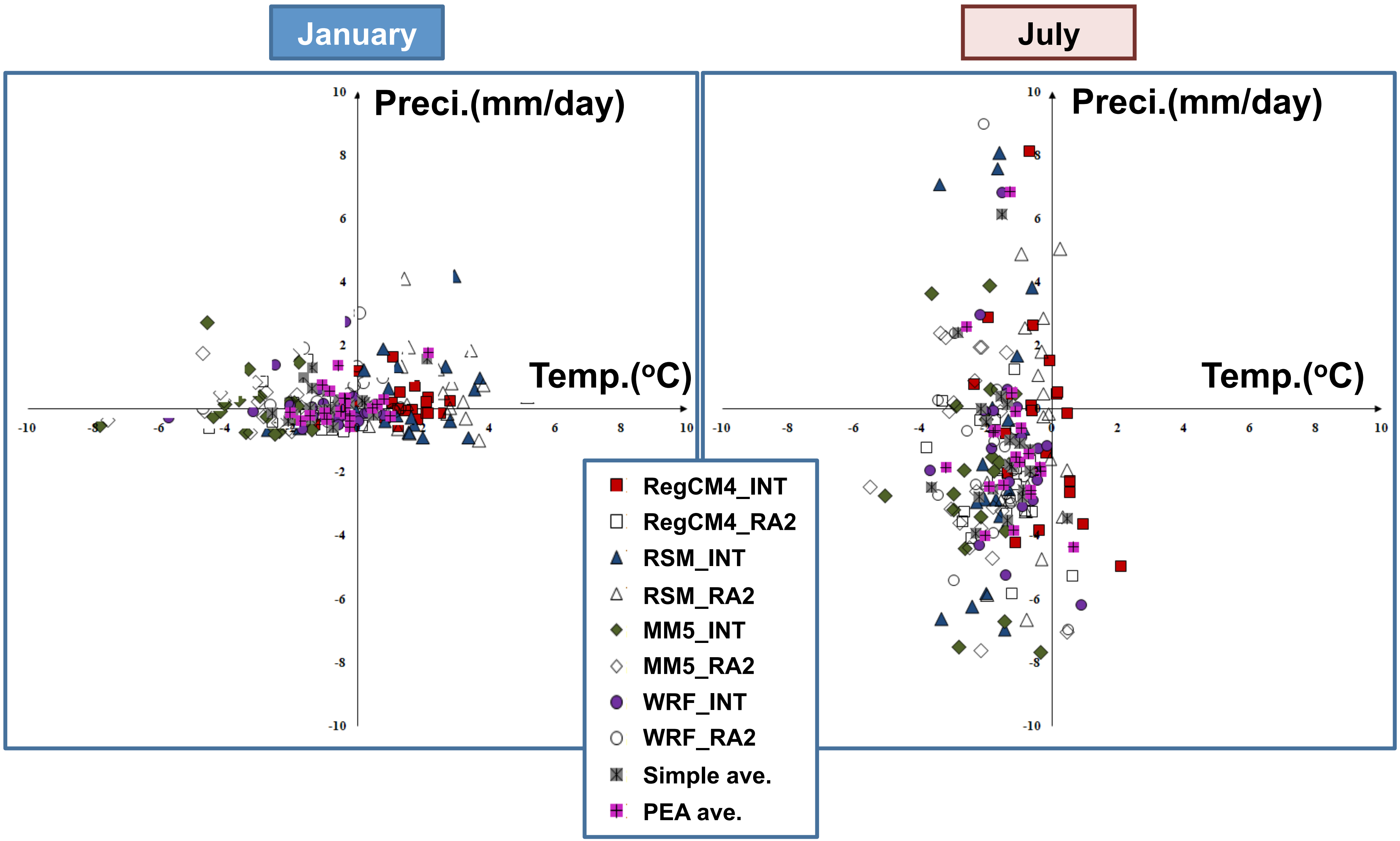
T_{isp} : Simulated value at point p by model i

T_{op} : Observed value at point

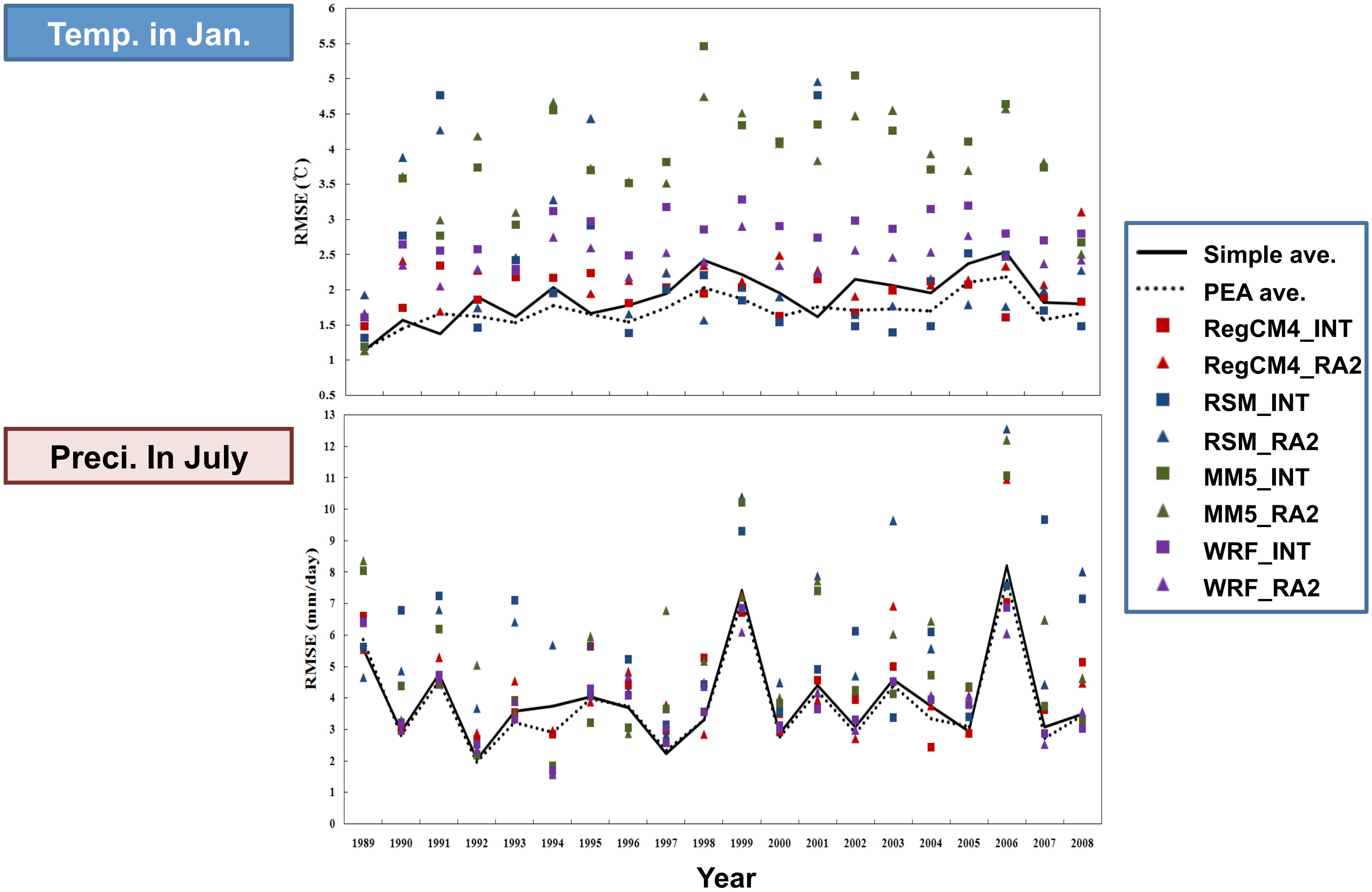
ΔT_i : Bias of the Model i

$\Delta \widetilde{T}$: Modified

Bias over South Korea



Interannual Variability of RMSE



Summary

- With the most skilful precipitation physics, each RCM demonstrates the substantial reproducibility for precipitation and surface air temperature.
- RCM simulations driven by two reanalysis are different mainly in tropics, which is caused by more moist (roughly ~ 0.8 g/kg) and stronger southward circulation in the ERA-interim compared with the NCEP/DOE RA2.
- In 20-yr long simulations, in general, each RCM tends to overestimate precipitation over Southern China and Indochina peninsula due to the enhanced summer monsoon
- The performance based ensemble averaging approach improves performance of simulation results.

Plan

- Based on the results of evaluation framework's simulations, the metrics for GCMs, RCMs, RCPs, and periods should be confirmed very soon for projection framework.

- Robust diagnostics for specific sub-regions and phenomena (e.g., monsoon, typhoons, heavy rainfall, heat waves, etc...) are required.

- Other participants, particularly RMIP community, who are interested in East-Asia domain are always welcomed for contribution to KMA-APCC Data Center to share data, analysis experiences, and scientific knowledge.