Evaluation of simulated Asia summer monsoon in AMIP experiment with high-resolution Climate Model & Possible involvement in CORDEX Southeast Asia

9 June 2014

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Introduction

❖ Recent climate study

- As more detailed and localized information is required regarding future clima te change due to the global warming, there is increasing demand for simulati ons by the high-resolution climate models.
- The use of higher-resolution models does not simulates only the large-scale phenomena but also reflects the regionally localized phenomena and tropical cyclones associated with small-scale orography.

❖ Previous study..

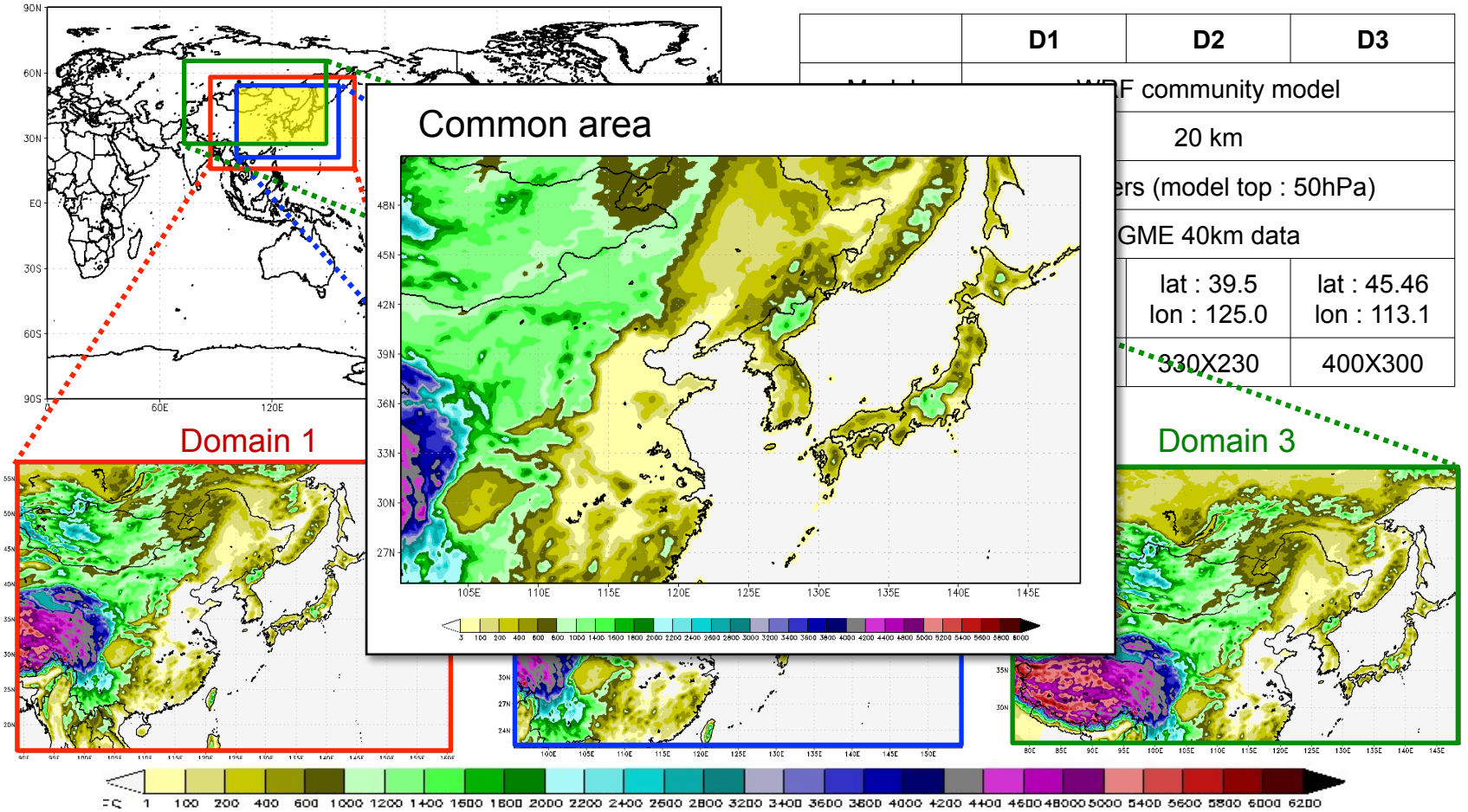
- Future climate simulation in time-slice method using MRI-AGCM (20km grid)
  - provide a large amount of information
    : East Asia monsoon (Kusunoki et al., 2006); Tropical cyclone (Oouchi et al.
,
    2006; Murakami et al., 2006), Extreme events (Kamiguchi et al., 2006)

- Regional climate simulation using dynamic downscaling
  - provide a detailed regional information and there are a lot of research activities (CORDEX, ENSEMBLES, NARCCAP, RMIP, etc)
  - limitation from lateral boundary problems

Limits of Regional Downscaling Methods

- Experiment on dependence of domain size and location of RCMs

1. Set of 3 different domains including the East Asia and Korean peninsula
2. Seasonal prediction for 1981-1982 using WRF regional model

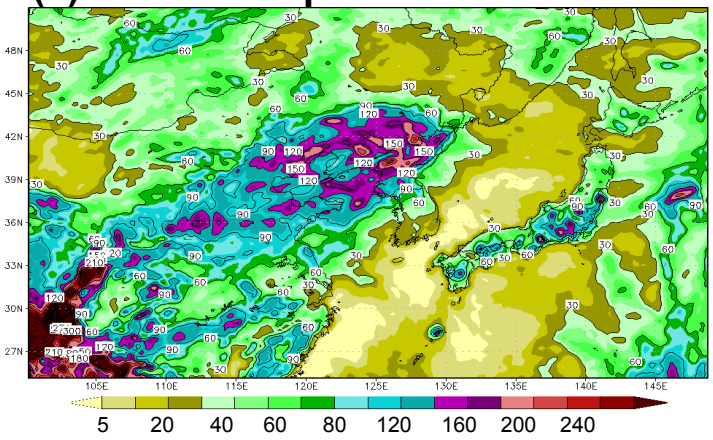


	D1	D2	D3
	F community model		
	20 km		
	rs (model top : 50hPa)		
	GME 40km data		
	lat : 39.5 lon : 125.0	lat : 45.46 lon : 113.1	
	330X230	400X300	

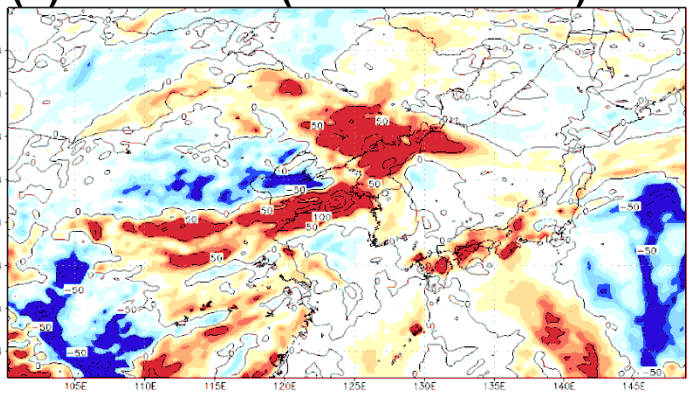
Limits of Regional Downscaling Methods

- Mean and Difference of Precipitation (July, 1982)

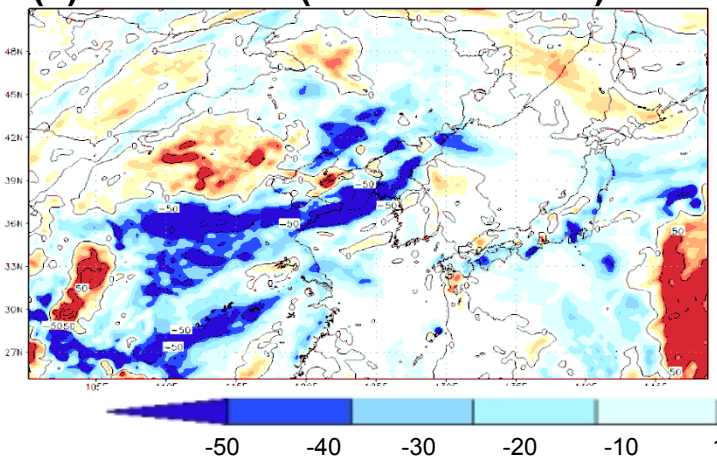
(a) Mean Precipitation of 3 domains



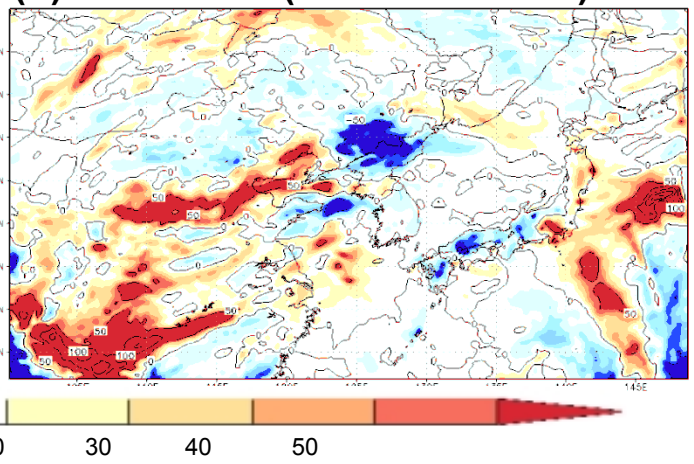
(b) Difference (D1 – 3domains)

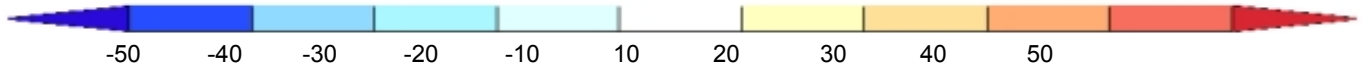


(c) Difference (D2 – 3domains)



(d) Difference (D3 – 3domains)

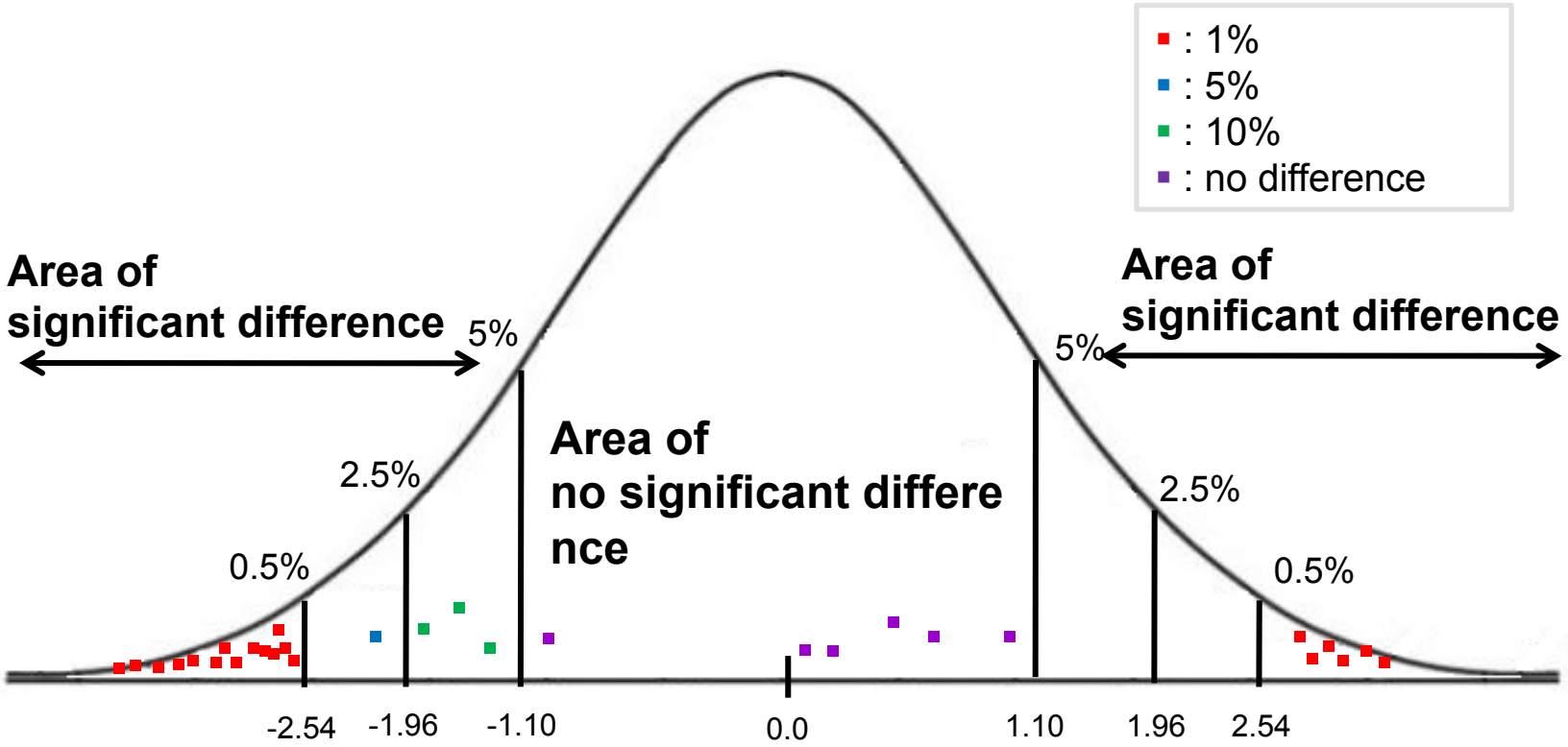




- When the domain size and location are changed, it shows the difference in spatial temperature (not shown) and especially precipitation pattern.

Limits of Regional Downscaling Methods

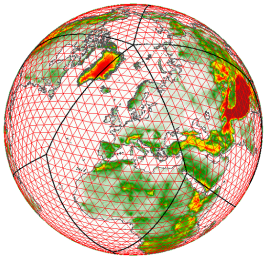
• Student's T-test of Precipitation (1981)



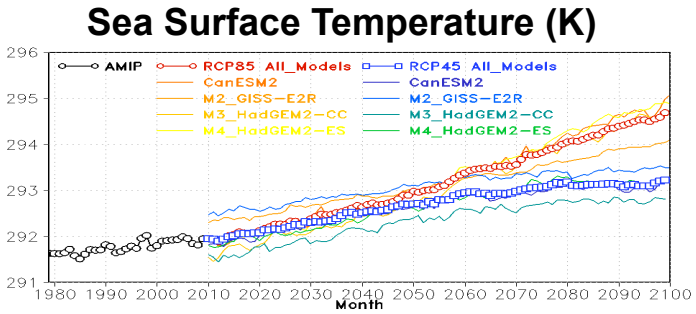
• Compared with the regional downscaling, global downscaling method can avoid t he lateral boundary problems.

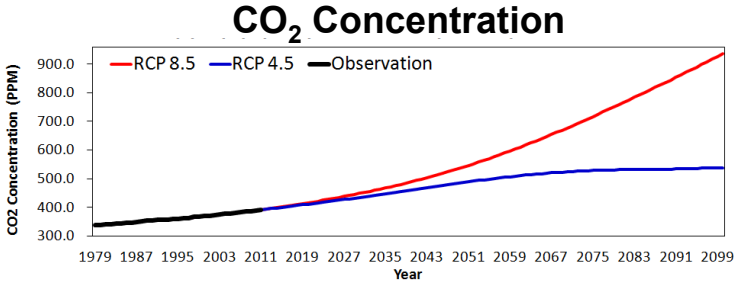
• So In this study, we suggest the climate simulation using **atmospheric global cli mate model** with horizontally high-resolution grid.

Configuration of the Experiment

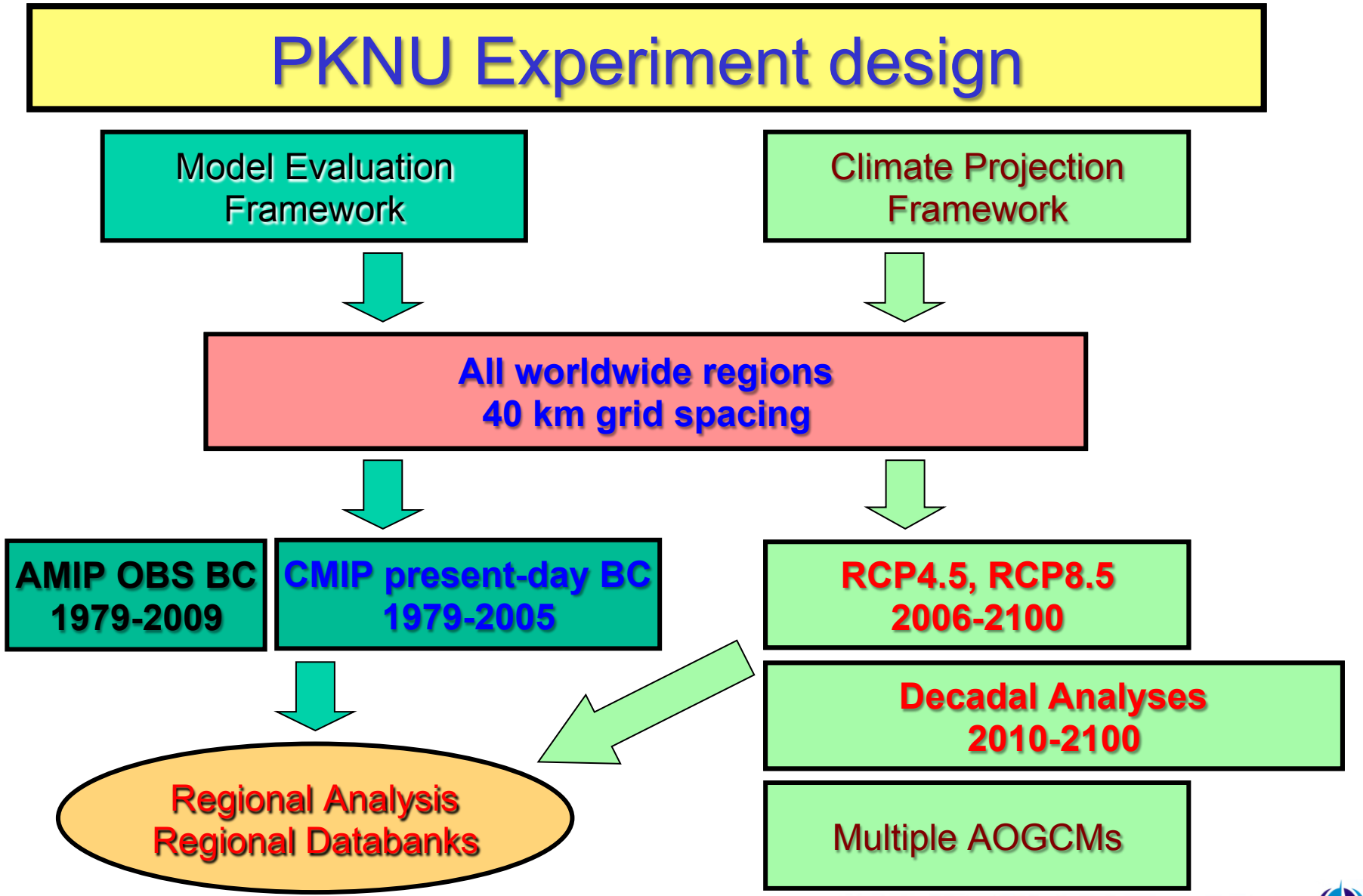


- Model : AGCM model GME with Icosahedral-Hexagonal grid
- Resolution : 40km grid/40 hybrid Layers ➔ 368,642 gridpoints/layer
- Boundary condition : Daily SST & Sea Ice Concentration
  - Historical run(1979-2009) : AMIP observation data
  - Present-day run(1979-2005) : Present-day based CMIP5 multi-models by IPCC
  - Future(2006-2100) : RCP 8.5, RCP 4.5 CMIP5 multi-models by IPCC
- Interval of BC : Daily interval
- Prognostic variables : ps, u, v, t, qv, qc, qi, o3
- Time integration: semi-Lagrangian scheme
- Convection Scheme : Tiedtke, 1989
- CMIP5 multi-models
  - CanESM2 (Canada) : 128×64 grid
  - CNRM-CM5 (France) : 256×128 grid
  - HadGEM2-ES (UK) : 192×145 grid
  - MIROC5 (UK) : 256×128 grid
- Control of CO_2 Concentration
  - Observation : GISS NASA (http://data.giss.nasa.gov/modelforce/ghgases)
  - RCP8.5, 4.5 : RCP Database (http://www.iiasa.ac.at/web-apps/tnt/RcpDb)





CORDEX Experiment design



Results of the Experiment

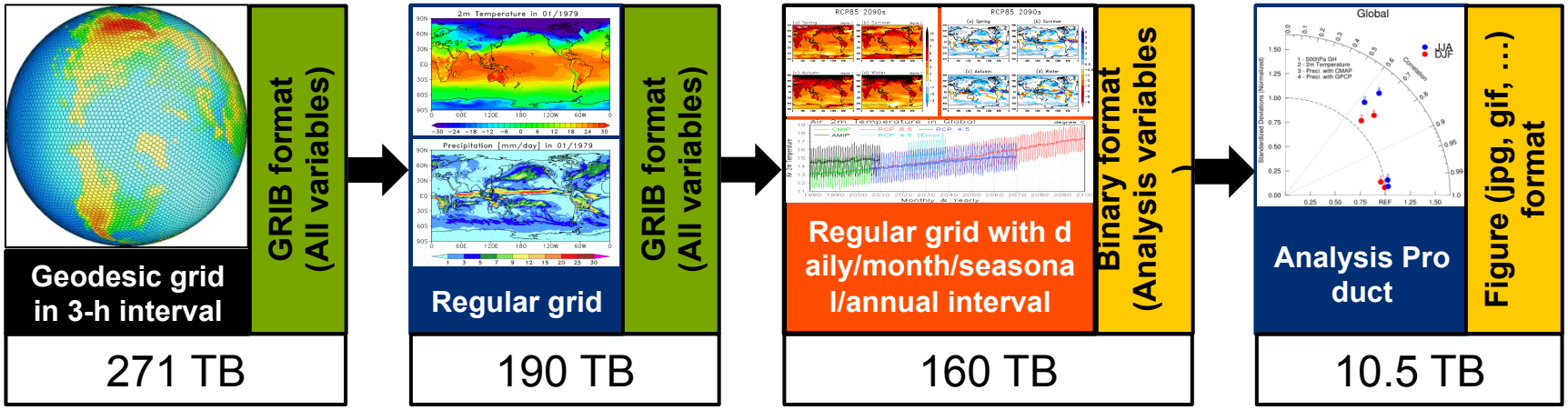
◦ Resolution : 900×451 (40km)/ 17 Layers

◦ Interval of Model output : 3 hourly

◦ Variable : Surface - 2m Air T, Precipitation, 10m U·V, MSLP, etc. (totally 80 variables)

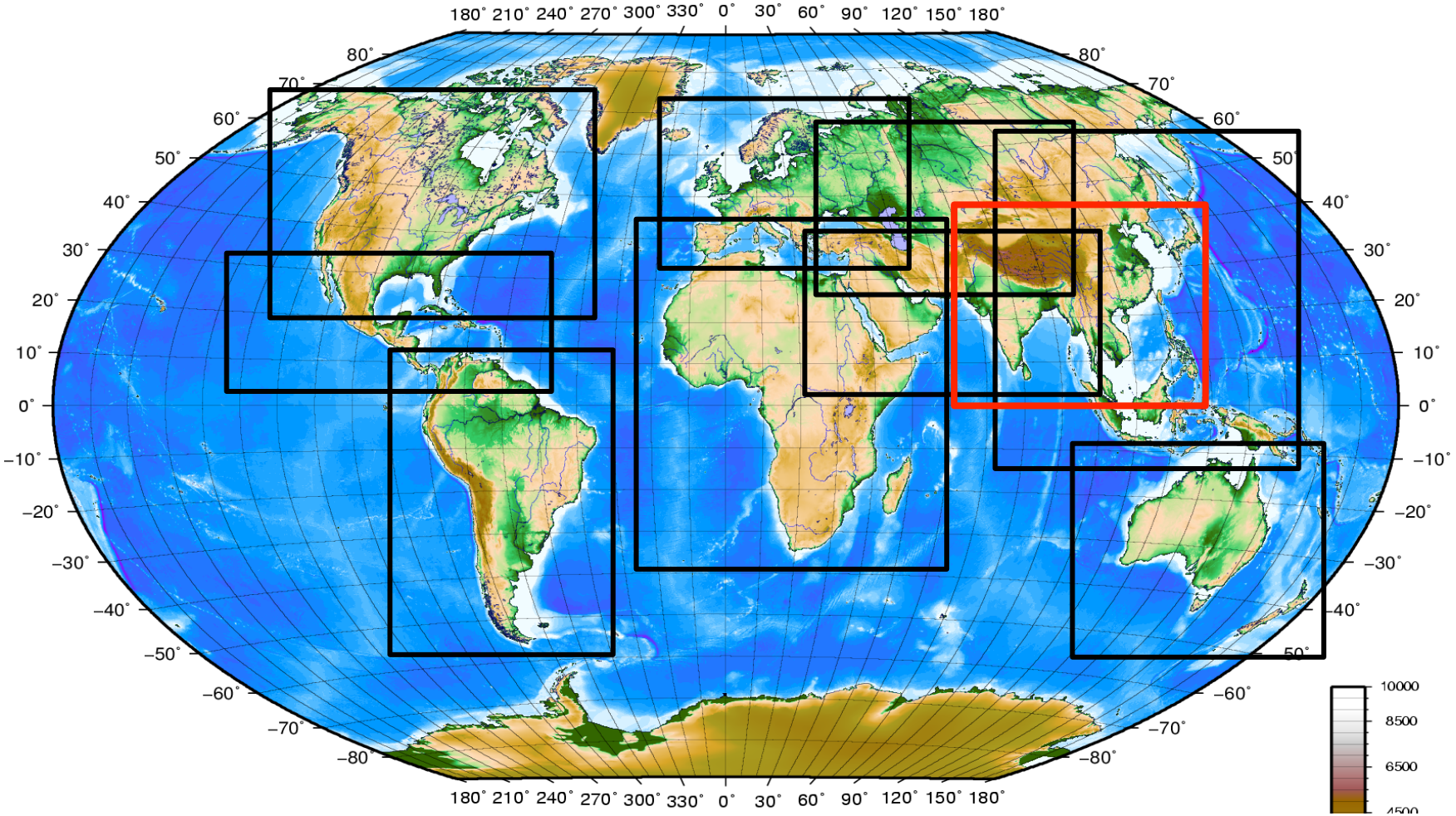
Vertical (17 layers) - Z, T, U, V, PS, QV, QC, QI, O3

◦ Data Processing (including the total data size)



◦ The model output data and all processed data are stored in GSDC(Global Sciences experimental Data Hub Center)/KISTI.

Analysis Domains



• The 40-km mesh long-term climate simulation data can cover the any CORDEX do main all over the world as well as detailed regional features in domain of SEACLID/C ORDEX Southeast Asia

Evaluation of AMIP experiment with high-resolution Climate Model

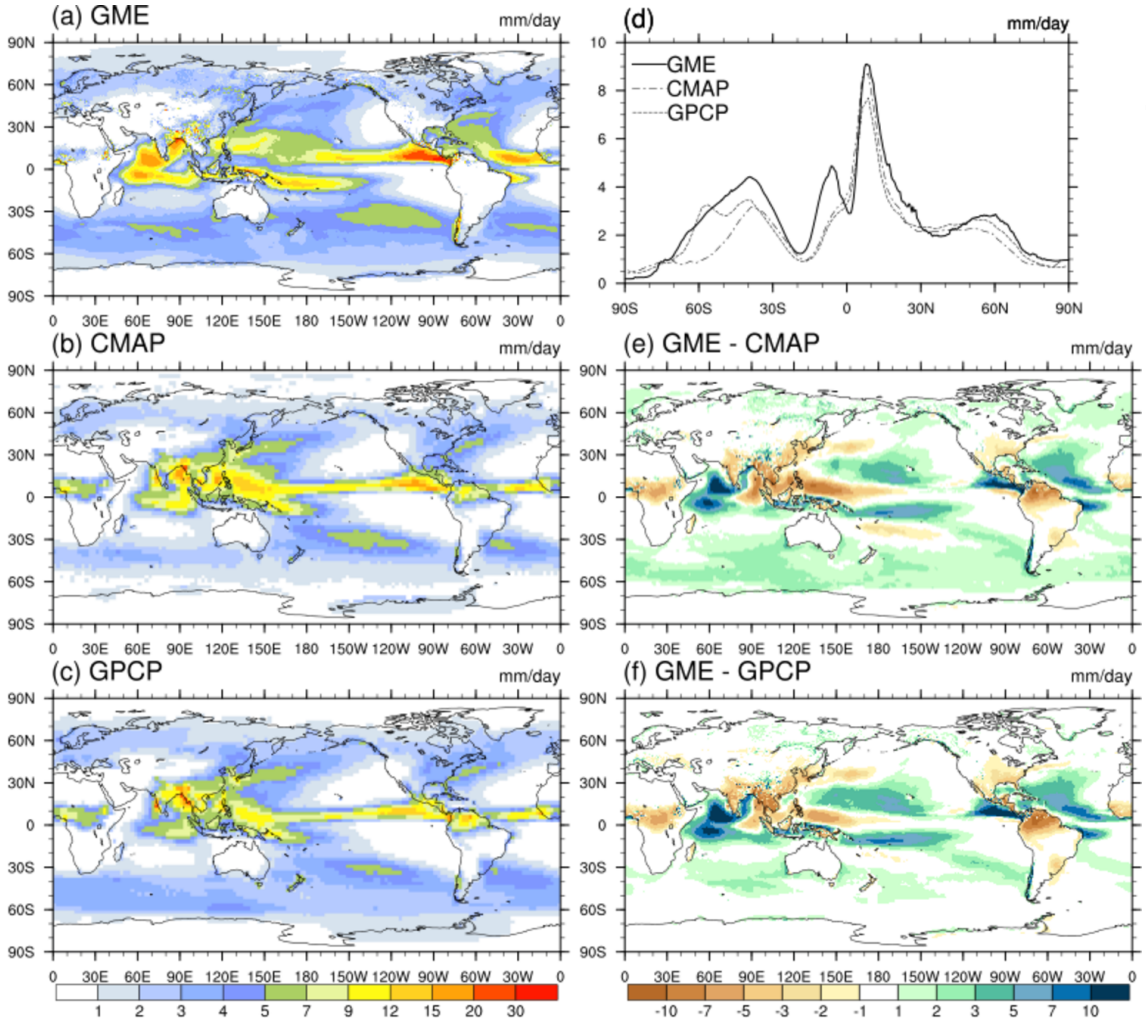
- GME 40km grid driven by AMIP Observation during 1979-2009 (31 yrs)
- Comparison of Performance with 4 CMIP5 multi-models

Model	CanESM2	CNRM-CM5	HadGEM2-ES	MIROC5
Grid Info.	128×64	256×128	192×145	256×128
Nation	Canada	France	UK	Japan

* These are best four model selected by Lee and Wang, 2014

- Evaluation with Observation :
  - NCEP/NCAR Reanalysis II (monthly, 2.5°, 1979-2009)
  - ERA-Interim Reanalysis (monthly, 1.5°, 1979-2009)
  - CMAP (monthly, 2.5°, 1979-2009)
  - GPCP (monthly, 2.5 °, 1979-2009)
  - GPCP11 (daily, 1°, 1998-2009)
  - TRMM-3B42 (daily, 0.25°, 1998-2008)
  - APRODITE (monthly, 0.25°, 1951-2007)

(1) Validation in Seasonal Climatology



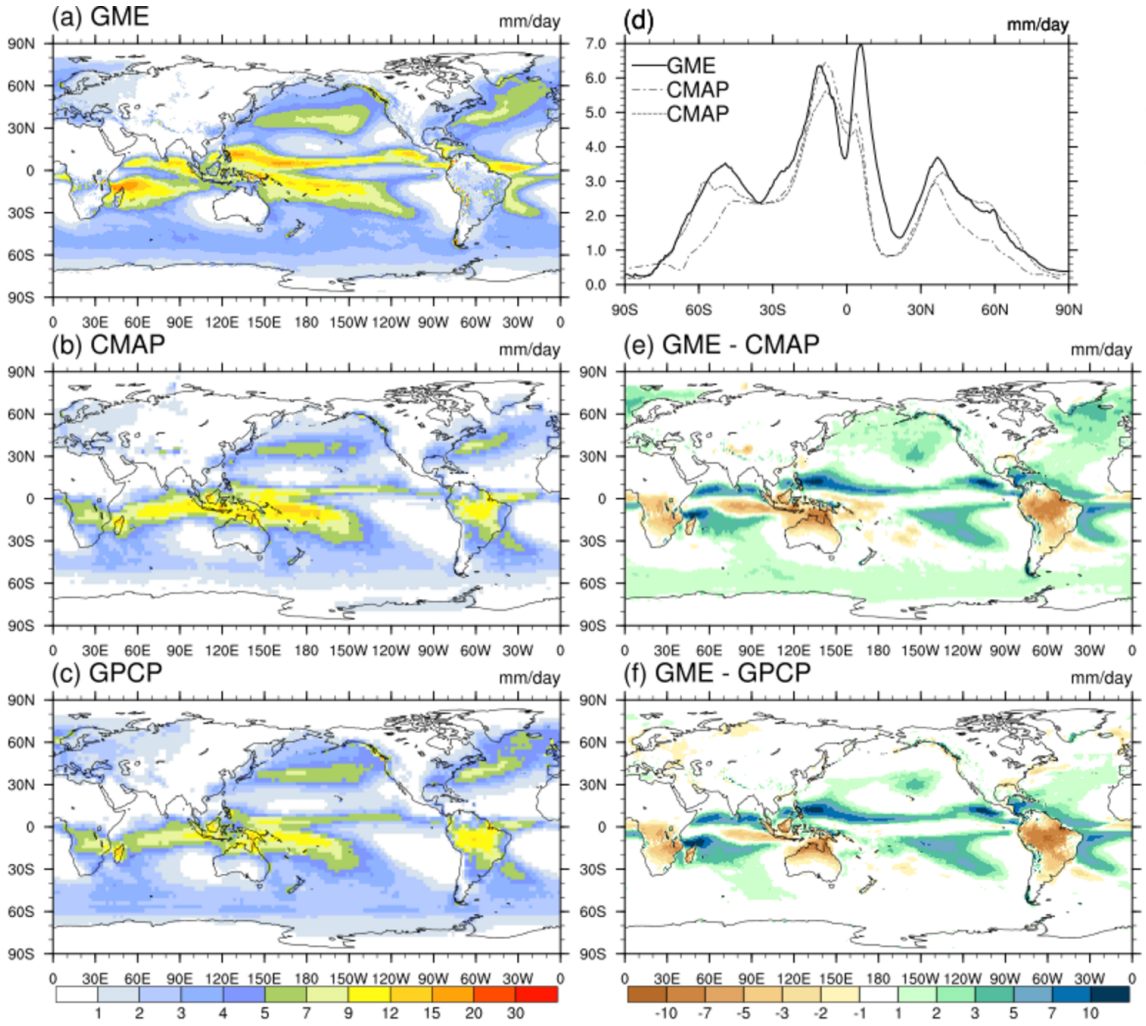
Horizontal distribution of long-term mean precipitation in Summer (June-August)

- GME (40km) and CMAP, GPCP during 1979-2009 (31 years)

- reproduce the general precipitation pattern (PCC : 0.692 with GPCP, 0.707 with CMAP)
- underestimate over southern Asia region.
- capture the zonal-mean precipitation well excepting the two rainfall bands over Equator region (∵ Double-ITCZ problem)

Fig. 1 Spatial distribution of seasonal mean precipitation in Summer [June-August (JJA)] for (a) the GME model (40-km, 1979-2009, 31 years), (b) observation of CMAP (2.5°, 1979-2009, 31 years), (c) observation of GPCP (2.5°, 1979-2009, 31 years) and (e), (f) difference between the GME model and observations (CMAP and GPCP). (d) Seasonal zonal-mean precipitation in JJA and for the GME model (solid line), observation of CM AP (dot-dash line) and observation of GPCP (dot line). Units are mm day^{-1}.

(1) Validation in Seasonal Climatology



Horizontal distribution of long-term mean precipitation in Win ter (December-February)

- GME (40km) and CMAP, GPCP during 1979-2009 (31 years)

- good agreement the precipitation pattern (PCC : 0.705 with GPCP, 0.707 with CMAP)
- underestimate over south America and South Africa region

Fig. 2 Spatial distribution of seasonal mean precipitation in Winter [January-February (DJF)] for (a) the GME model (40-km, 1979-2009, 31 years), (b) observation of CMAP (2.5°, 1979-2009, 31 years), (c) observation of GPCP (2.5°, 1979-2009, 31 years) and (e), (f) difference between the G ME model and observations (CMAP and GPCP). (d) Seasonal zonal-mean precipitation in DJF and for the GME model (solid line), observation of CMAP (dot-dash line) and observation of GPCP (dot line). Units are mm day^{-1}.

(1) Validation in Seasonal Climatology

Overall performance of AMIP-Type simulation using the Taylor (2001) analysis

- GME (40km) and CMAP, GPCP, ERA Interim and EBAF during 1979-2009 (31 years)

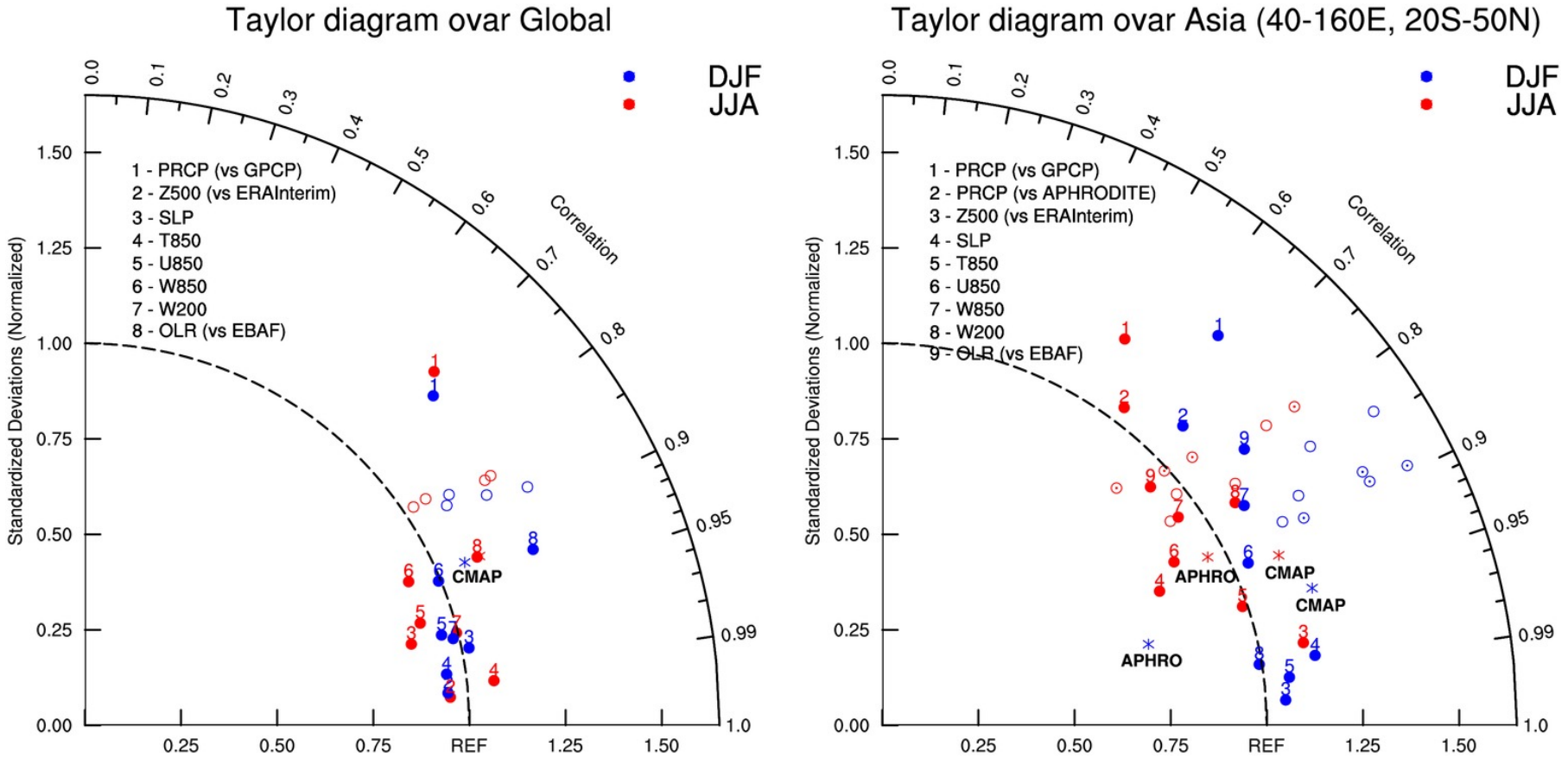


Fig. 4 Taylor diagram for the global and Asia region. The terms "PRCP", "Z500", "SLP", "T850", "U850", "W850", "W200" and "OLR" indicate precipitation, geopotential height at 500hPa, sea level pressure, temperature at 850hPa, zonal velocity at 850hPa, wind speed at 850hPa and 200hPa, and longwave radiation. The skill for precipitation is compared with GPCP and APHRODITE (over Asia) and skill of GPCP data relative to CMAP and APHRODITE is plotted by mark *asterisk* for reference. Other variables are compared with ERA Interm and OLR is validated with EBAF data. And in case of precipitation, four CMIP5 models are also compared with GPCP (*open circles*) and APHRODITE (*open circles & center point*) used for comparison.

(1) Validation in Seasonal Climatology

Overall performance of AMIP-Type simulation using the Taylor (2001) analysis

A measure of skill score S for precipitation is calculated as

$$S = \frac{4(1+R)}{\left(\sigma + \frac{1}{\sigma}\right)^2 (1+R_0)},$$

R: pattern correlation, s: normalized spatial standard deviation

R_0 : achievable maximum (here set as 1)

Variable♪	Data♪	Region♪	Skill Score♪	
			JJA♪	DJF♪
PRCP♪	CMAP♪	Global♪	0.842 (0.896-0.923)♪	0.849 (0.904-0.926)♪
PRCP♪	GPCP♪	Global♪	0.795 (0.883-0.915)♪	0.820 (0.875-0.915)♪
Z500♪	ERA♪	Global♪	0.996♪	0.995♪
SLP♪	ERA♪	Global♪	0.968♪	0.990♪
T850♪	ERA♪	Global♪	0.992♪	0.992♪
U850♪	ERA♪	Global♪	0.970♪	0.982♪
W850♪	ERA♪	Global♪	0.950♪	0.963♪
W200♪	ERA♪	Global♪	0.985♪	0.986♪
OLR♪	CERES_EBAF♪	Global♪	0.948♪	0.917♪
PRCP♪	**APHRODITE♪**	**Asia♪**	**0.800 (0.816-0.873)♪**	**0.844 (0.797-0.911)♪**
Z500♪	ERA♪	Asia♪	0.979♪	0.997♪
SLP♪	ERA♪	Asia♪	0.905♪	0.977♪
T850♪	ERA♪	Asia♪	0.974♪	0.992♪
U850♪	ERA♪	Asia♪	0.918♪	0.955♪
W850♪	ERA♪	Asia♪	0.905♪	0.918♪
W200♪	ERA♪	Asia♪	0.915♪	0.993♪
OLR♪	CERES_EBAF♪	Asia♪	0.869♪	0.870♪

Table 1 Skill Scores for Seasonal Climatology. For the comparison, the range (Min./Max.) of skill scores in CMIP5 best mod els (referred by Lee et al., 2012) are used.

(1) Validation in Seasonal Climatology

Summary

- The high-resolution atmospheric general circulation model (GCM) have been used for regio nal detail climate response for the future climate simulation due to the RCP scenarios.
- For the model evaluation, we have performed the AMIP-type simulation during 1979-2009 (31 y ears) with AMIP observed SST and sea ice.
- In AMIP-type simulation using GME, the model shows the good agreement in spatial distribution of long-term seasonal mean precipitation with observation.
- In overall performance of AMIP-type simulation by Taylor analysis, the model has good skill scor es with high magnitude (almost > 0.9) of pattern correlation excepting the precipitation.
- In case of precipitation, the model has comparable/better skill scores comparing with four CMIP 5 models in the comparison with high-resolution observation (APHRODITE, 0.25^{o}) than others (CMAP and GPCP, 2.5^{o}).

(2) Validation in Global Monsoon

Proposed by Wang and Ding (2008)

• The GM (Global Monsoon) represents the dominant mode of the annual variation of the tro pical precipitation and low-level winds, which defines the seasonality of Earth's climate.

Definition of Global Monsoon Indices

Following Liu et al. (2009) and Hsu et al. (2011)

- Global Monsoon Area (GMA) :

regions where (1) annual precipitation range (i.e., the difference between local summer and winter [MJJAS-NDJFM]) > 1.5 mm/day
(2) local summer precipitation > 55 % of annual rainfall

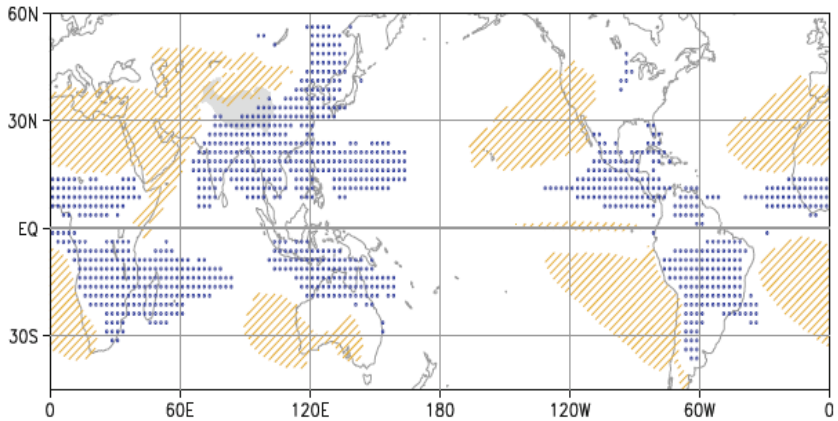
divided 6 monsoon regions as Asian, Australian, North American, South American, West African, and South African monsoon regions

- Global Monsoon Precipitation (GMP):

total summer monsoon rainfall falling in the monsoon domain

- Global Monsoon Intensity (GMI):

monsoon precipitation per unit area

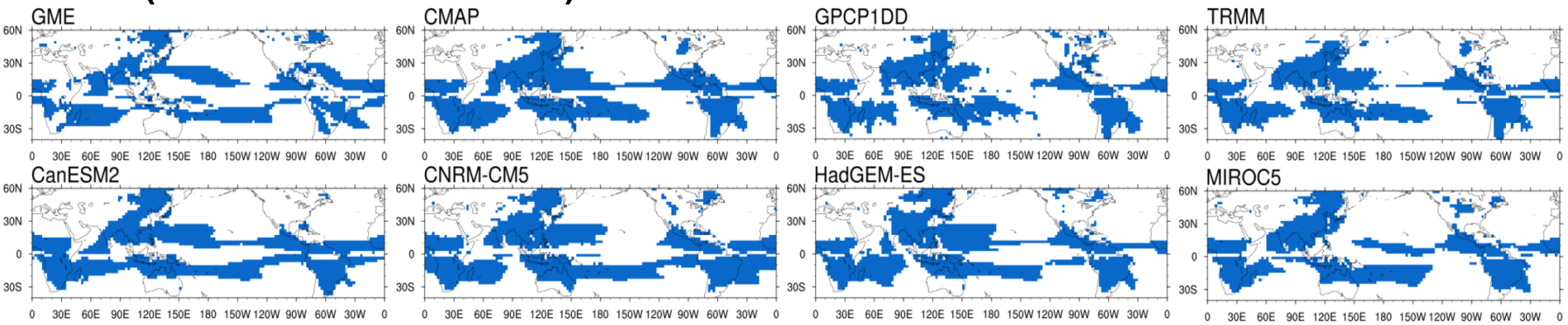


Global monsoon precipitation domain
referred by Wang B et al., 2012

(2) Validation in Global Monsoon

- GME and CMAP, GPCP1DD, TRMM and 4 CMIP5 models during 1979-2009 (31 years)

- **GMA (Global Monsoon Area)**



- **GMP (Global Monsoon Precipitation)**

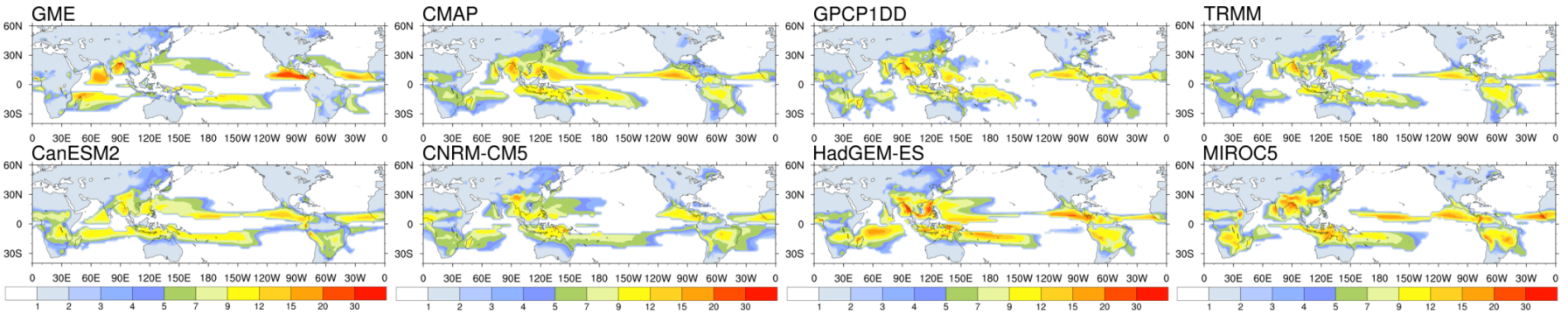


Fig. 5 Global monsoon area (GMA) and Global monsoon precipitation (GMP). For the comparison, observed CMAP, GPCP1DD and T RMM data and 4 CMIP5 models are used .GMA is defined as the regions where the annual range (i.e., the difference between local sum mer and winter) of precipitation exceeds 1.5 mm d^{-1}, and the local summer precipitation exceeds 55% of annual rainfall. GMP is define d as the difference between local summer (JJA in the Northern Hemisphere and DJF in the Southern Hemisphere).

(2) Validation in Global Monsoon

- Simulation biases of GMA(Global Monsoon Area), GMP(Global Monsoon Precipitation), and GMI(Global Monsoon Intensity) relative to observation (GPCP) [i.e., $(X_{model} - X_{obs.})/X_{obs.}$]

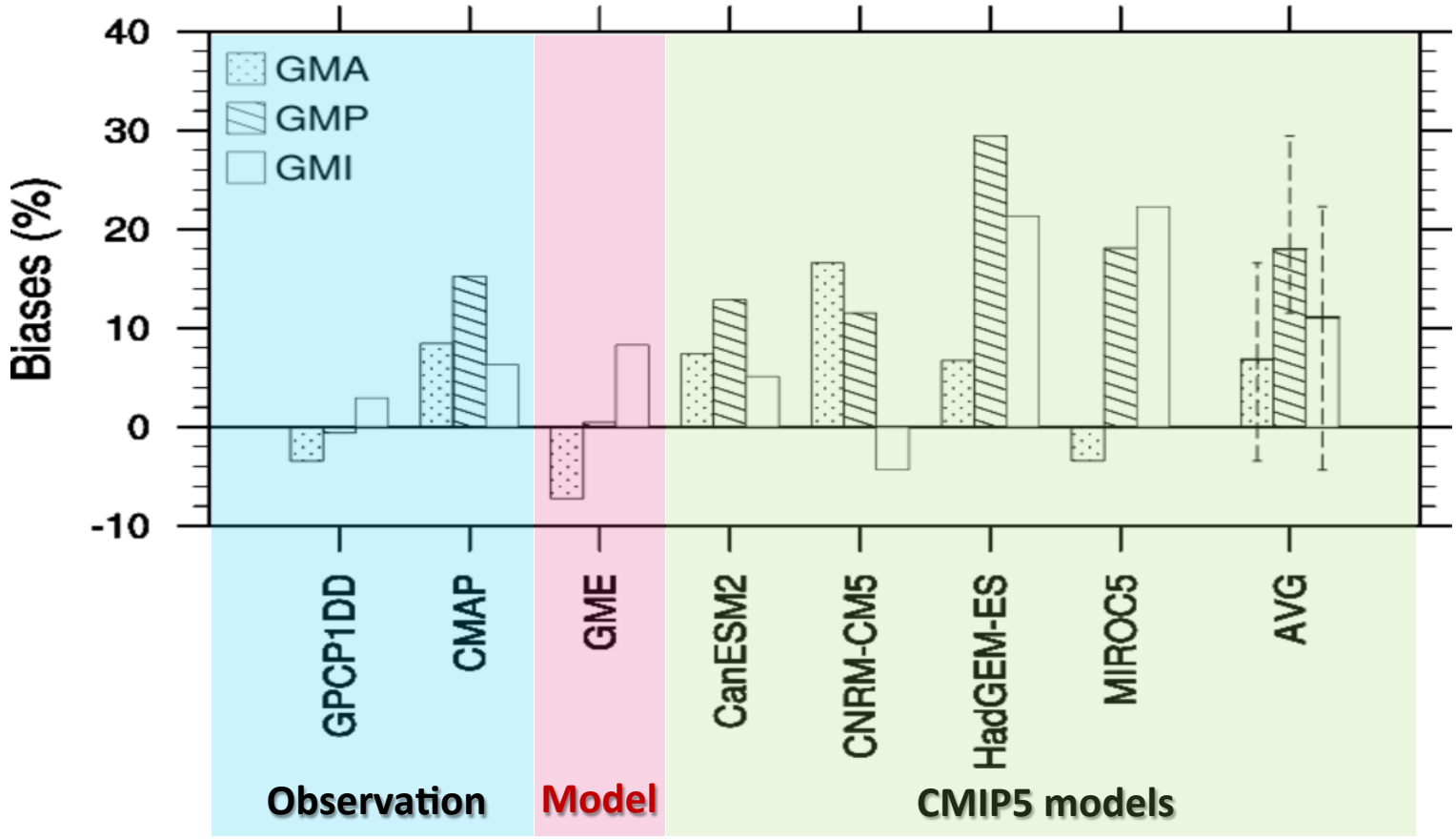


Fig. 6 Simulation biases of global monsoon activities [GMA (global monsoon area), GMP (global monsoon precipitation), and GMI (global monsoon intensity) relative to GPCP observation [i.e., $(X_{model} - X_{obs.})/X_{obs.}$]. For the comparison, CMIP5 best models (referred by Lee et al., 2012) and their average are also used.

(2) Validation in Global Monsoon

- Monthly Precipitation within GMA (Global Monsoon Area)

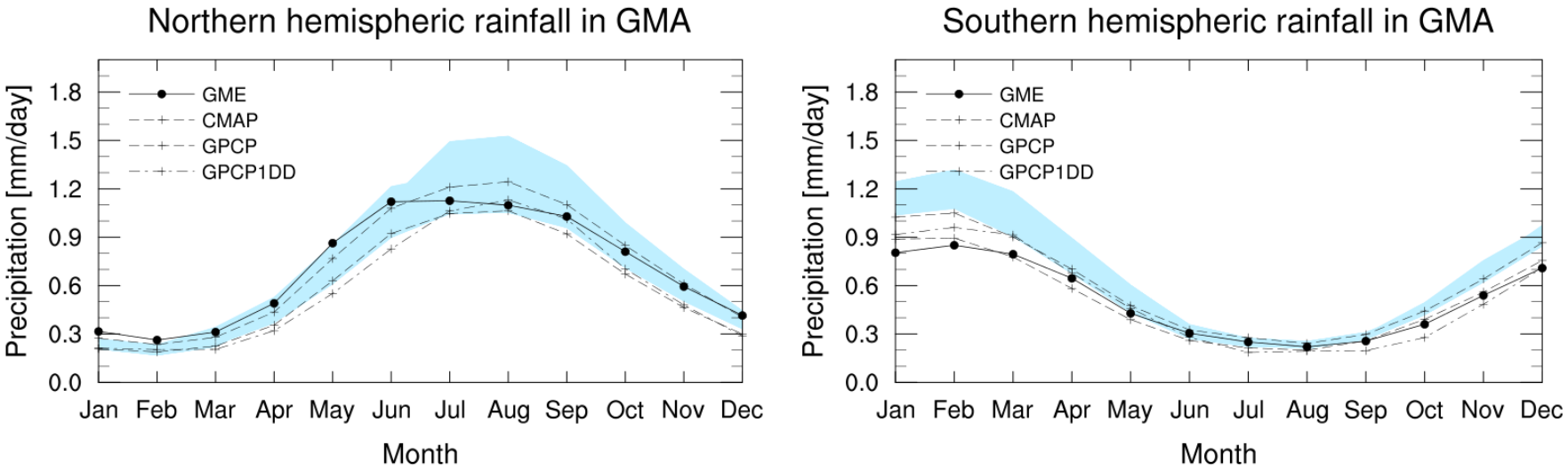


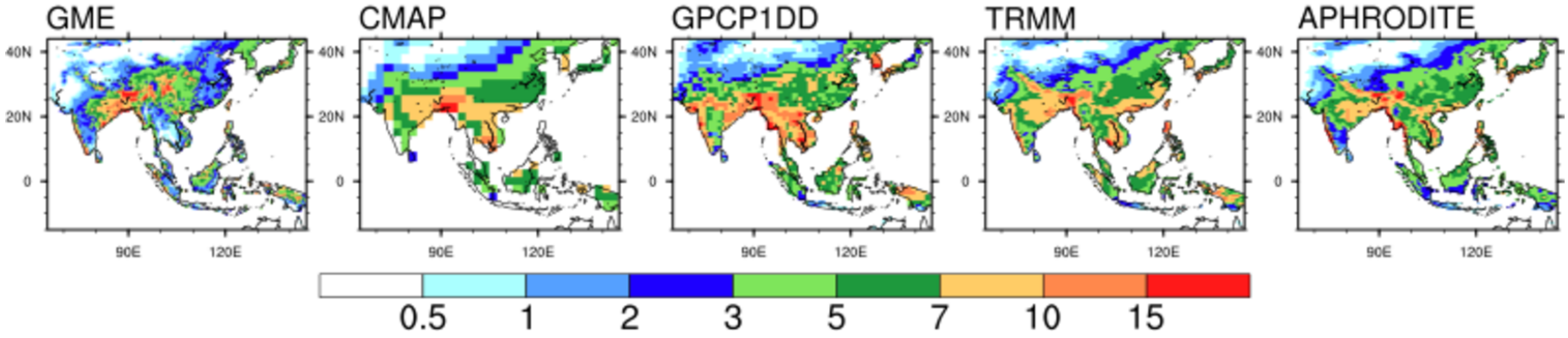
Fig. 7 Monthly rainfall variations within the northern hemispheric and southern hemispheric monsoon regions. GME model (*soild line wit h big circle*) are compared with CMAP, GPCP, GPCP1DD observation data (*all dot line with small circle*) The four CMIP5 models are al so used (*shaded*)

Summary

- The GME model clearly reproduced the six distinct monsoon areas. Although the GME shows t he underestimate of the Asian summer monsoon which recent CMIP5 model results also ha ve.
- In global monsoon indices, however, the model has little bias comparing four CMIP5 models . And it also represents the annual variation of the rainfall over the Global monsoon area. Ge nerally, the model reflects the rainfall trends comparing the four CMIP5 models

(3) Validation in Asia Monsoon Region

• Spatial Mean Precipitation during JJA, 1979-2009 (unit: mm/day)



• Annual Cycle in Zonal-averaged precipitation over South-East Asia (65-145°E)

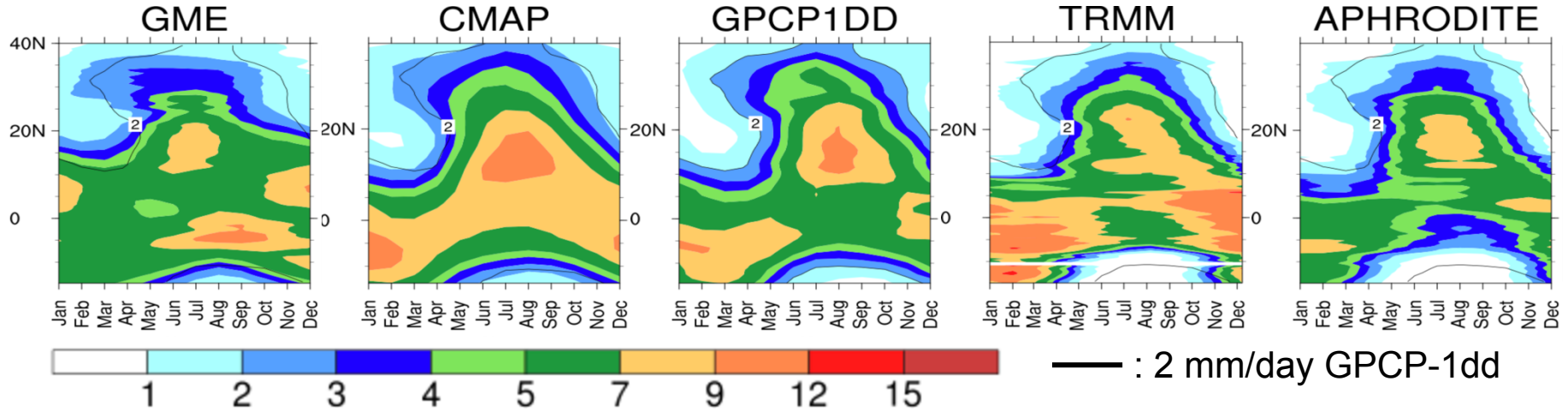


Fig. 8 JJA mean precipitation and Zonal-averaged monthly variation over the South-East Asia region (65-145°E) during 1979-2009 (31 y ears). For the comparison, CMAP (2.5°, 1979-2009), GPCP1DD (1°, 1998-2009), TRMM (0.25°,1998-2009) and APHRODITE (0.25°, 1 979-2007) are used.

(3) Validation in Asia Monsoon region

Summary

- In the evaluation over the Asia monsoon region, the model reflects the detailed feature of p recipitation as well as the spatial pattern well over Asia region (India, Bay of Bengal, Centr al China).
- Although the model underestimates the amount of precipitation over the Thailand, China a nd Korea which most CMIP5 models have, it captures the almost precipitation pattern well over the South East Asia region.
- The model shows the monthly pattern during Asia monsoon season (from May to Septemb er) over the South East Asia region (65-145^{o}W). Especially, the model is matched the spati al and temporal distribution with high-resolution observation data (APHRODITE, 0.25^{o}).
- The model simulates the seasonal evolution of the Asian monsoon defined monsoon indices.
- Based on these analysis, we could project the detailed regional climate change until 2100 over the Asian monsoon region as well as global due to the RCP scenario.

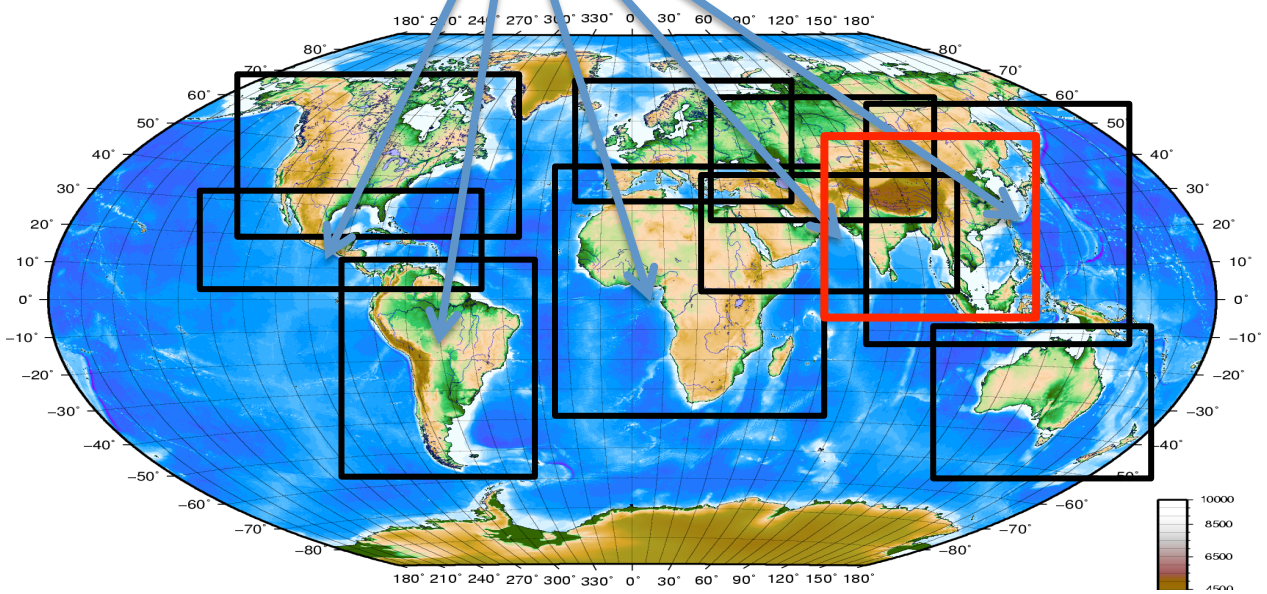
Possible involvement in CORDEX Southeast Asia

Korean Gov.
MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

support

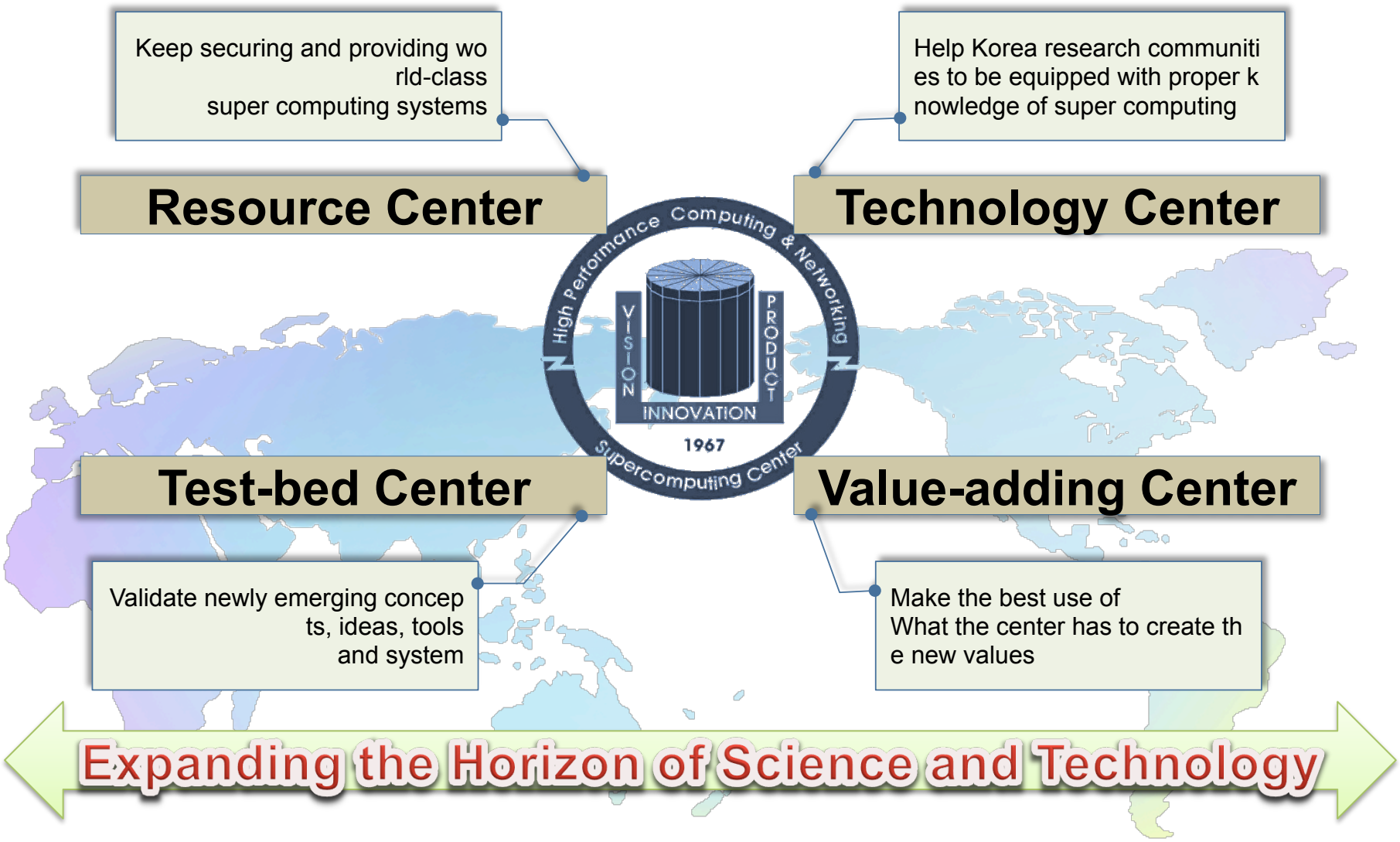
SDC KiSTi
www.kisti.re.kr

- Computing and Storage Infrastructure
- Technology Development
- Apply Grid Technology to legacy app.



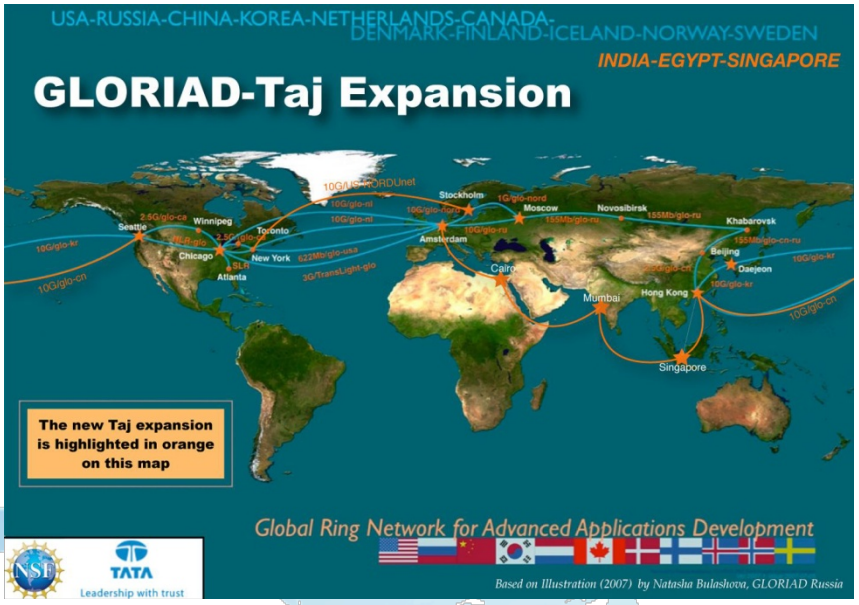
SUPPORTING DATA CENTRIC RESEARCH COMMUNITIES
&
PROMOTION OF RESEARCH COLLABORATION

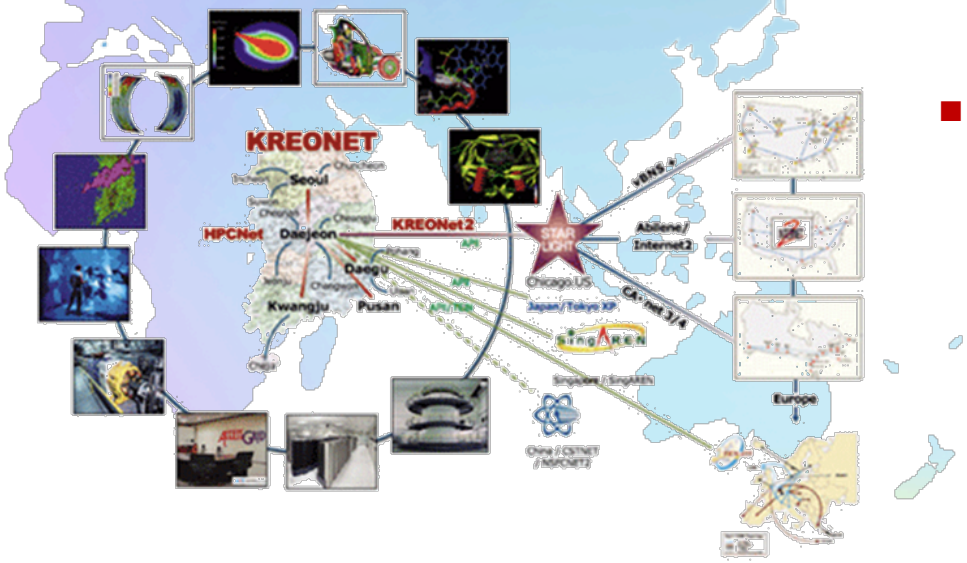
KISTI Super Computing Center Mission



Global Research Networks

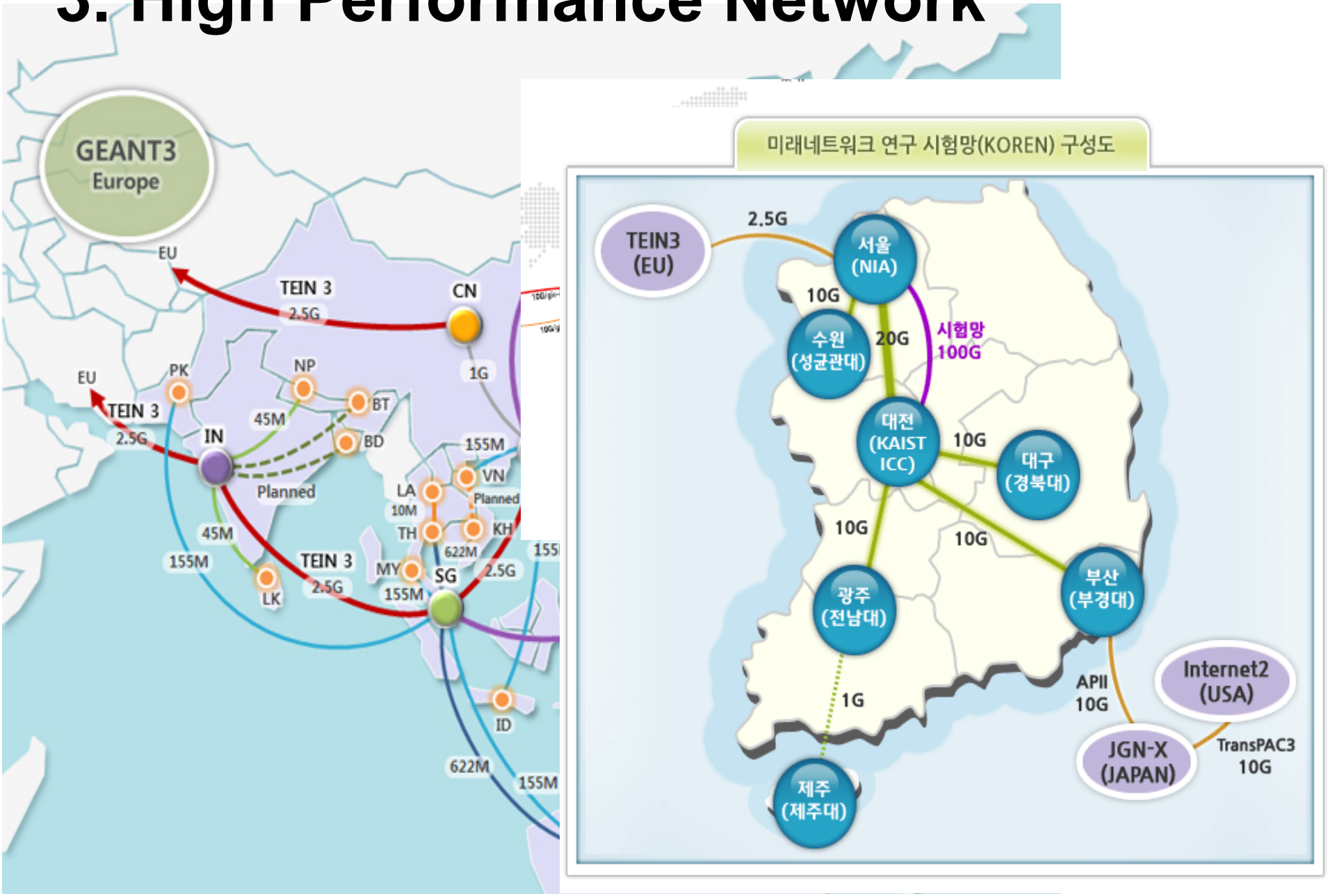
- **GLORIAD**
  - Ü **GLO**bal **RI**ng Network for **A**dvanced Applic ations **D**evelopment) with 10/40Gbps Optical lambda networking
  - Ü **Consortium of 11 Nations**: Korea, USA, Ch ina, Russia, Canada, the Netherlands and 5 Nordic Countries
  - Ü **Supporting Advanced Application Develo pments** such as **HEP**, Astronomy, Earth Sys tem, Bio-Medical, HDTV etc.
  - Ü Funded by MEST (Ministry of Education, Sci ence and Technology) of KOREA



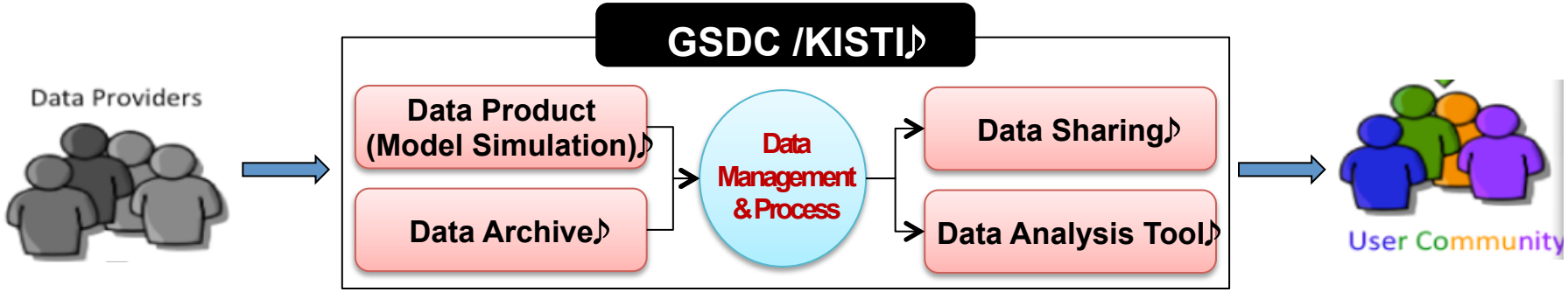


- **KREONET**
  - Ü **K**orea **R**esearch **E**nvironment **O**pen **NET**wor k
  - Ü National Science & Research Network of Ko rea, Funded by Government since 1998
  - Ü **20Gbps Backbone,** 1 ~ 20Gbps Access Net works

3. High Performance Network



Role of GSDC for Asia CORDEX Data Center



- **Archival, management and sharing of CORDEX-SEA model output data in GSDC big data farm**
- **Development of multi-model ensemble projections regional climate change scenarios over CORDEX-SEA region**
  - Generation of global climate projection with high-resolution GCM at PKNU
  - Regional climate projections from partner institution using RCMs
- **Evaluation and analysis of regional climate projections over Southeast Asia region**
  - Analysis tools (eg. NCL, CDO, RCMES)
- **Support of User communities**
  - User's training workshop (including System user's guide)
  - Research conference

Support of GSDC for Asia CORDEX Data Center

- **Support of Computing & Data Resources**

Computing & Data Resources	2014
High-performance computing Facility	**200 Cores**
Data Storage Capacity (total archive volume)	**200 Terabytes**


<KISTI GSDC>

- **Construction of Evaluation and analysis System**
  - Analysis tools (eg. NCL, CDO, RCMES)
- **Support of User communities**
  - User's tutorial workshop
    (1) user's guide for access and use of GSDC system for data provider/user communities
    (2) system user's tutorial for model simulation

THANK YOU FOR YOUR ATTENTION !

PUKYONG NATIONAL UNIVERSITY