

# Multi Model Ensemble seasonal prediction of APEC Climate Center

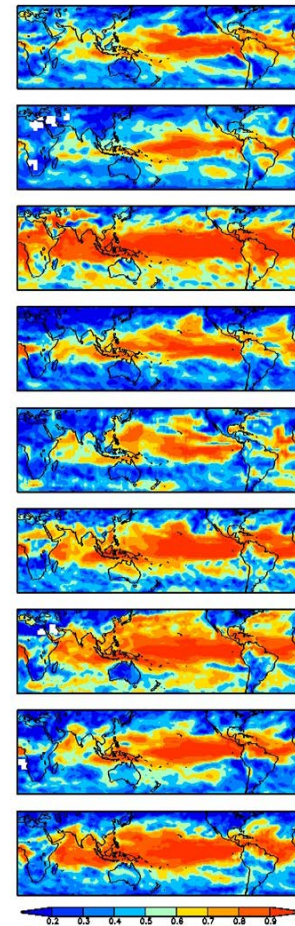
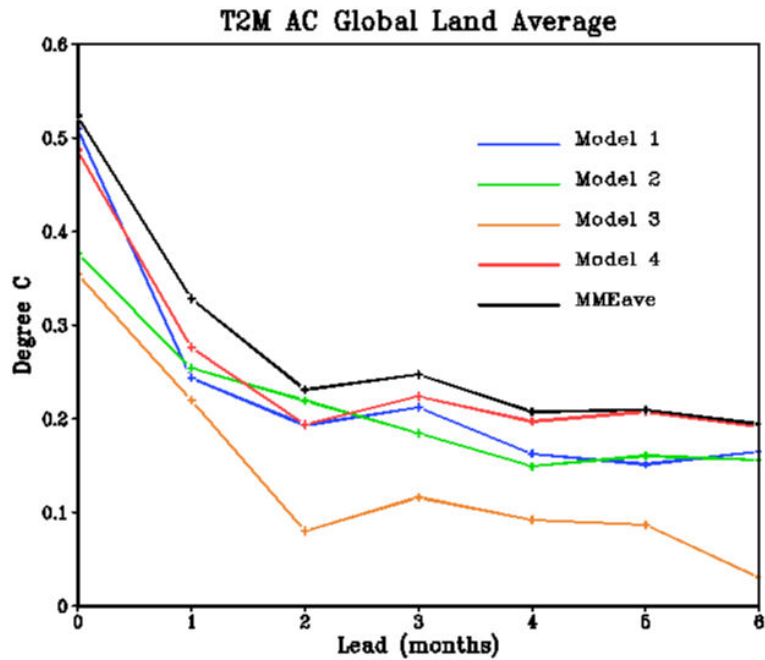
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Y.-M. Min, S.-J. Sohn, D.-Y. Lee,  
H. J. Park, J. Y. Seo and S. M. Oh



# Outline

- APCC and operational MME forecast
- Works for more useful products
  - Calibration and correction of MME forecast
    - Deterministic and probabilistic
  - Diversification of products
  - Case study : Arctic-East Asia connection

# Background



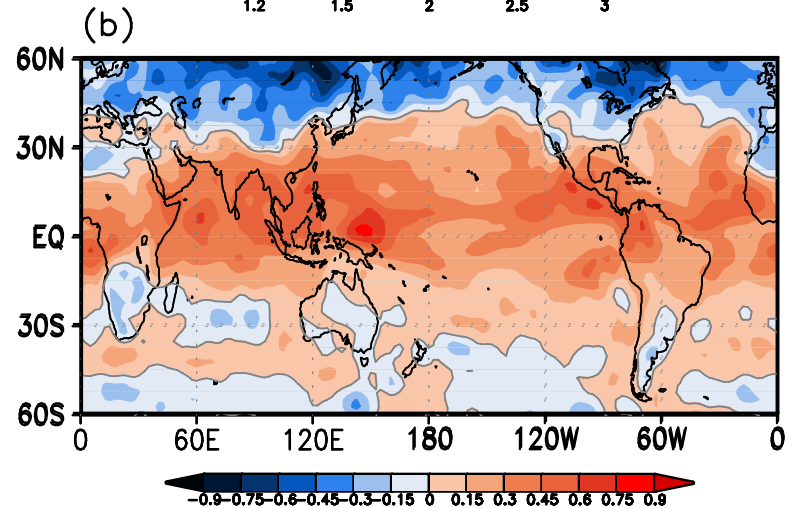
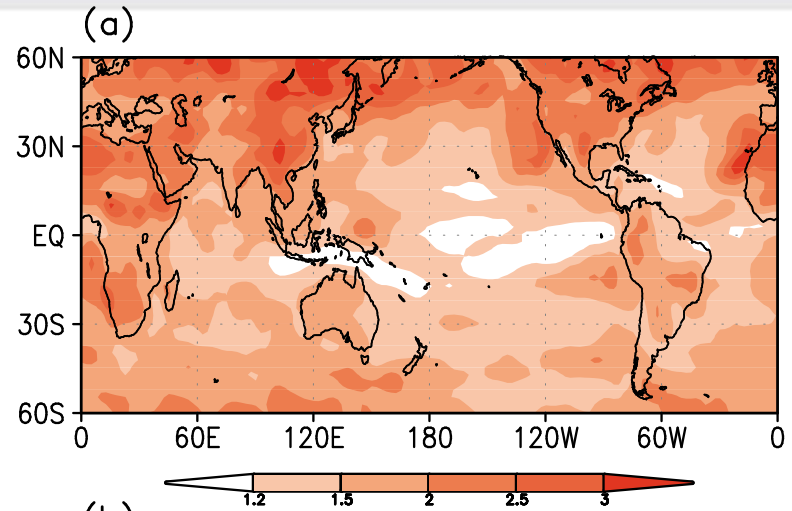
Potential predictability of summer rainfall

# Benefit of Multi Model Ensemble

$$R_{MM} = \frac{\langle R \rangle}{\sqrt{V(\langle y \rangle)}} = \frac{\langle R \rangle}{\sqrt{\langle r \rangle}}$$

$$\langle R \rangle = \frac{1}{M} \sum_i R_i \quad \langle r \rangle = \frac{1}{M^2} \sum_i \sum_j \frac{\overline{y_i y_j}}{V}$$

**Independent and good models :**  
**Best forecast result (on average)**



# Beauty of Democracy

- Independent and Rational individuals :
  - Best decision for society (in a long run)



# Operational MME initiatives



- Need and scientific evidences for useful operational services of seasonal forecast based on MME
- International technical cooperation (APEC recommends)
- APEC Climate Network was (APCN) proposed at 1998

# Establishment



Located at Busan, Korea  
~45 staffs from 5 economies

- 1998 – The creation of the **APEC Climate Network (APCN)** was proposed at the 3<sup>rd</sup> APEC Science and Technology Ministers Meeting in Mexico.
  - semi operation function in 2004
- 2004 – **APEC Climate Center** was proposed at the 27<sup>th</sup> APEC Industrial Science and Technology Working Group meeting in Singapore.
- 2005 – APEC member economies unanimously endorsed the establishment of APCC at the 1<sup>st</sup> APEC Senior Officials Meeting in Korea.
- 2005. Nov. – APCC was established

# APCC Goals

- Facilitating the **sharing** of high-cost climate data and information
- **Capacity building** in prediction and sustainable social and economic applications of climate information
- Accelerating and extending socio-economic innovation

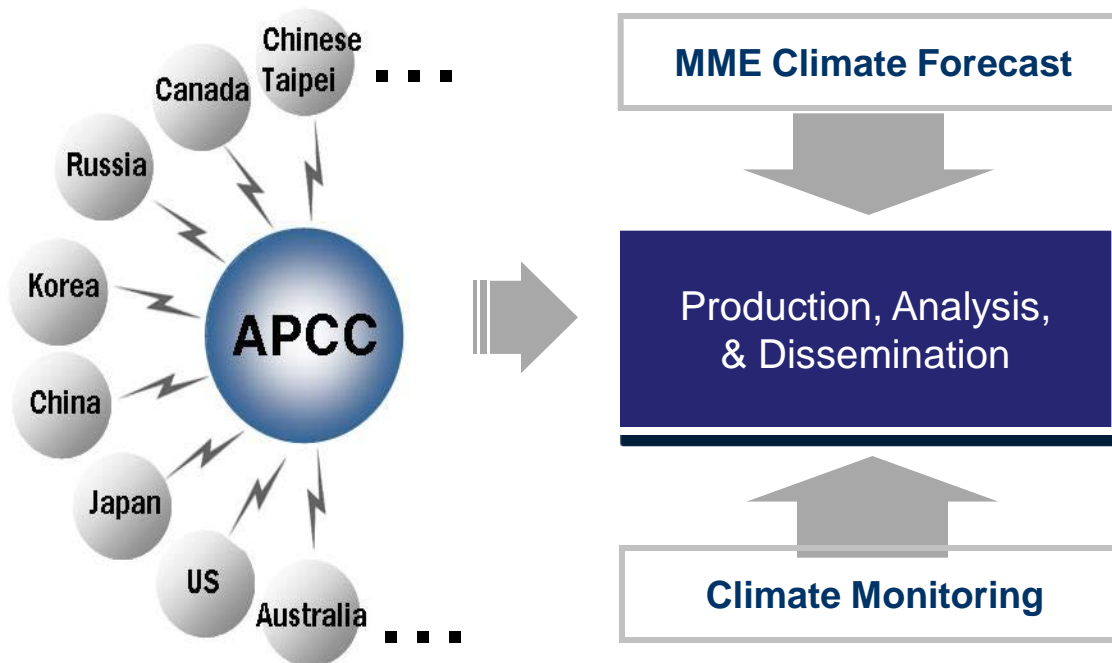


# **APCC operational Multi Model Ensemble forecast**

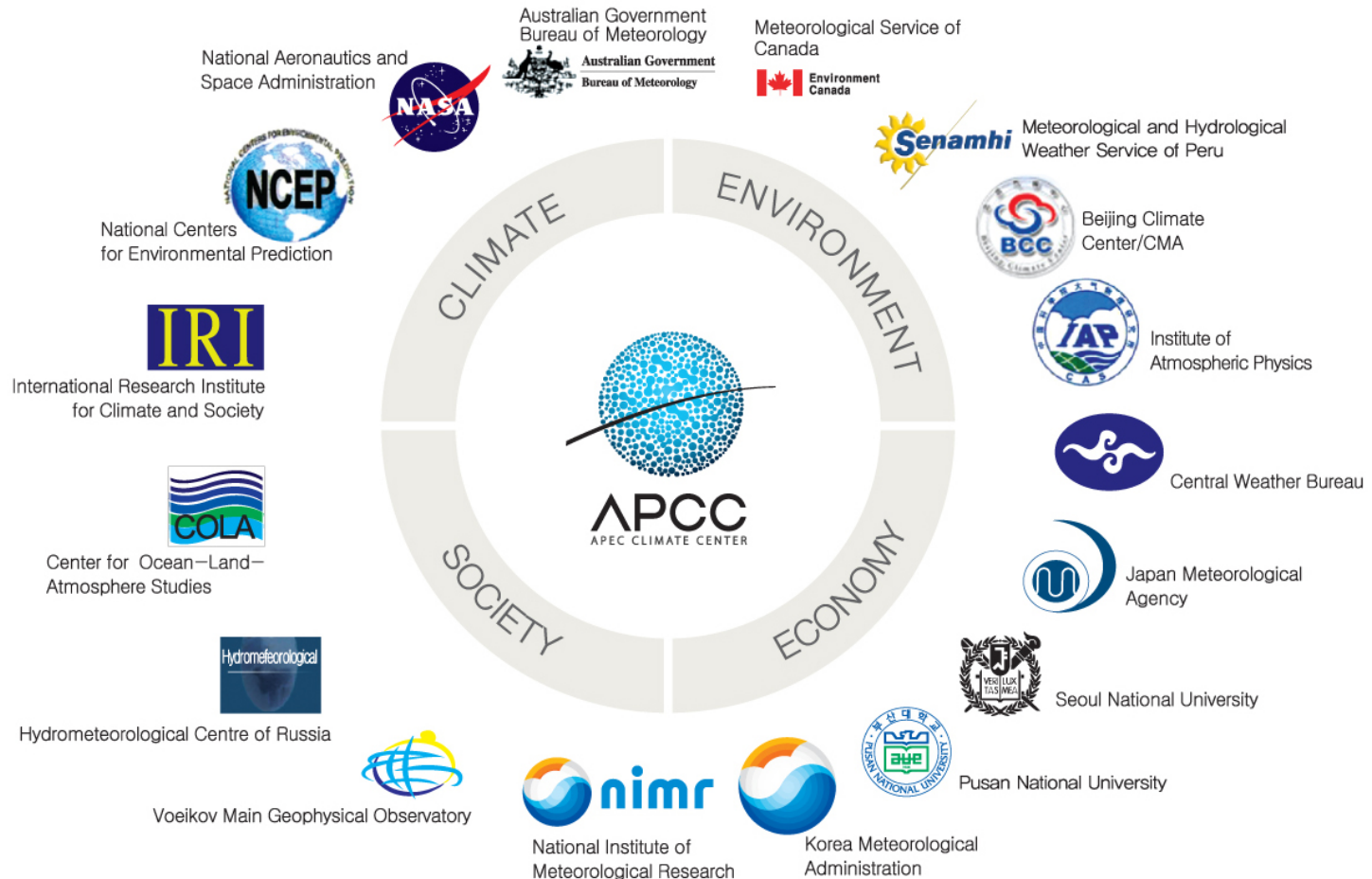
# Operational Multi Model Ensemble

## - Seasonal Forecast

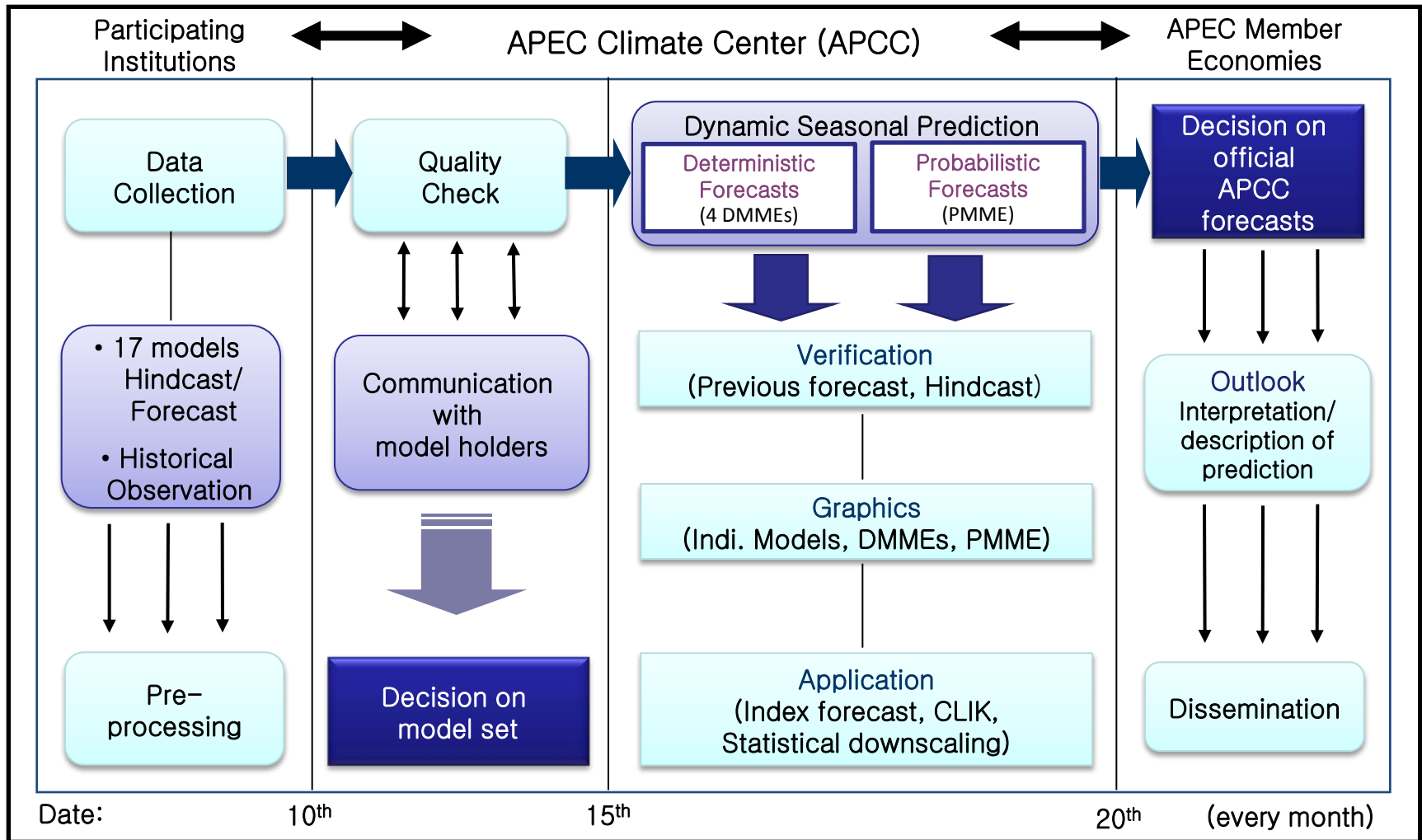
- Global climate forecast collected from 17 institutes (9 countries) issue *Monthly rolling 3-month MME climate forecast*
- Researches on intraseasonal to climate change projection, Extreme events (drought/flood) forecast, regional downscaling



# Multi-Institutional Cooperation

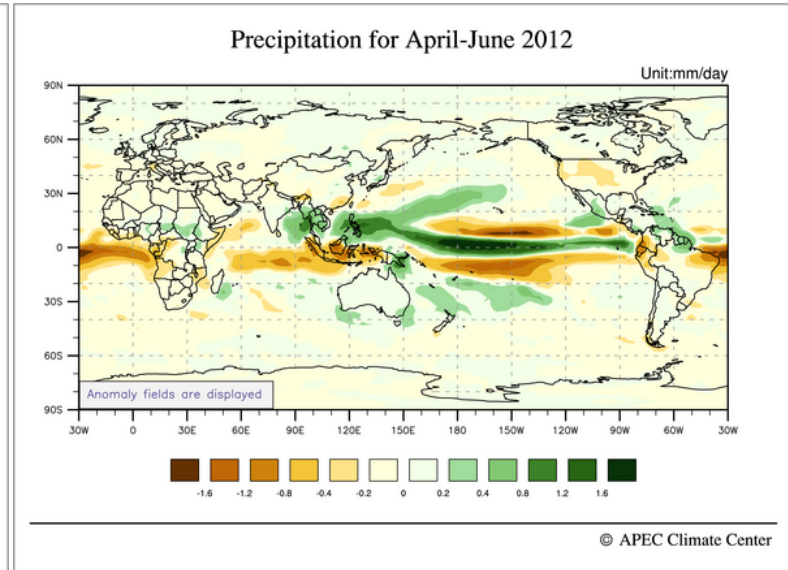
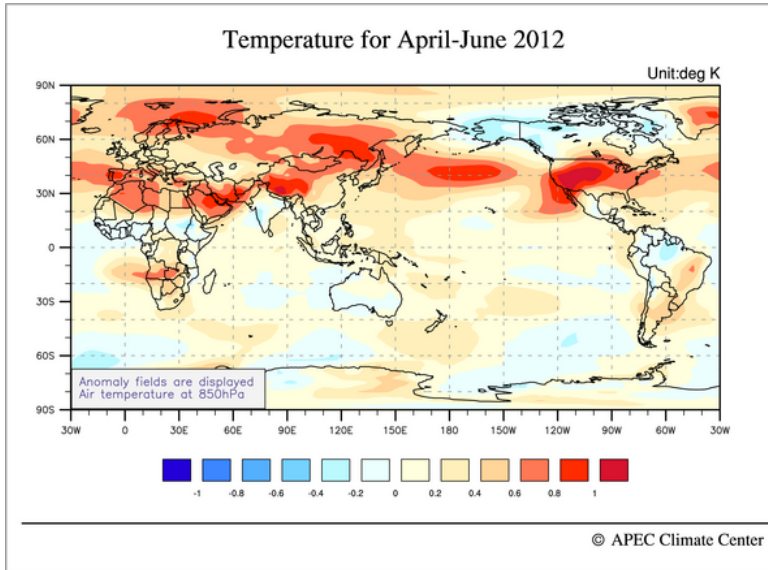


# Procedure of Seasonal Forecasts

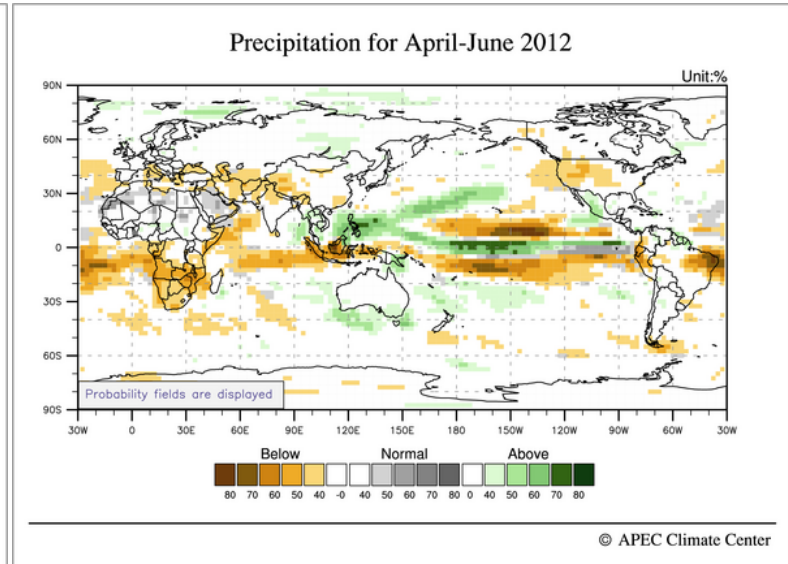
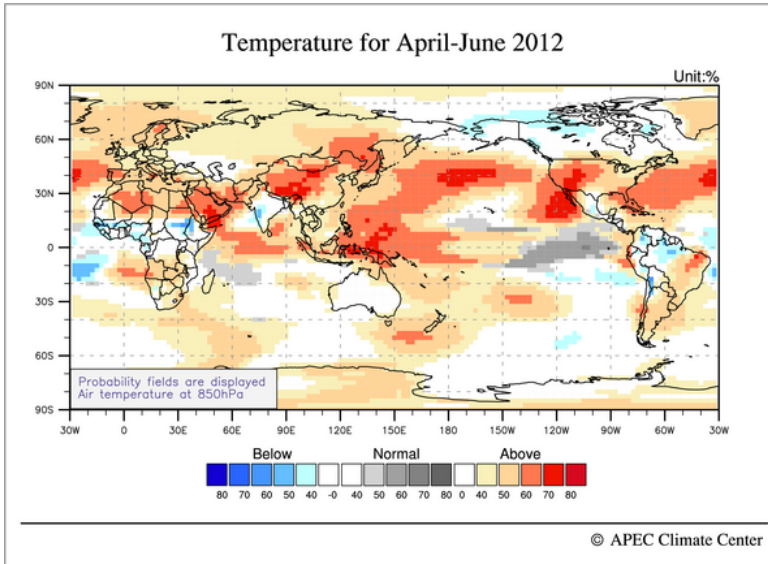


# MME Forecasts output: T, P

SCM



PMME



# Participating models

Name/ Economy	Hindcast Period	SST Specification (Hindcast/Forecast)	Ense mble (H/F)
<b>BCC China</b>	1983-2008	Predicted SST/ Predicted SST	8/8
COLA U.S.A.	1982-2002	OISSTv2/ IRI SST Forecast	10/10
<b>CWB Chinese Taipei</b>	1981-2005	Predicted SST/ Predicted SST	10/10
GCPS Korea	1979-2009	Predicted SST/ Predicted SST	12/12
<b>GDAPS_F Korea</b>	1979-2009.	Predicted SST/ Predicted SST	20/20
HMC Russia	1979-2003	Persistent SST/ Persistent SST	10/10
IAP China	1979/Jan.	Observed SST/ IAP-TOGA SST Forecast	7/7
IRI U.S.A.	1979-2005	Observed SST/ Persistent SST	24/24
IRIF U.S.A.	1979-2005	Observed SST/ Predicted SST	24/24

Name/ Economy	Start Year/Month	SST Specification (Hindcast/Forecast)	Ense mble (H/F)
<b>JMA Japan</b>	1979-2008	Predicted SST/ Predicted SST	5/51
NIMR Korea	1979-2009	Persistent OISST/ Persistent OISST	10/10
MGO Russia	1979-2004	Observed SST/ Persistent SST	6/10
<b>MSC_CanCM3 Canada</b>	1981-2009	Predicted SST/ Predicted SST	10/10
<b>MSC_CanCM4 Canada</b>	1981-2009	Predicted SST/ Predicted SST	10/10
<b>NASA U.S.A.</b>	1981-2009	Predicted SST/ Predicted SST	9(10)/ 9(10)
<b>NCEP U.S.A.</b>	1982-2008	Predicted SST/ Predicted SST	15/15
PNU Republic of Korea	1980-2009	Predicted SST/ Predicted SST/	10(3)/ 10(3)
<b>POAMA Australia</b>	1982-2006	Predicted SST/ Predicted SST	30/30

\* Shaded: coupled model; red: participating models in MME; grey: not available now

# MME Schemes

- **Deterministic Forecast:**

- **Simple Composite Method (SCM)**: Simple composite of individual forecast with equal weighting
- **Stepwise Pattern Projection Method (SPM; Kug et al. 2008)**: Calibrated MME which is obtained from the adjusted (or corrected) single-model predictions based on a stepwise pattern projection method
- **Multiple Regression Method (MRG; Krishnamurti et al. 2000)**: Empirically weighted MME with coefficient computed by multiple linear regression
- **Synthetic Multi-Model Super Ensemble Method (SSE; Yun et al. 2003)**: Empirically weighted MME with EOF-filtered data

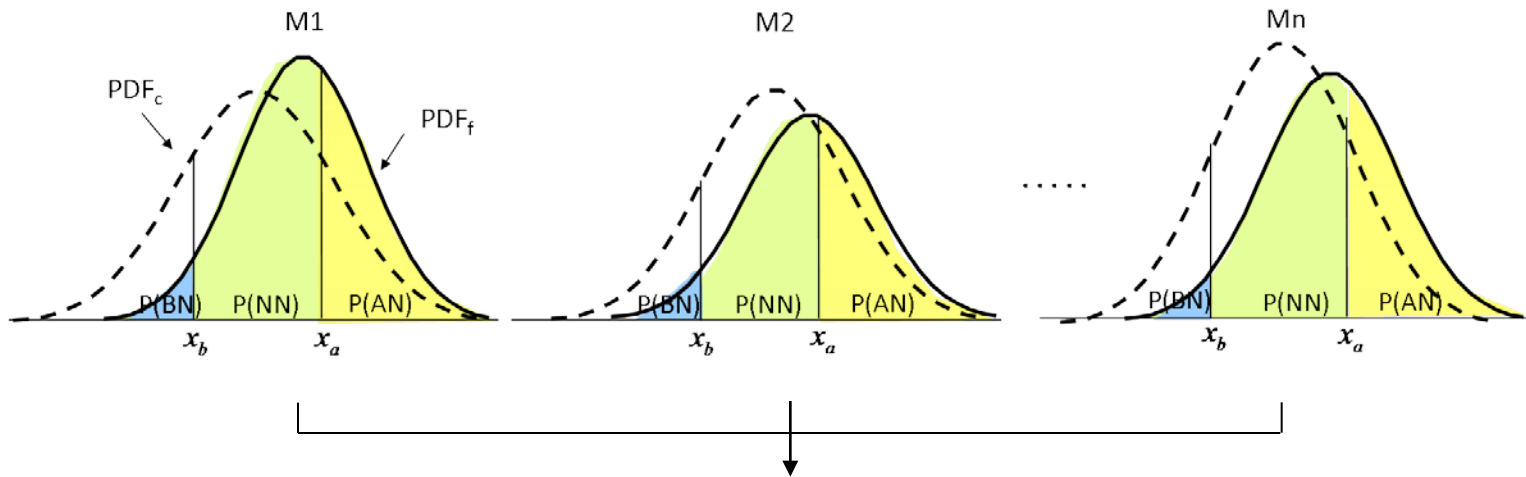
- **Probabilistic Forecast:**

- **Probabilistic Multi-Model Ensemble (PMME; Min et al. 2009)**: Probabilistic MME based on position of the forecast PDF in respect to the historical PDF using Gaussian fitting method

# Probabilistic MME

## ○ Characteristics of the APCC operational models

- Inconsistencies between the model ensemble sizes in hindcast and forecast, with the individual model ensembles essentially differing in size



$$P(E) = \sum_{i=1}^M P(\text{Model}_i) \times P(E / \text{Model}_i)$$

**Model Weight**      **Forecast Probability of an Event**



# How to Combine Forecast Probabilities?

## ① Equal weight (EW)

→ Most simple and logical choice, given the **difference between model forecasts (DF)** being large

$$DF_{mm} = \sqrt{\frac{\sum_{i=1}^M (\mu_i - \mu_{mm})^2}{M-1}}$$

$M$  : number of model

$\mu_i$  : i-model ensemble mean

$\mu_{mm}$  : mean of the individual model ensemble means

## ② Weights proportional to the ensemble size (ES; Taylor 1997)

→ An **increase of the ensemble size** of a single model improves its performance because it reduces the **standard error (SE)**; e.g., Robertson et al. 2004; Hagedorn et al. 2005).

$$SE = \frac{\sigma}{\sqrt{n}}$$

$\sigma$  : standard deviation of the model spread

$n$  : model ensemble size

## ③ Weight proportional to the squared root of the ensemble size (PMME)

→ Inversely proportional to the maximum error in forecast probability associated with the standard error of the mean

$$P(E_j) = \frac{1}{\sum_{i=1}^M \sqrt{n_i}} \sum_{i=1}^M \sqrt{n_i} P(E_j | mdl_i)$$

$P(E_j | mdl_i)$  : probability of the model of the j event, conditioned on the i model

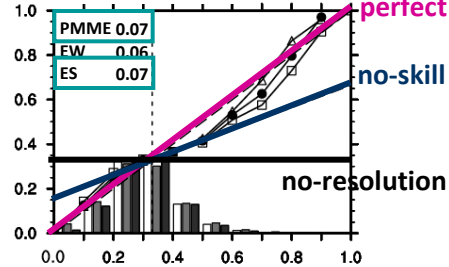
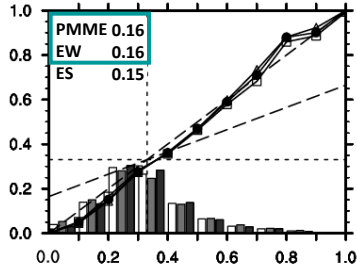
$n$  : size of the sample

# Comparison of Different Combinations

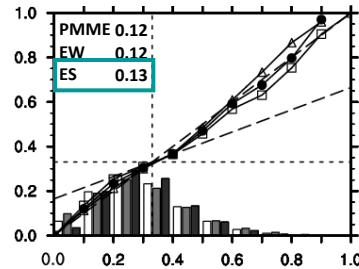
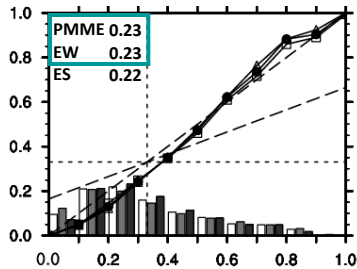
## Temperature

## Precipitation

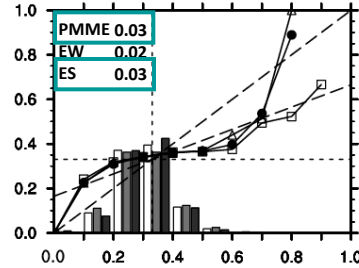
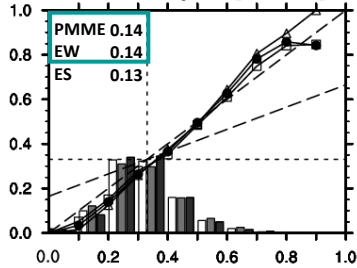
### Global



### Tropics [20°S-20°N]



### N. Extratropics [>20°N]



● PMME    □ EW    ▲ ES

Forecast Probability

- ❖ Focus on the most appropriate method for use in an operational global prediction system
- ❖ Difficult to develop an optimal method in a realistic situation (Yoo and Kang 2005; Weigel et al. 2008)

- The PMME prediction shows **consistently good performance** for both variables and three regions.
- The PMME method is the appropriate choice for the operational approach for global probabilistic forecast.

Observed Relative Frequency

# Dissemination and Publicity

## ✓ How To Release APCC MME Forecast Issues

- **E-mailing** (to: 773 recipients) and **Webcast** (at: [www.apcc21.org](http://www.apcc21.org))
- **Deliverables** by E-mail:
  - **Climate Outlook** (incl. Climate Highlights and Forecast Outlook)
- **Information** available via Website:
  - **Details** such as monthly and regional prediction, and relevant verification

## ✓ How To Share APCC MME Forecast Data and Technology

- **CLIK** (<http://clik.apcc21.net>): 2-way tool kit to facilitate data exchange and downscaling
- **ADSS** (<http://cis.apcc21.net>) and **TRACE** (<http://trace.apcc21.net>)  
: protocols to exchange climate data and information

# CLIK On-line Climate Information Toolkit

<http://clik.apcc21.net>



**WHEN**

Year: 2010    Season: MAM

**VARIABLES**

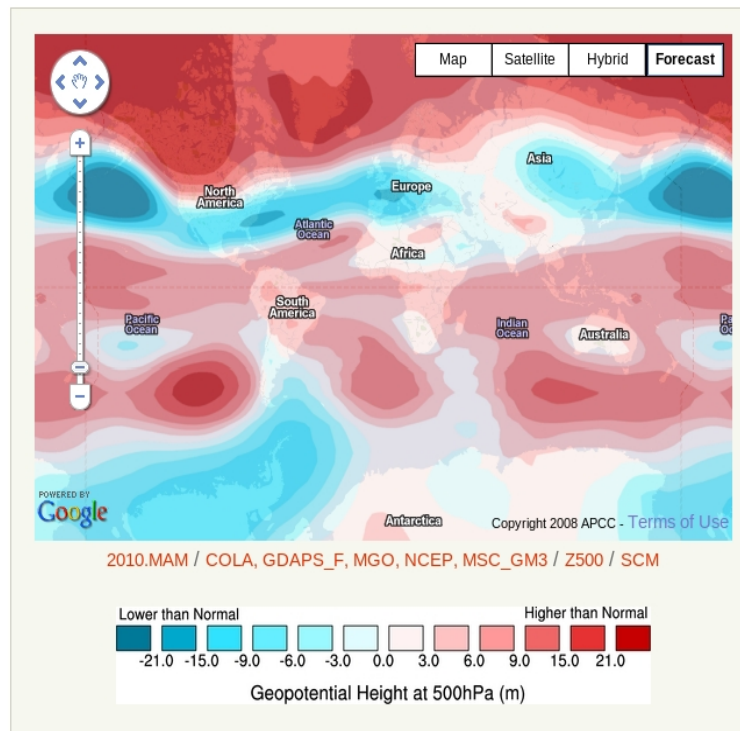
PREC     T850     Z500

**PROVIDER**

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<input type="checkbox"/> GGPS	<input checked="" type="checkbox"/> GDAPS_F	<input type="checkbox"/> HMC
<input type="checkbox"/> IRIF	<input checked="" type="checkbox"/> MGO	<input type="checkbox"/> MSC_GEM
<input type="checkbox"/> MSC_GM2	<input checked="" type="checkbox"/> MSC_GM3	<input type="checkbox"/> MSC_SEF
<input type="checkbox"/> NASA	<input checked="" type="checkbox"/> NCEP	<input type="checkbox"/> NIMR
<input type="checkbox"/> POAMA		

**METHODS**

SCM



- Web-based tool for data retrieval and climate prediction
- Customized 3-MON Multi-Model Ensemble Prediction
- Produce over 1,200 MME Prediction & 600 Verification results by user requests
- 3,882 visited CLIK came from 497 cities since March 2009 and the visiting count is continuously increasing

# CLIK On-line statistical downscaling feature

## Step 3. Set-up Downscaling

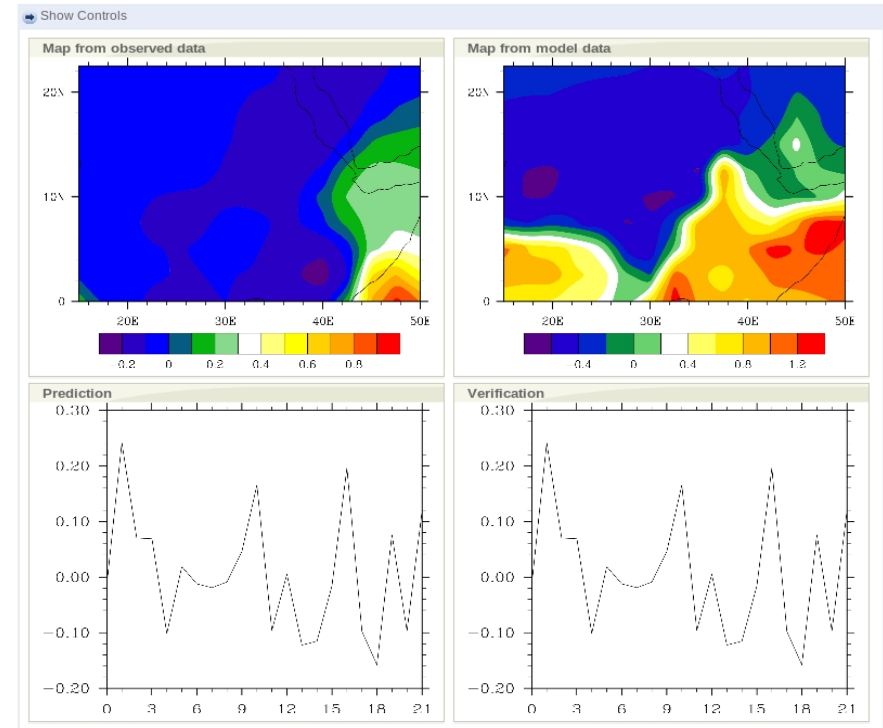
Station ID	Name	Data period for PREC	Data period for TEMP
63612000	LODWAR	1982 / 1 ~ 2006 / 12	N/A
63612001	LOKITAUNG	1982 / 1 ~ 2006 / 12	N/A
63619000	MOYALE	1982 / 1 ~ 2006 / 12	N/A
63624000	MANDERA	1982 / 1 ~ 2006 / 12	N/A
63641000	MARSABIT	1982 / 1 ~ 2006 / 12	N/A

*Selecting stations for downscaling*

- CLIK generates downscaling result based on user's selection with user's observation data and MME data which many institutions contributed
- User can recognize which stations data and MME data are reasonable for downscaling of specified area through the result

- User can upload/modify their own observation data for downscaling though CLIK
- CLIK provides customized downscaling feature, so user can select conditions for each downscaling

## Downscaling result

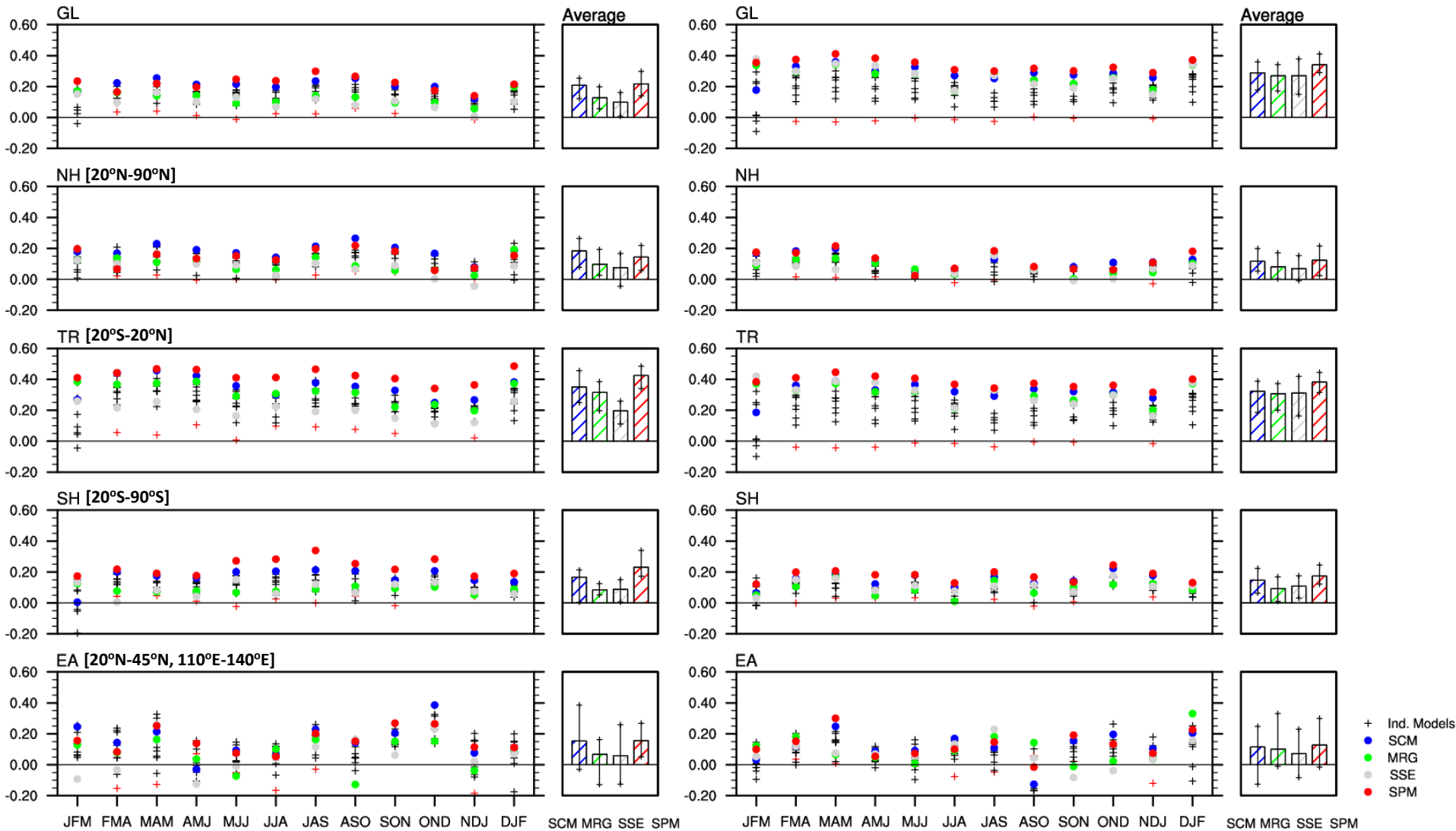


*Downscaling result for each station*

# MME Comparison: ACC (1983-2003)

Temperature

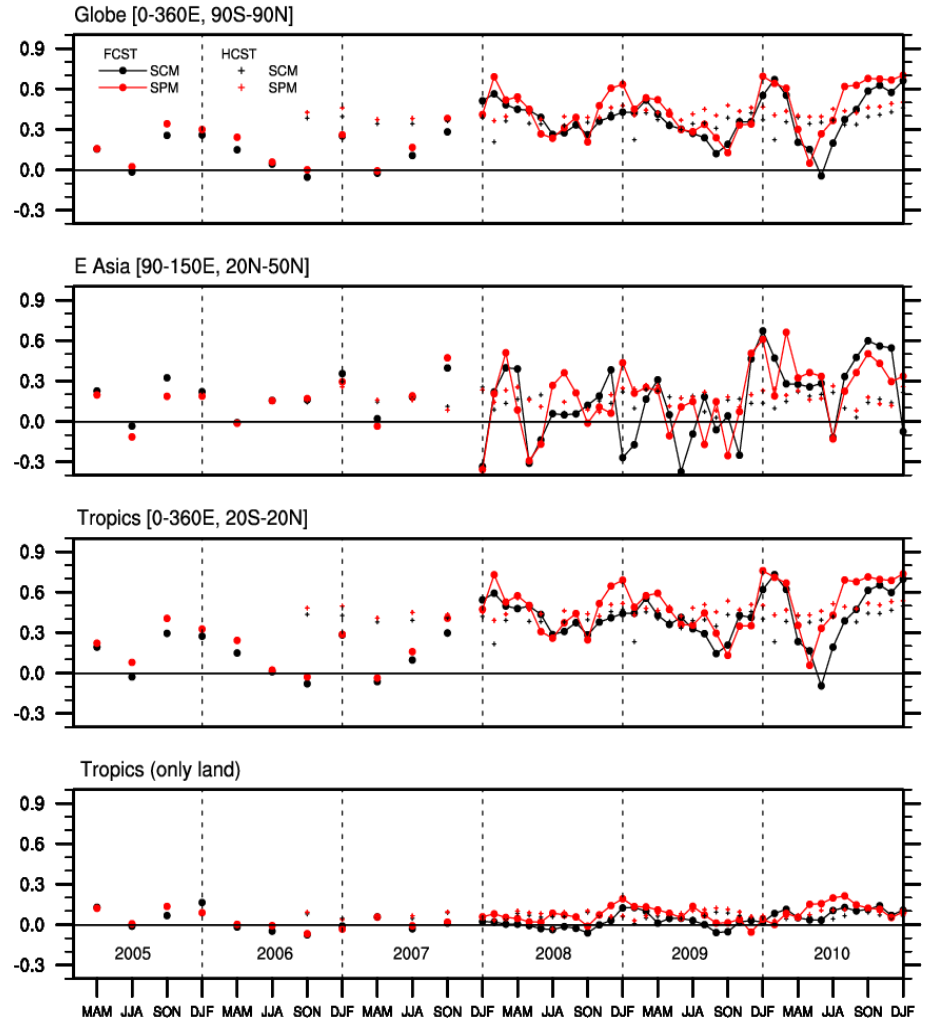
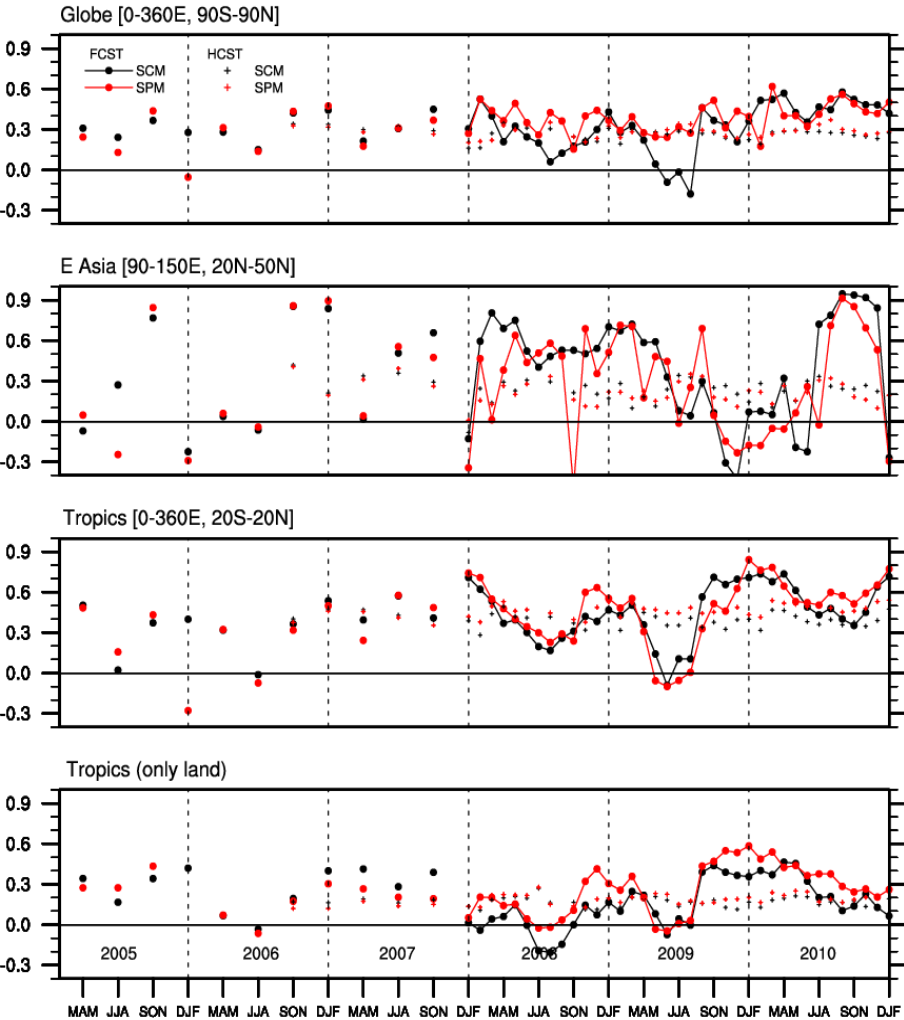
Precipitation



# MME Comparison: ACC (2005-2010)

Temperature

Precipitation



# **Calibration and correction of Multi Model Ensemble forecast**

**ENSEMBLE MEAN FORECAST**



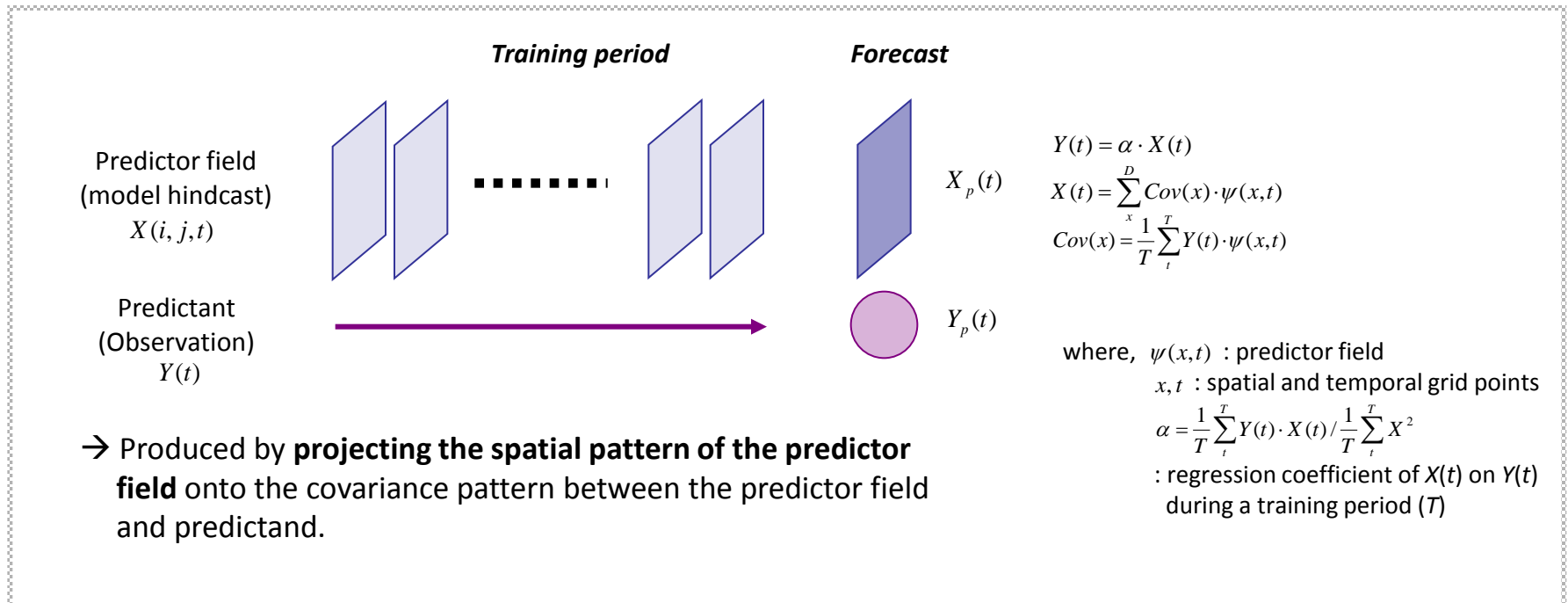
# Step-wise Pattern Projection Method (SPM) MME

- Simple composite of individual model forecasts, after **statistical correction** by **pattern projection method** (SPM; Kug et al. 2008)

$$P = \frac{1}{M} \sum_{i=1}^M \hat{Y}_i$$

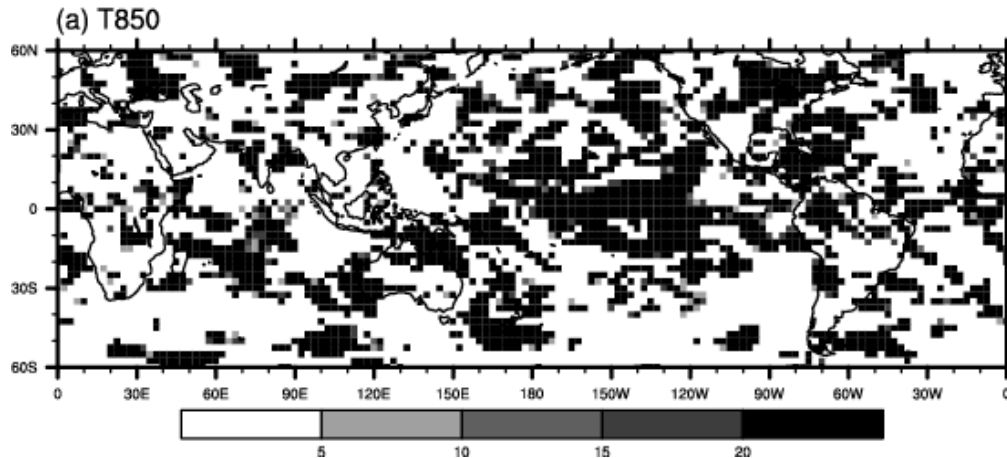
$M$ : number of forecast models  
 $\hat{Y}_i$ : corrected forecast of  $i^{\text{th}}$  model

- SPM: based on the large-scale patterns of the predicted variables by models (predictors) correlated with a local (or grid) observed variable (predictand)

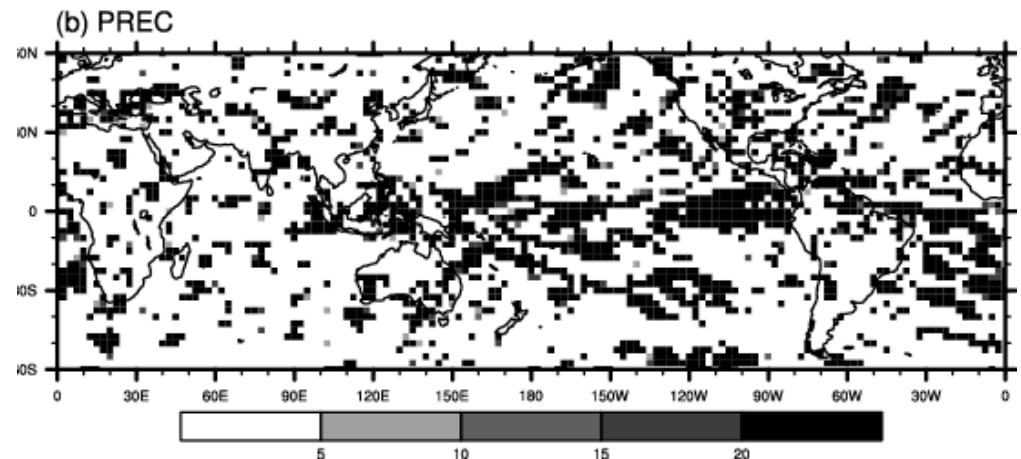


# Predictor area (selected no. in cross-validation)

Temperature



Precipitation



Number of selected variable as an optimal predictor in a cross-validation mode for summer mean temperature and precipitation during 23 years (as an example, JMA model).

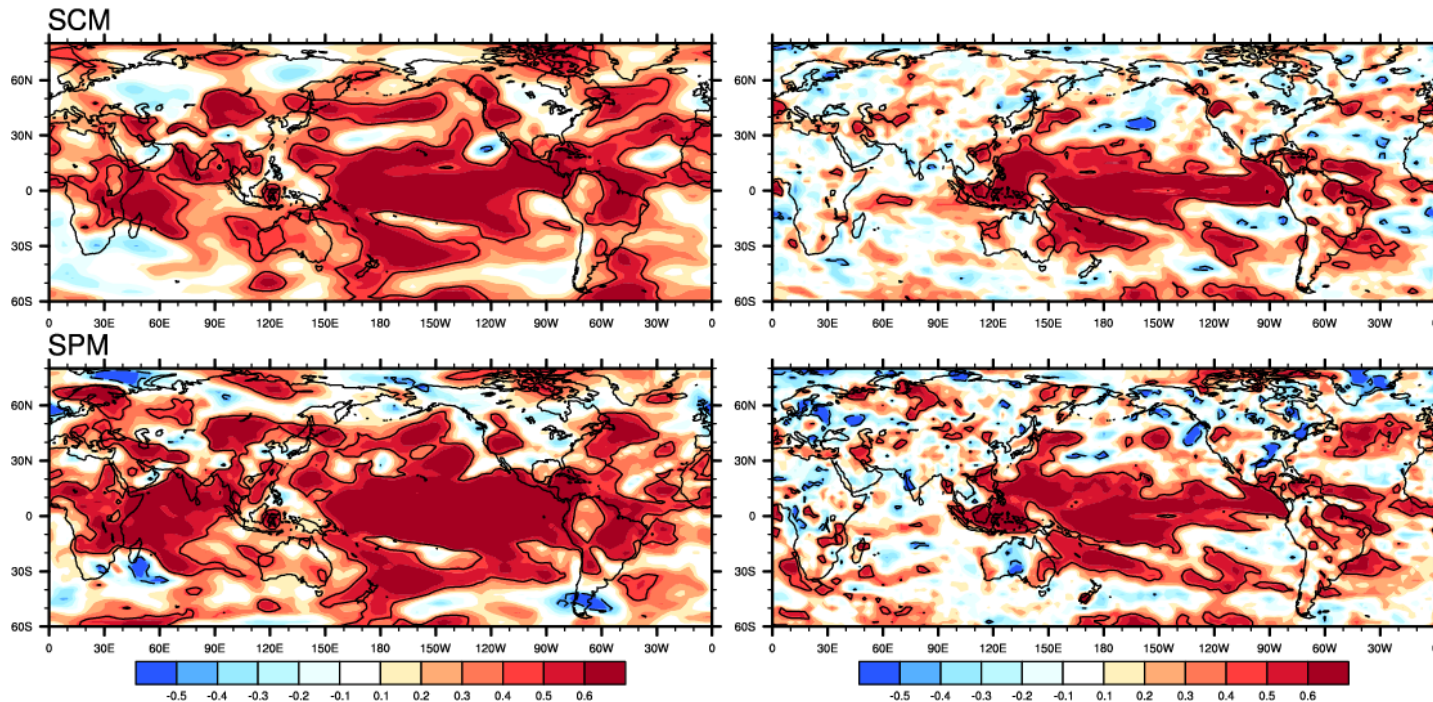
# Corrected MME Prediction System

- Corrected by SPM-based statistical correction methods based on the linear correlation between the model and observed patterns

## Temporal Cor. (JJA, 1983-2003)

(a) Temperature

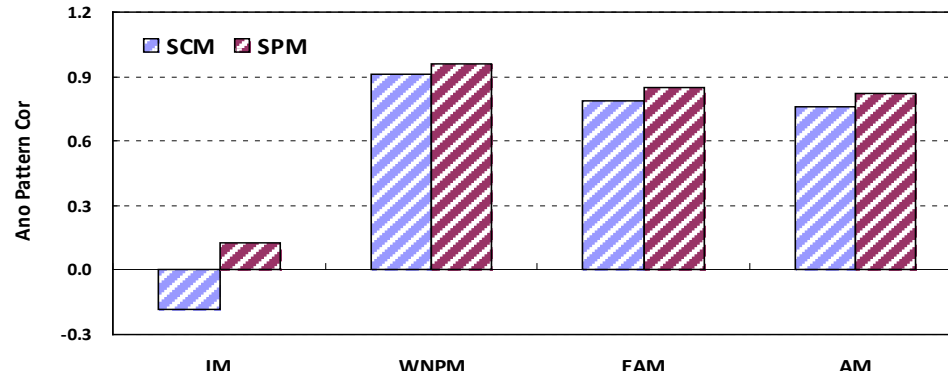
(b) Precipitation



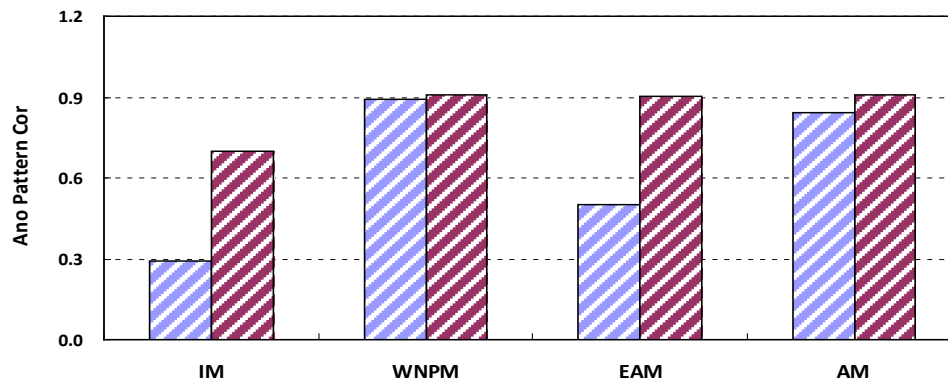
- **Contour:** Statistically significant at 5% level using Student t-test

# Precipitation

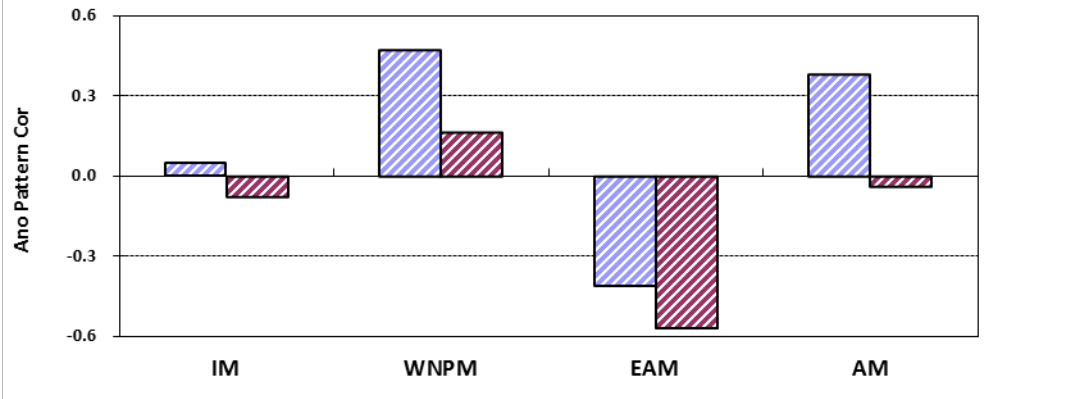
(a) El Nino DJF



(b) La Nina DJF



(c) Normal DJF

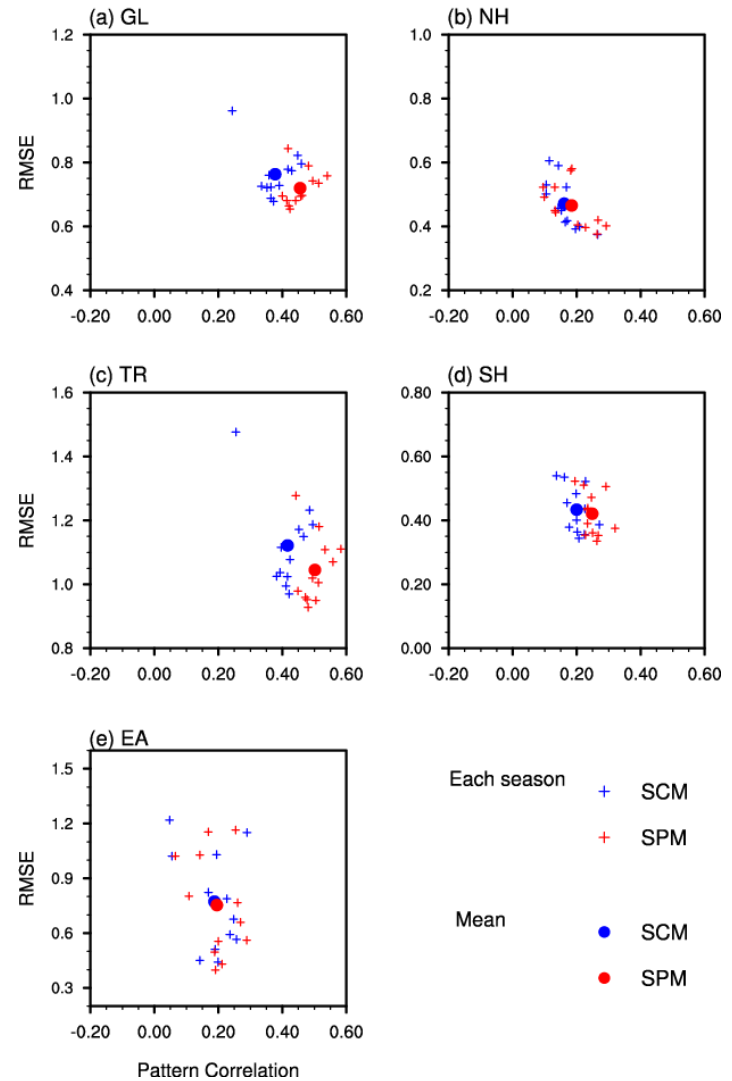
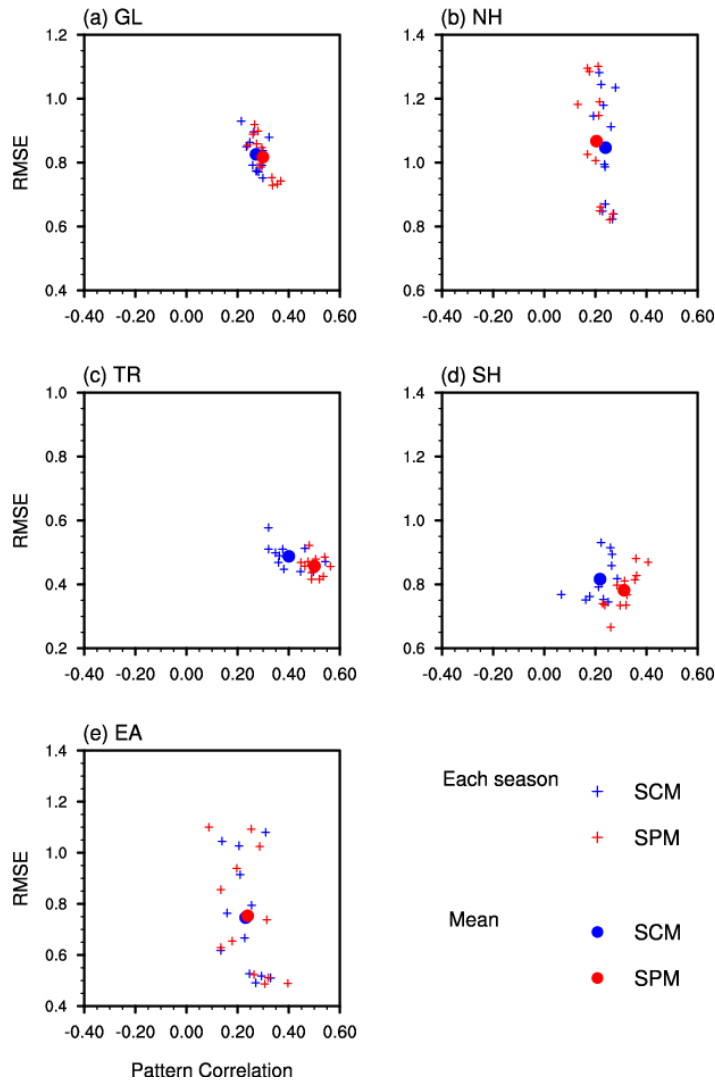


- **IM**: Indian Monsoon
- **WNPM**: WNP Monsoon
- **EAM**: East Asia Monsoon
- **AM**: Australian Monsoon

# Anomaly Pattern Cor–RMSE Diagram (1983-2003)

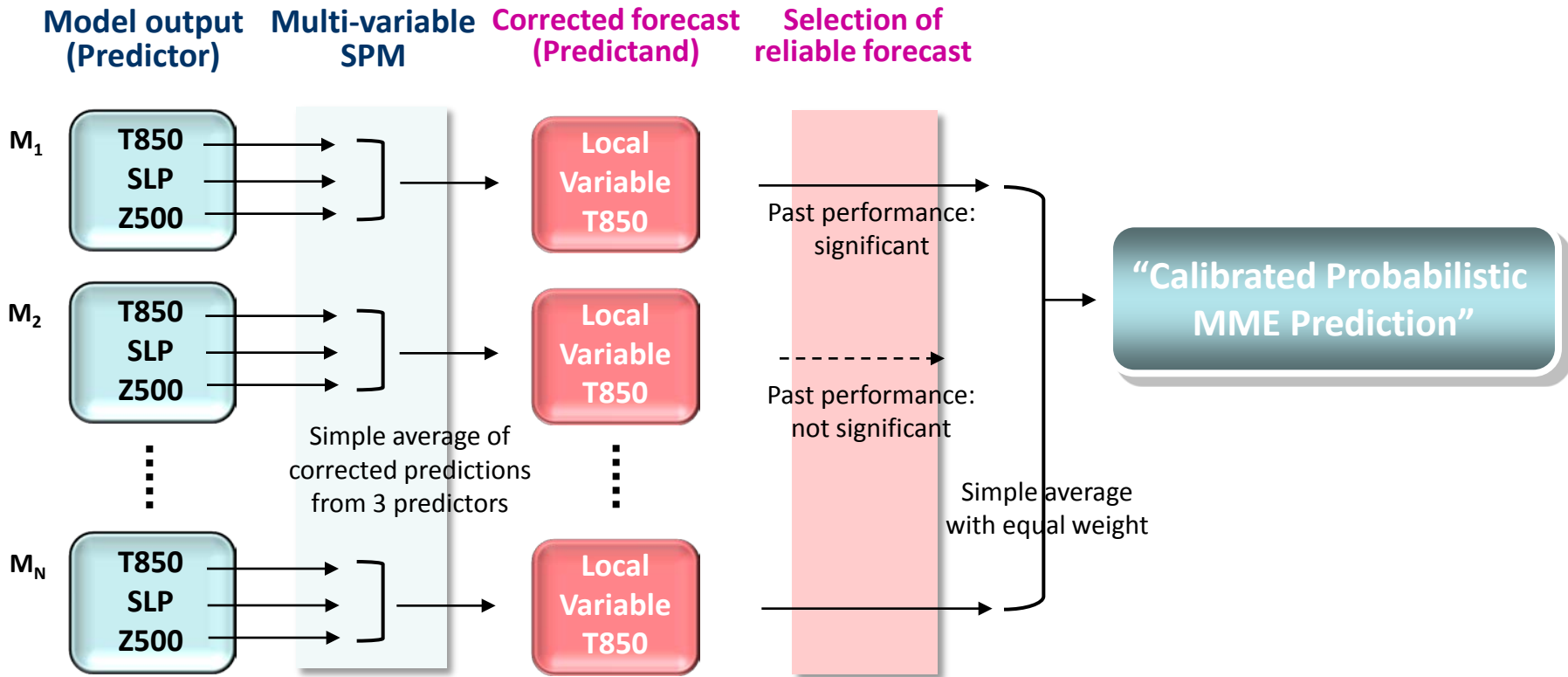
## Temperature

## Precipitation



**Calibration and correction of  
Multi Model Ensemble forecast**  
**PROBABILISTIC FORECAST**

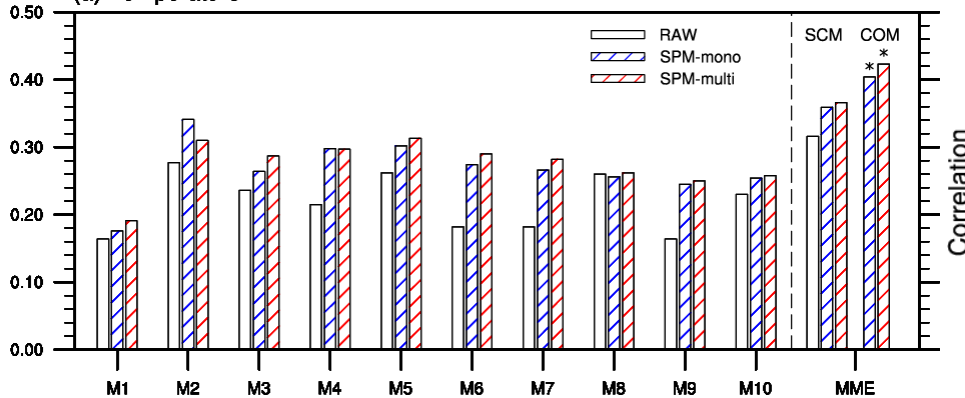
# Calibrated PMME Prediction System



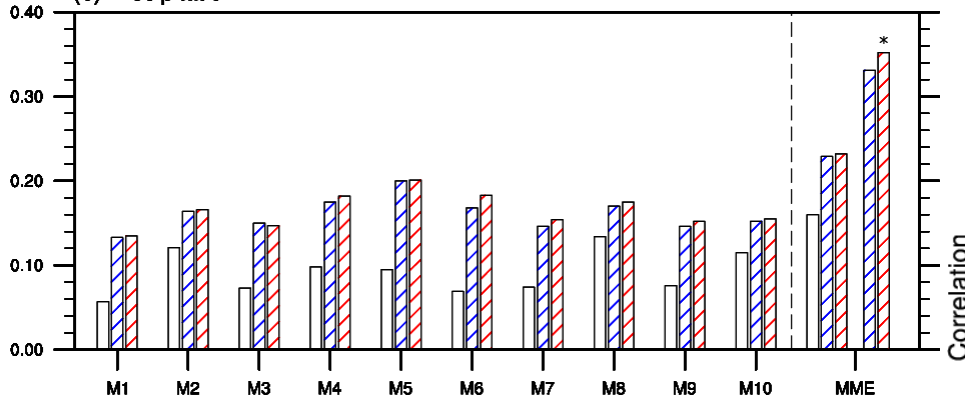
# Effects of Model Correction and Combination

## Temporal Correlation (1981-2003)

(a) Temperature



(b) Precipitation



**RAW:** raw model output

**SPM-mono:** mono-variable version of SPM

**SPM-multi:** multi-variable version of SPM

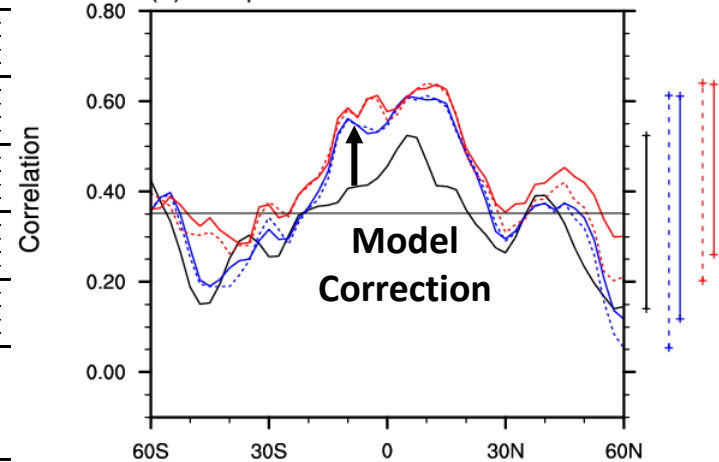
**SCM:** simple MME with all single-models (M1-M10)

**COM:** simple MME with the skill-based selected models

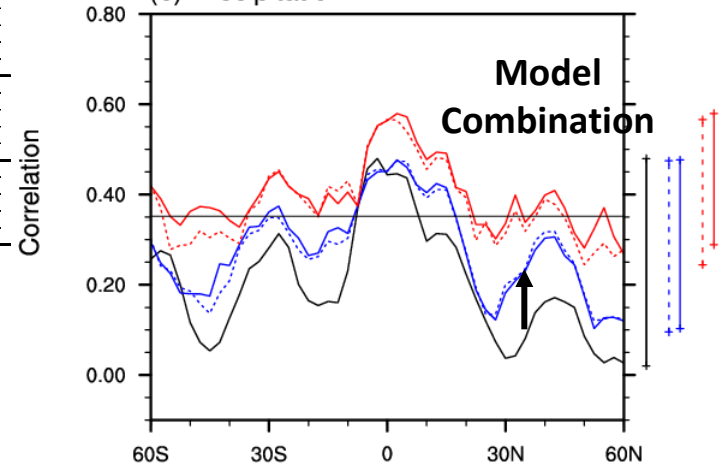
\*: statistically significant at the 5% level

## Zonal Mean Temporal Correlation

(a) Temperature



(b) Precipitation



COM  
 — SPM-multi  
 - - SPM-mono  
 SCM  
 — SPM-multi  
 - - SPM-mono  
 — RAW

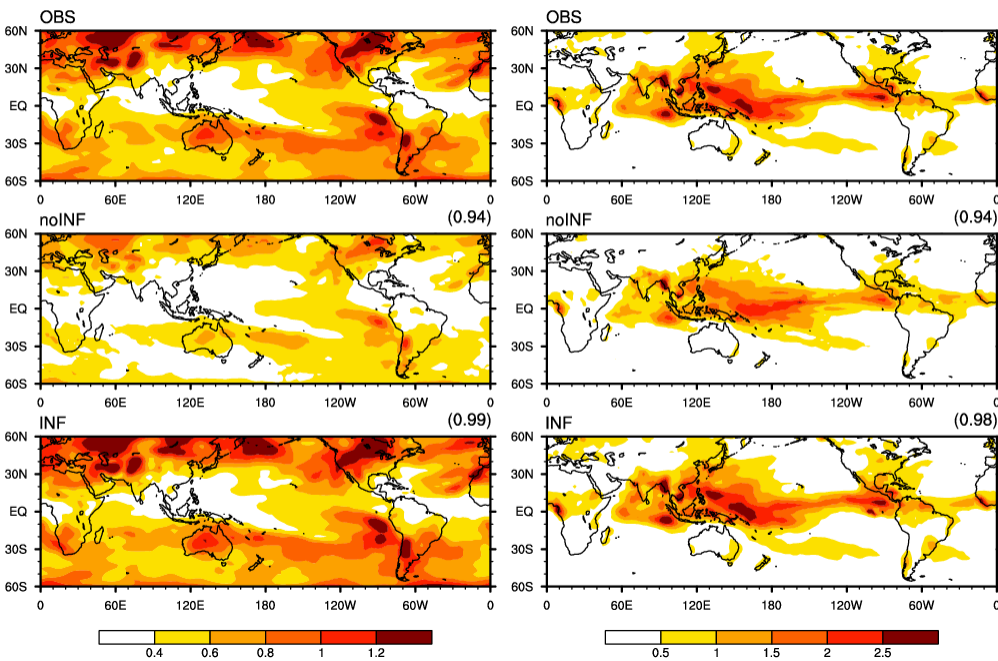


# Effects of Variance Inflation

## Standard Deviation of IAV

(a) Temperature

(b) Precipitation



**RAW:** raw MME prediction

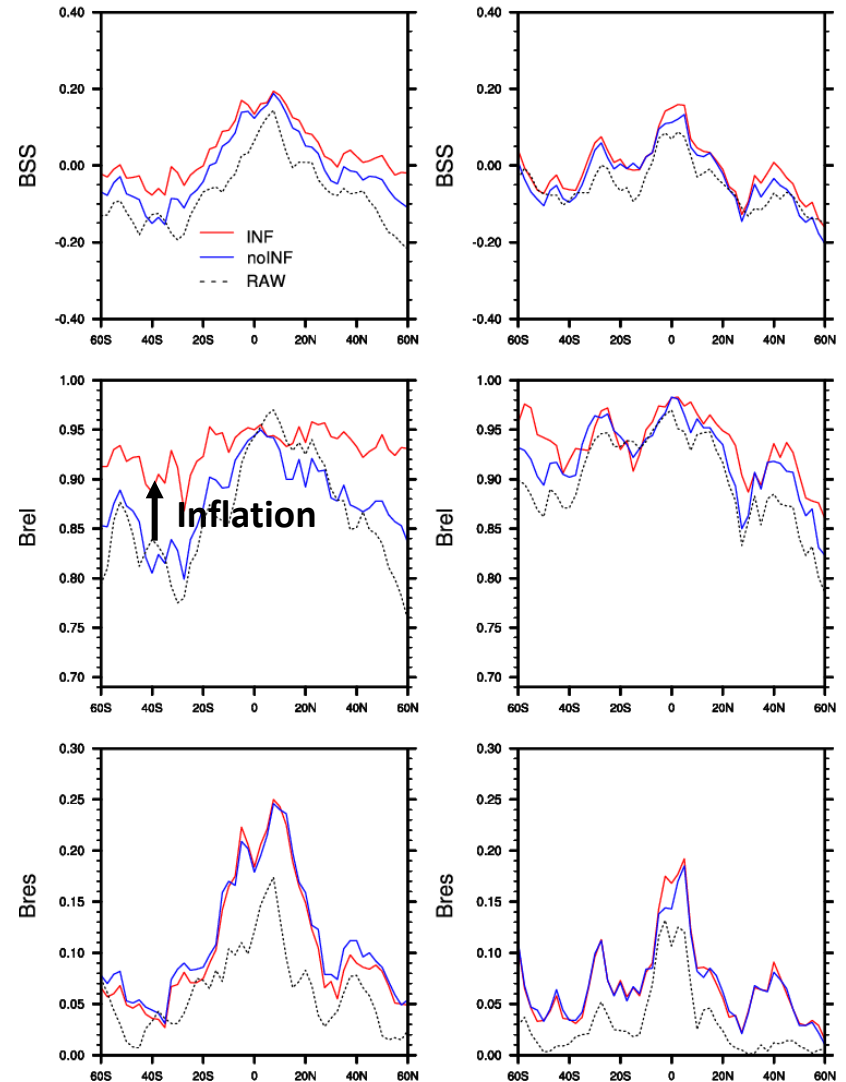
**noINF:** corrected and combined MME prediction **without** variance inflation

**INF:** corrected and combined MME prediction **with** variance inflation

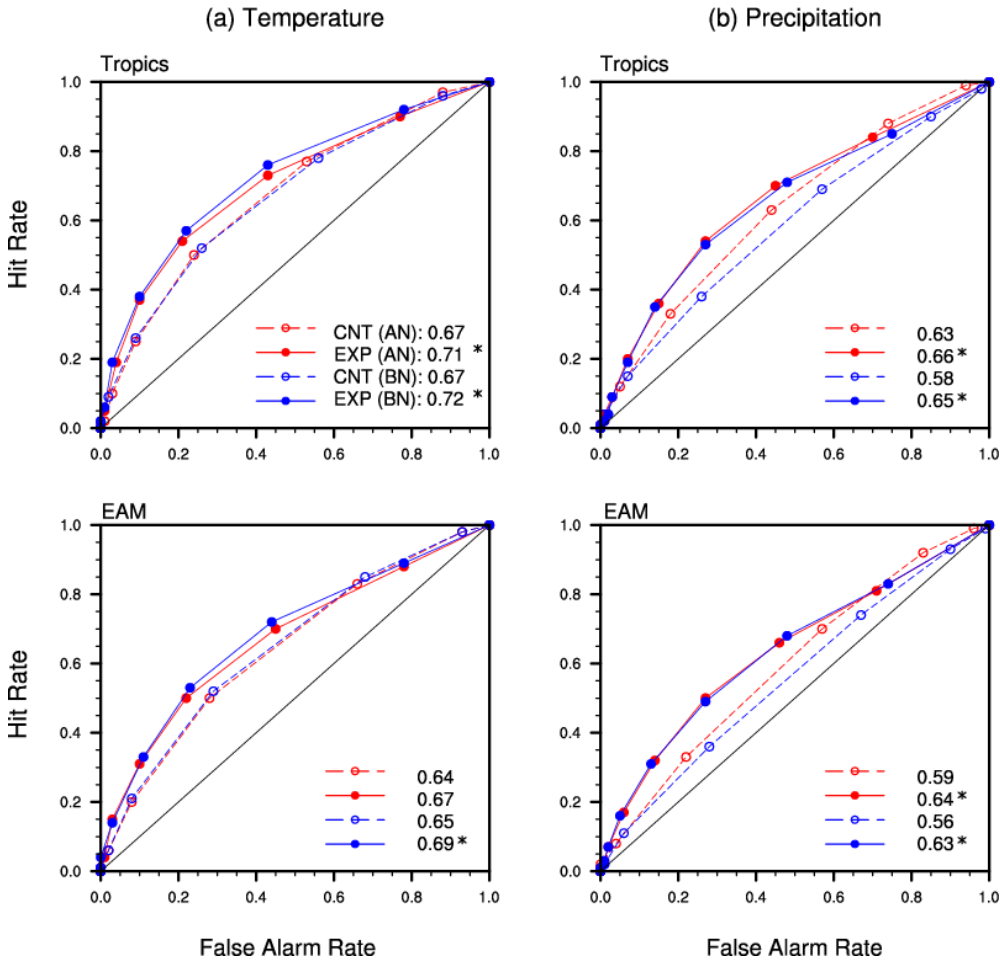
## Zonal Mean BSS

(a) Temperature

(b) Precipitation



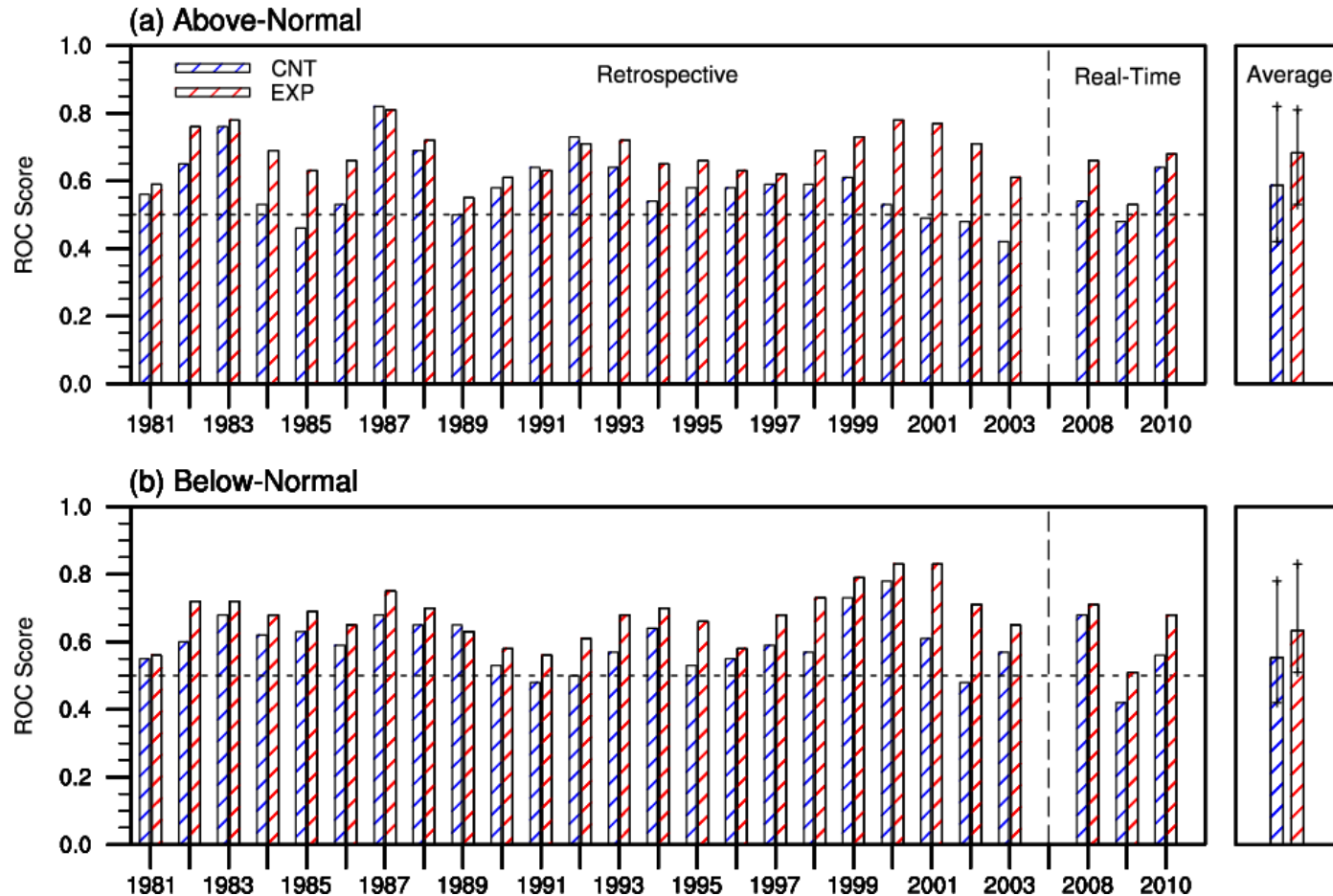
# Operational vs. Calibrated PMME Prediction



**CNT:** operational PMME prediction (control forecast)  
**EXP:** calibrated PMME prediction (experimental forecast)

# Operational vs. Calibrated PMME Prediction

## Aggregated ROC score for temperature



CNT: operational PMME prediction (control forecast)  
EXP: calibrated PMME prediction (experimental forecast)

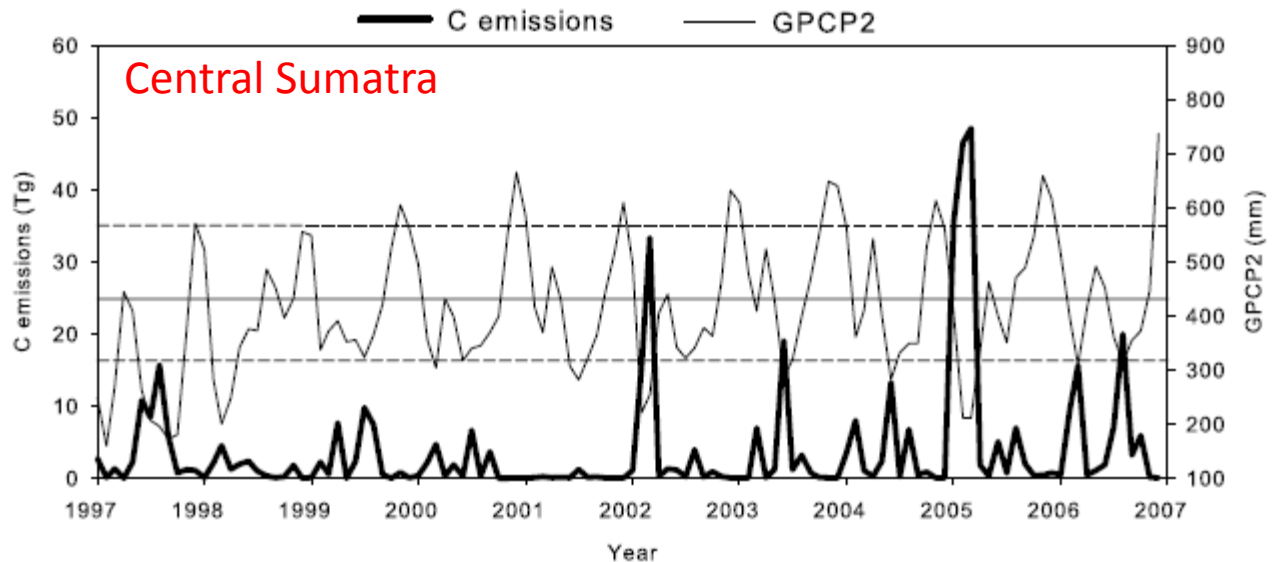
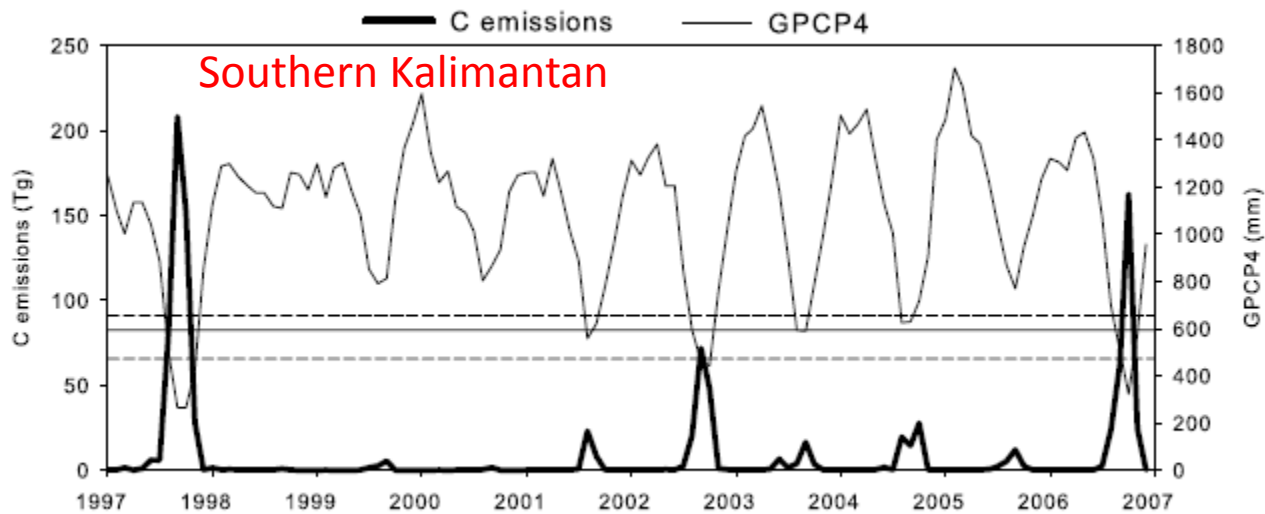
# **Diversification of products**

**USER DEFINED CATEGORICAL FORECAST**

# Tercile (?)

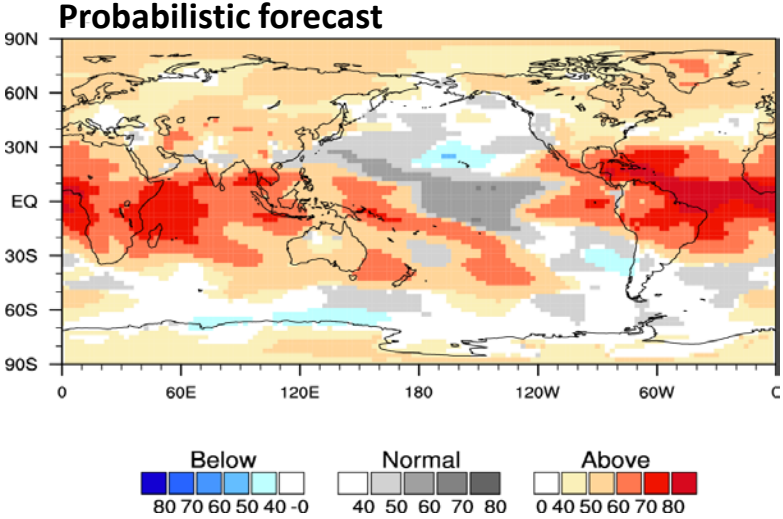
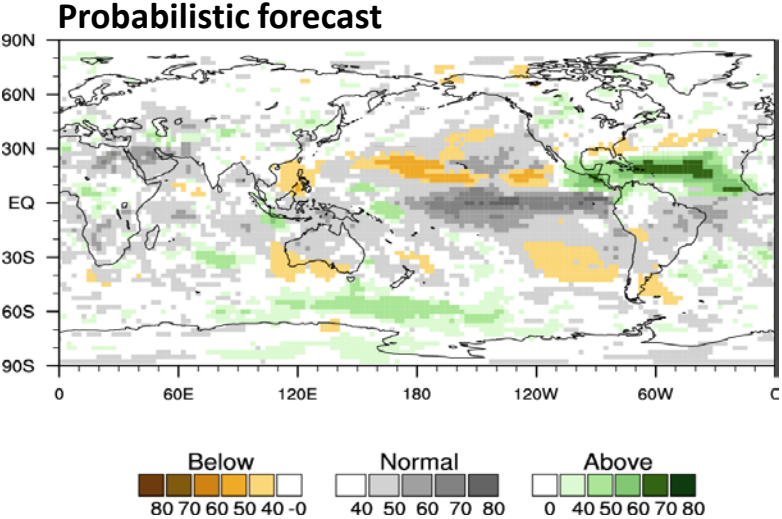
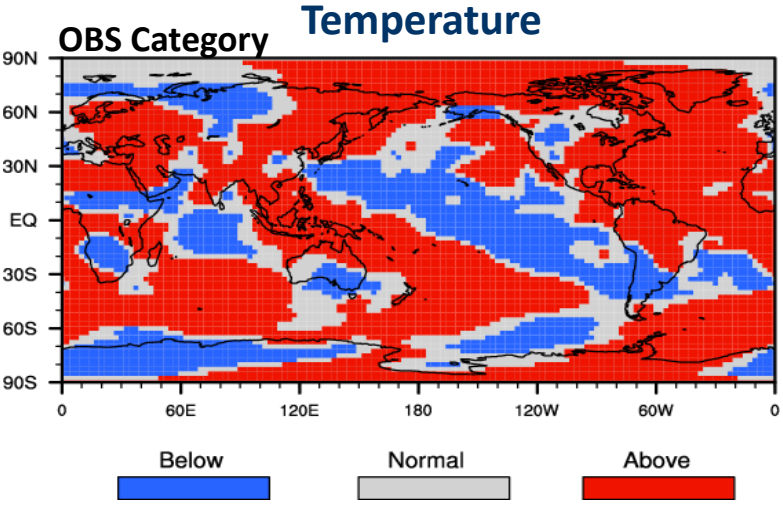
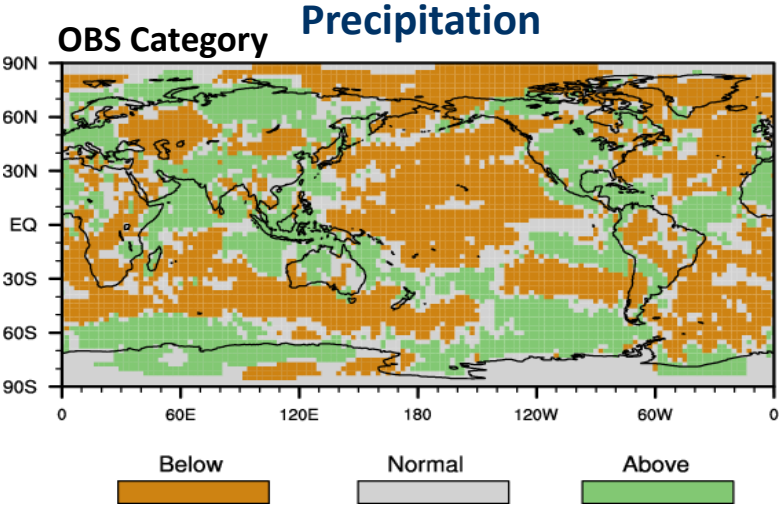
- Critical value to be predicted
- Decisions relying on previous year(s)'s experiences

# Towards Early warning system for fire and haze in Indonesia



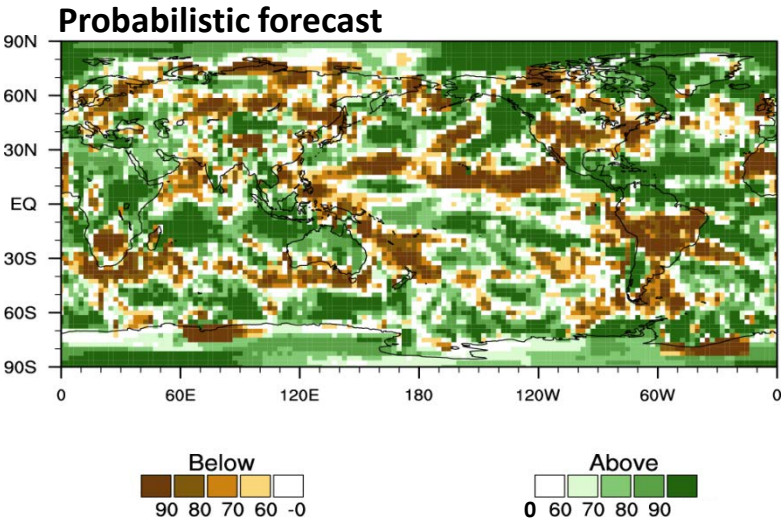
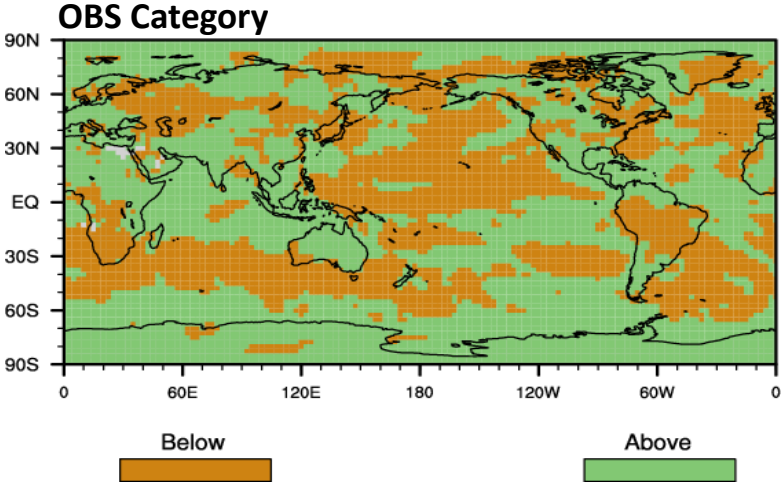
(Field and Shen 2008)

# 2010 Probabilistic Forecast (Climatology)

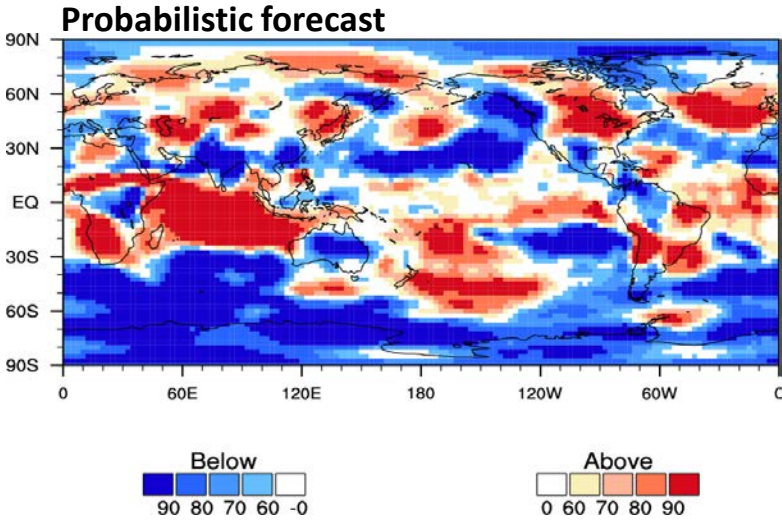
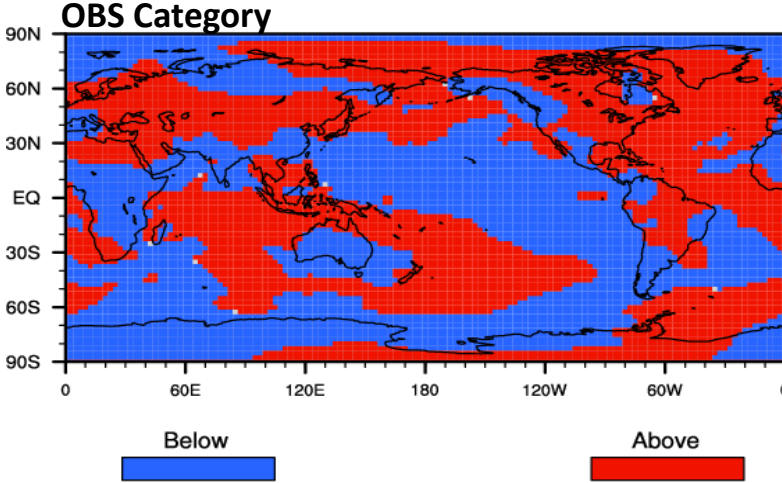


# 2010 Probabilistic Forecast (Last Year)

## Precipitation



## Temperature

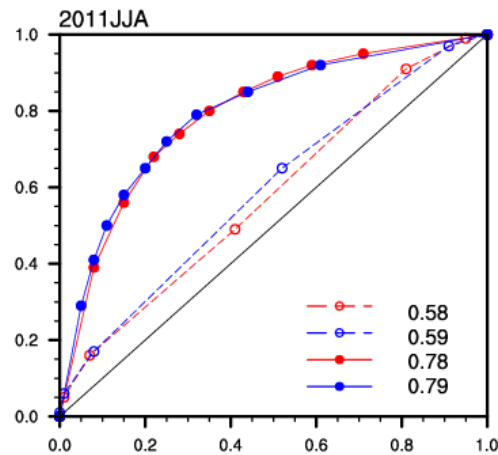
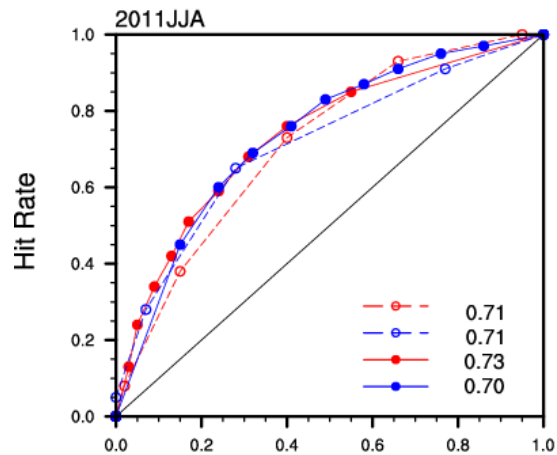
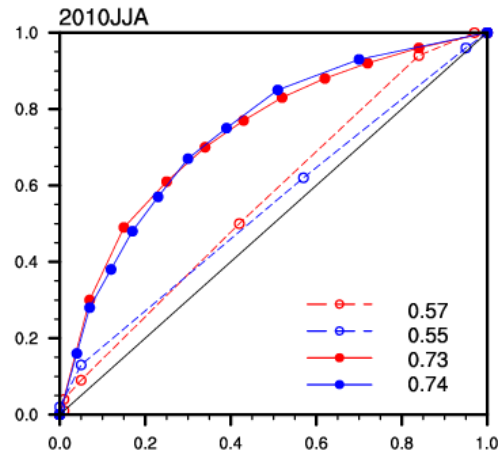
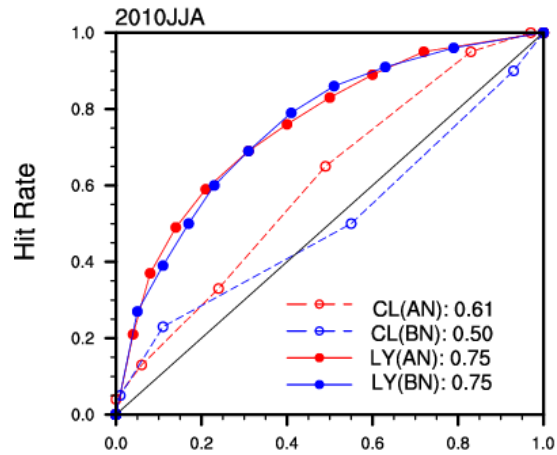




# Verification: Aggregated ROC Curve and Score

(a) Temperature

(b) Precipitation

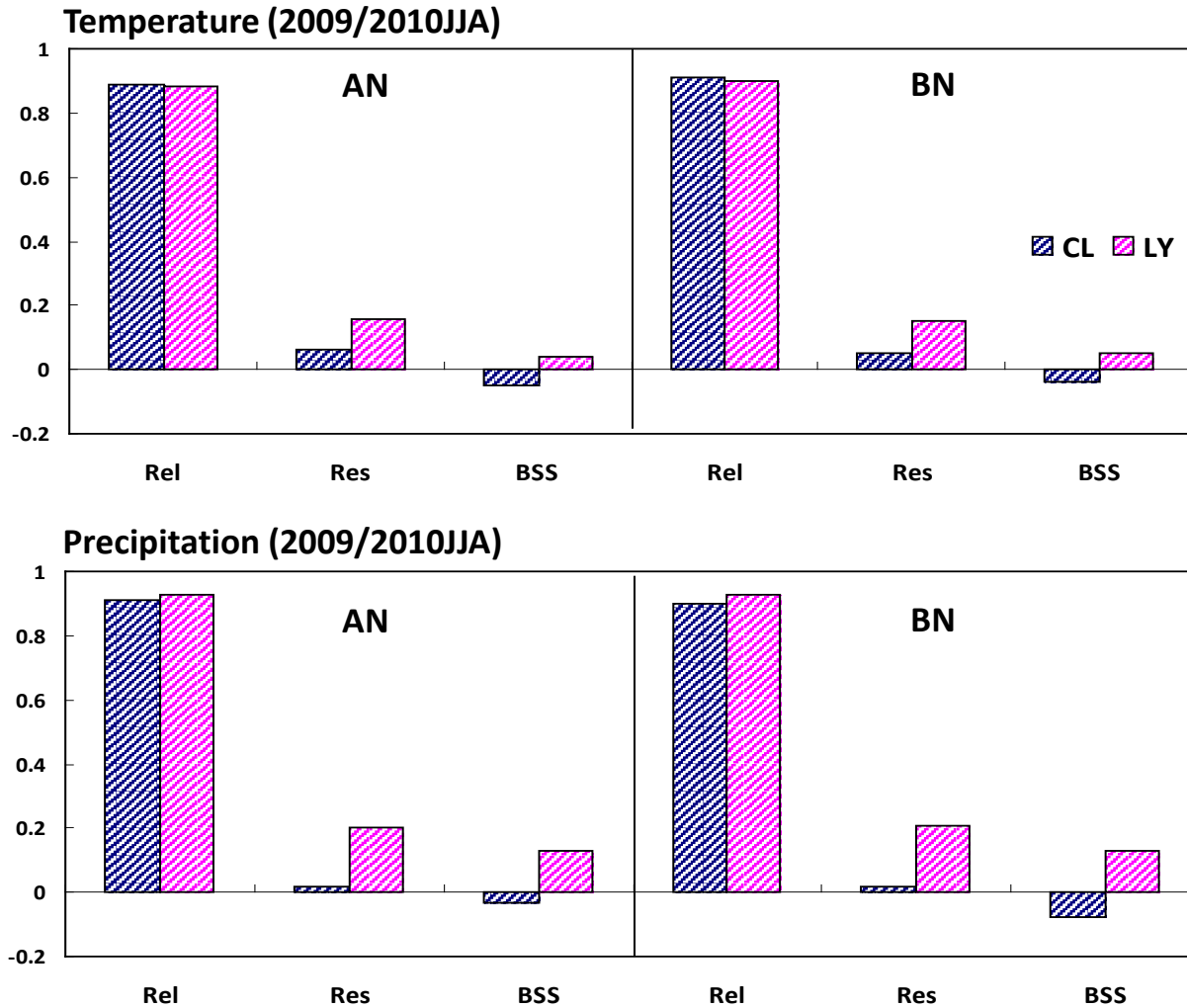


False Alarm Rate

False Alarm Rate

CL: with respect to climatology  
 LY: with respect to last year  
 AN: Above-normal  
 BN: Below-normal

# Verification: Aggregated Brier Skill Score

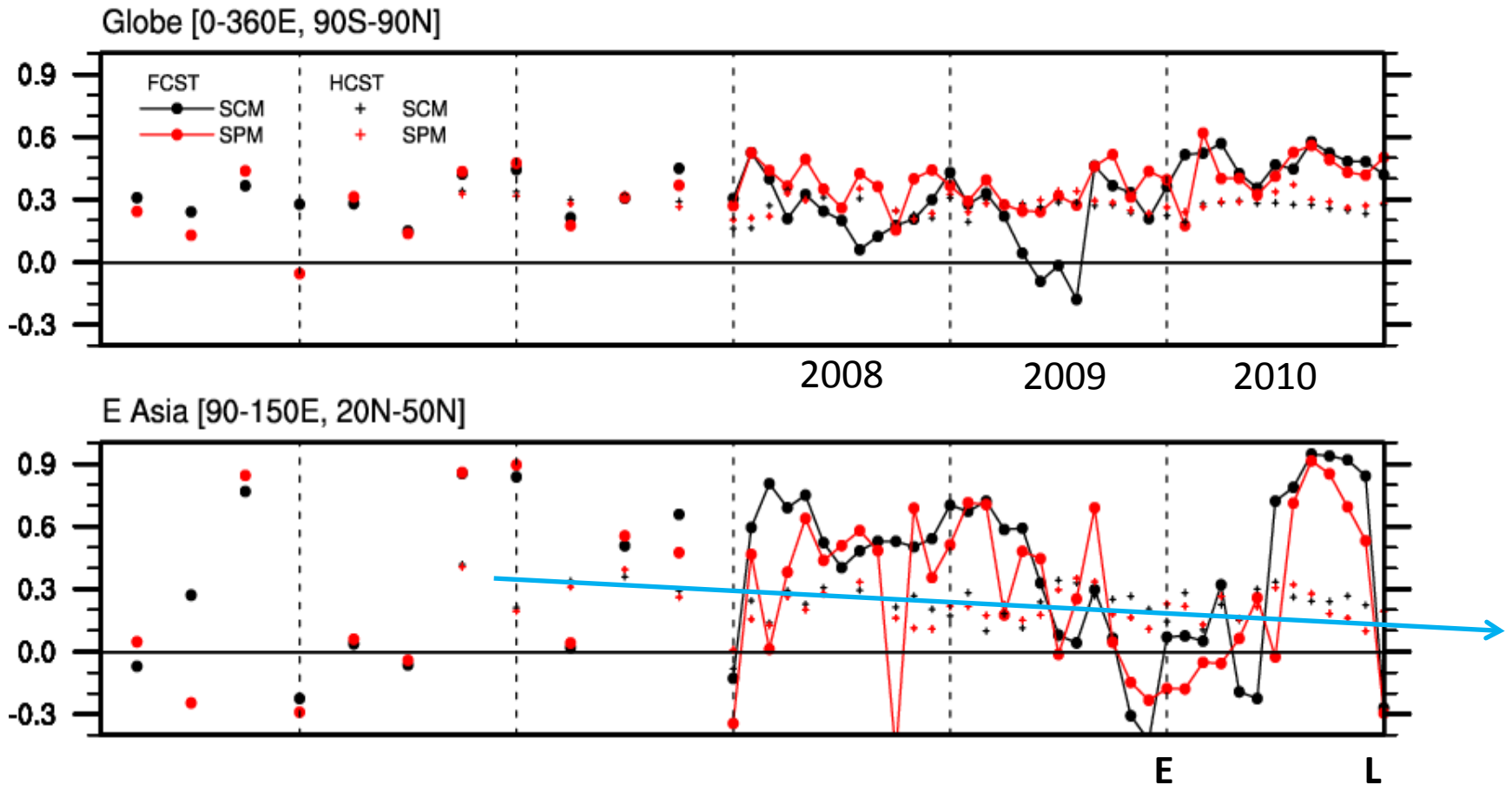


# **Risk(?) management**

**RECENT IMPACT OF ARCTIC REGION  
TO E.ASIA WINTER**

# Failure of East Asia winter temperature forecast

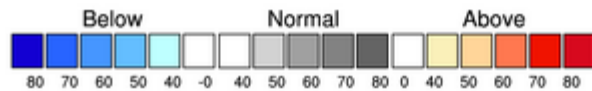
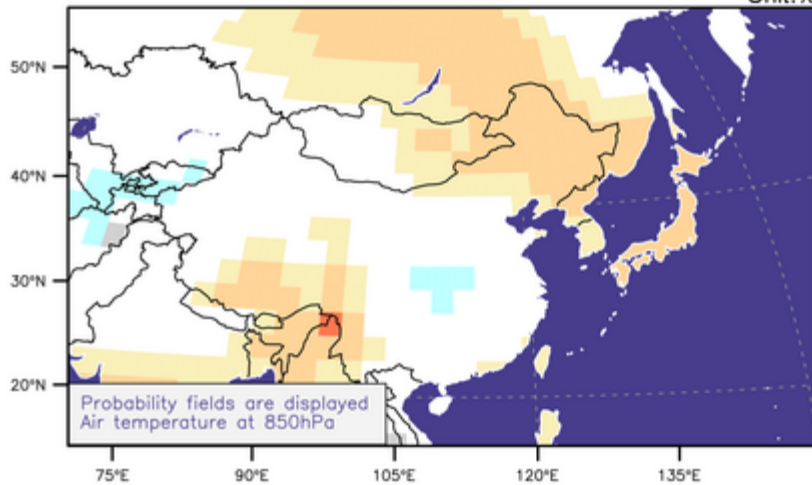
## Temperature



# Failure of East Asia winter temperature

Temperature for December 2011-February 2012

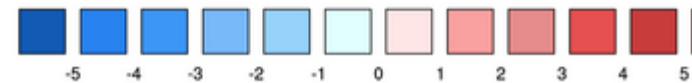
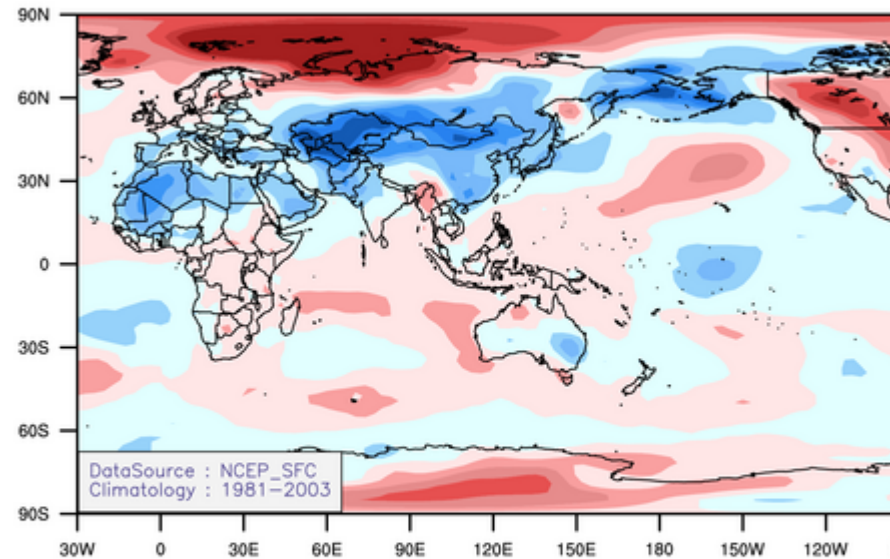
Unit: %



© APEC Climate

Surface Air Temperature Anomaly

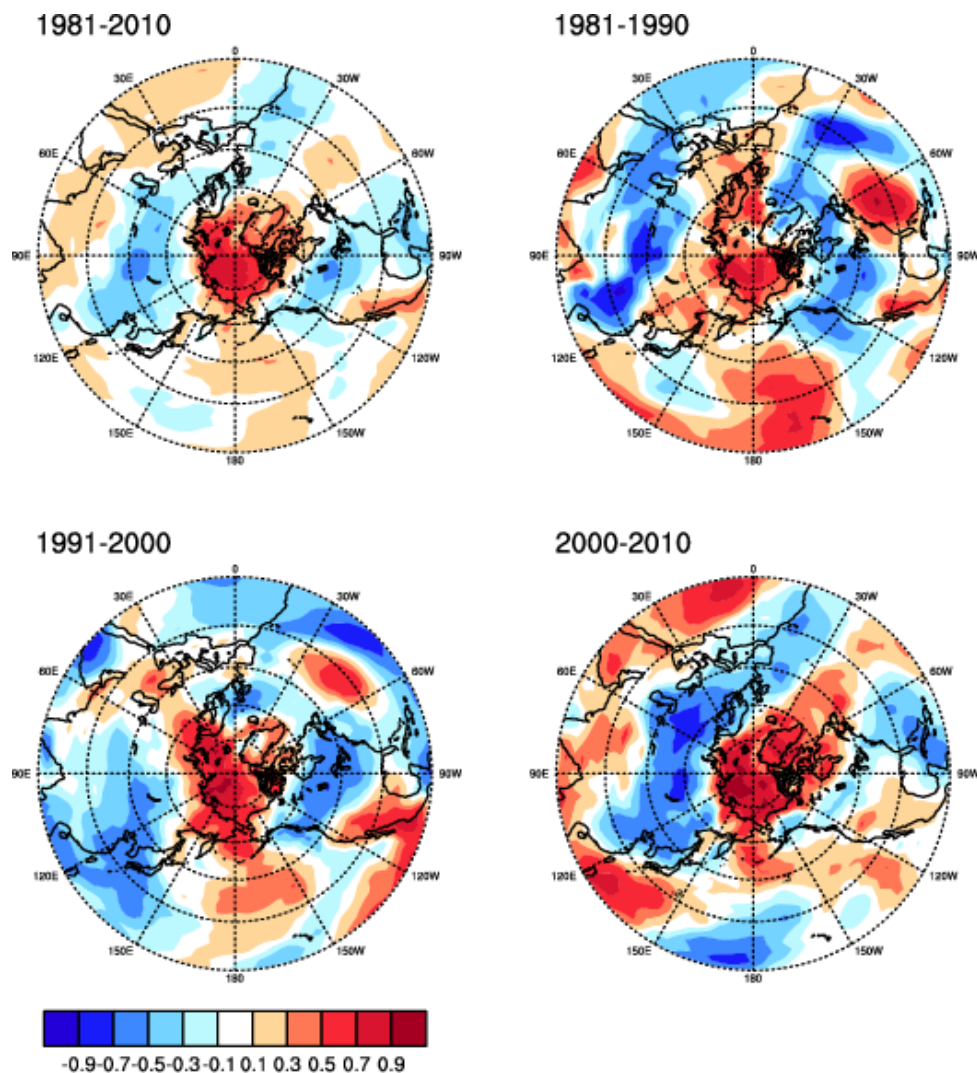
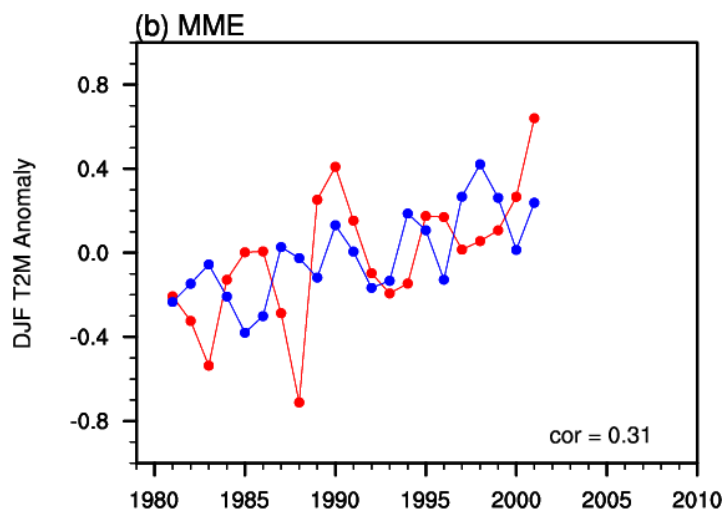
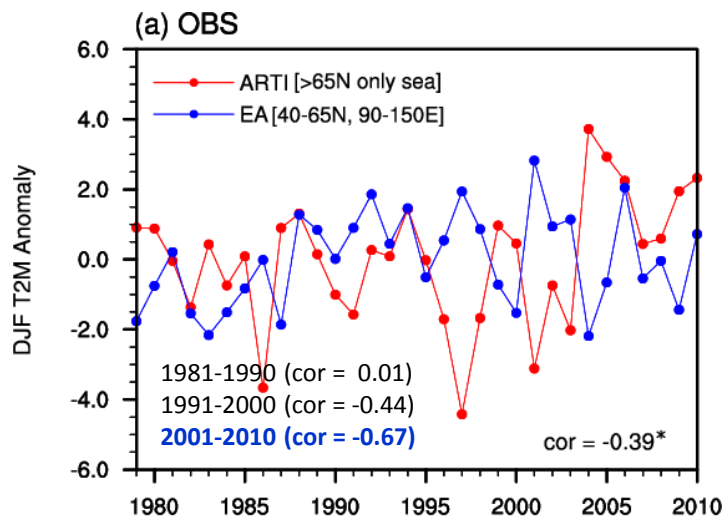
DJF 2011/12



© APEC Climate Cent

# ARTI & EA T2M Relationship

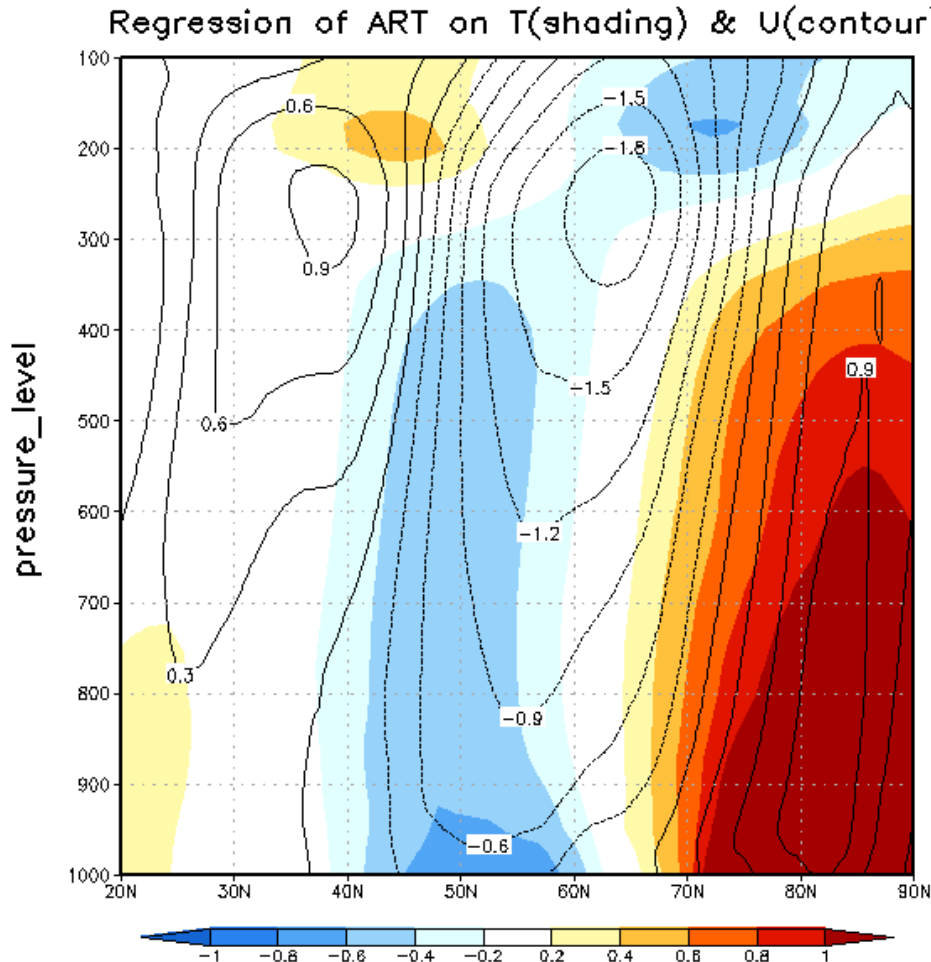
## OBS COR (ARTI & T2M)



\* : significant at 5% level

# Arctic and Mid-Lat. temperature

## T & GPH (0-130E)



**Weak Temperature Gradient**

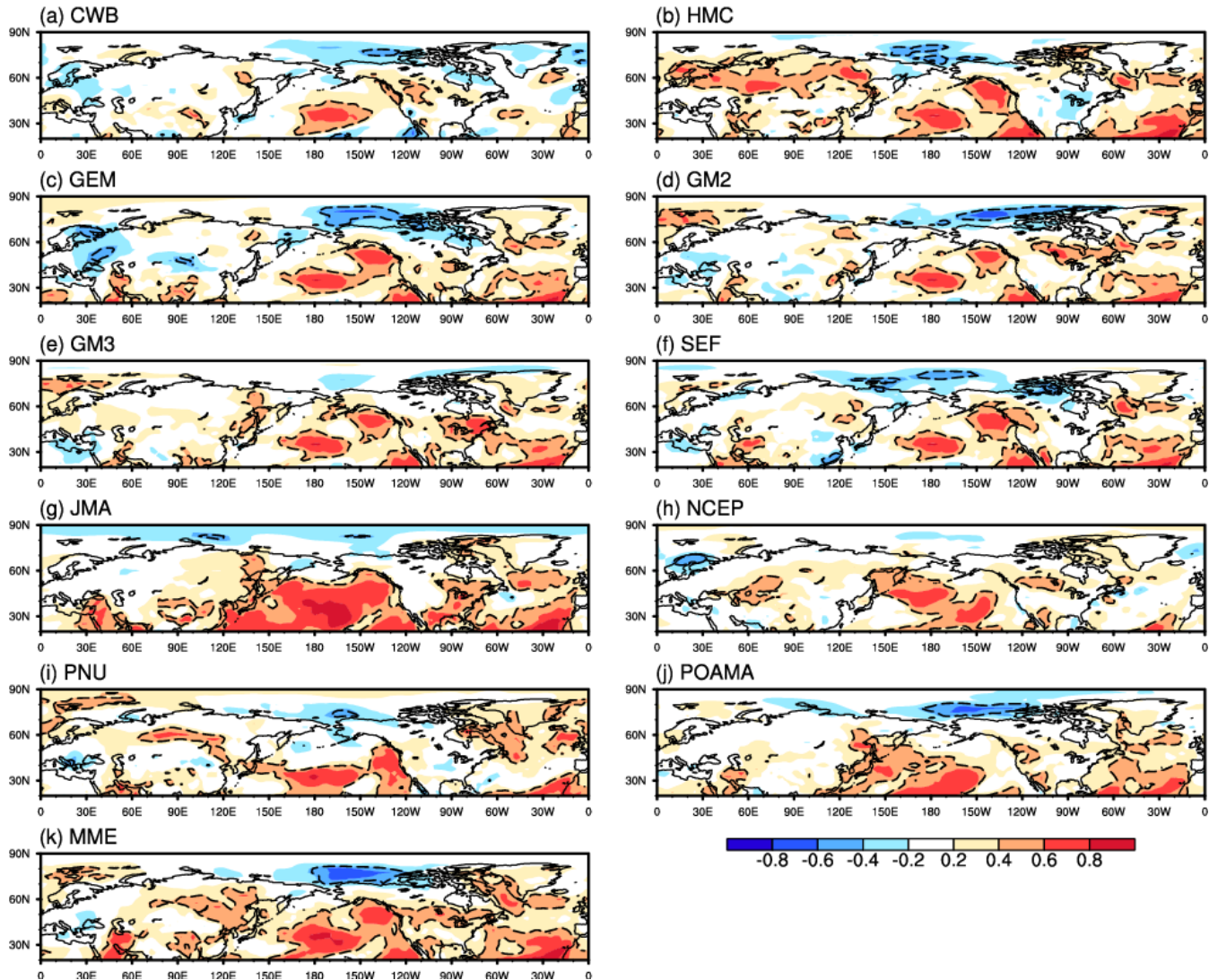
➔ **Weakened Westerlies**

➔ **More Frequent intrusion of Cold Polar air to Mid-latitude**

The zonal mean structure for the monthly-mean anomalous air temperature (shading) and zonal wind (contour) regressed on the ART index during DJF. The variables are averaged between 0° and 130°E.

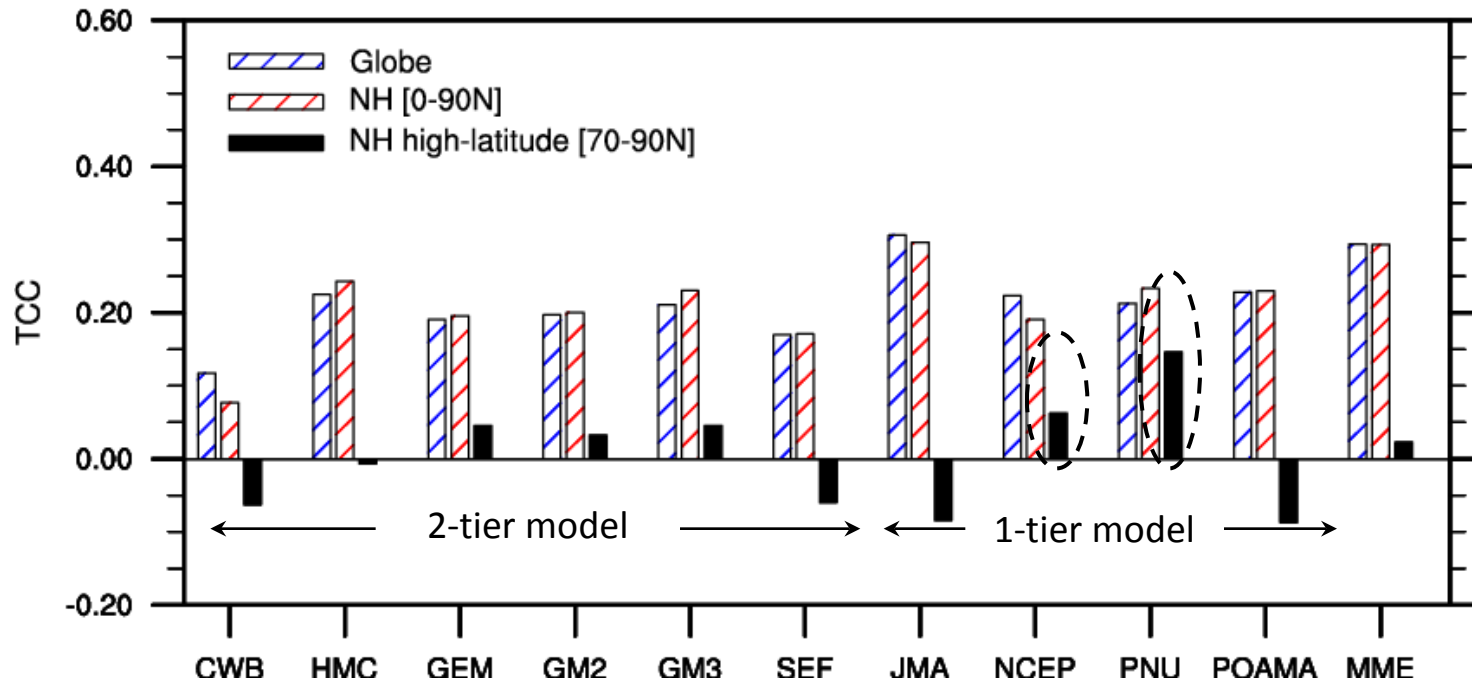
From Kug et al. 2012

# Temporal Correlation Coefficient (DJF, 1981-2002)



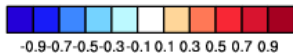
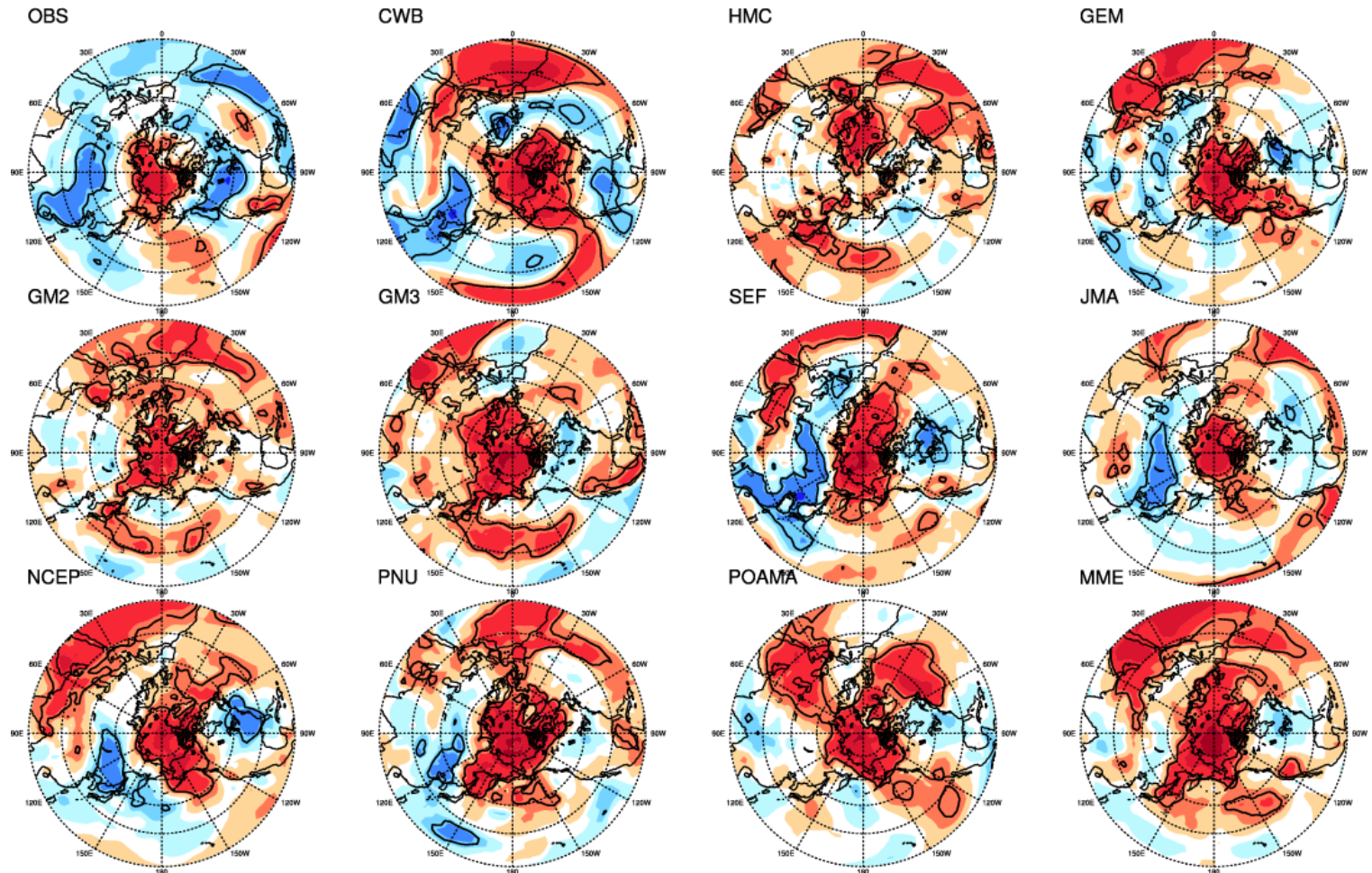


# Area-averaged Correlation Coefficient (DJF, 1981-2002)



- Sea ice, snow initialization: NCEP, PNU → forecast  
JMA, POAMA → climatology

# COR (ARTI & T2M, 1981-2002)

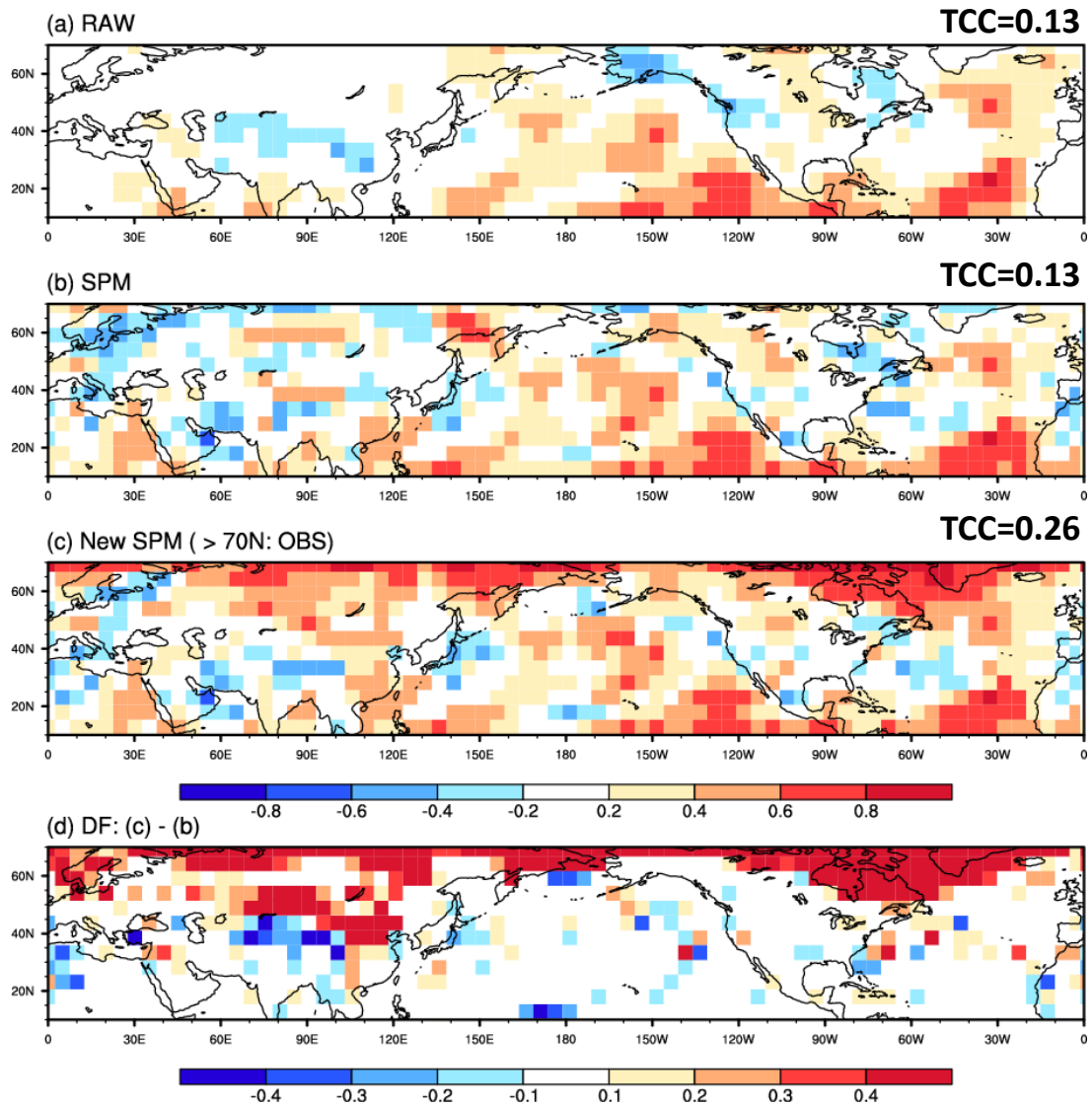


Contour: significant at 5% level

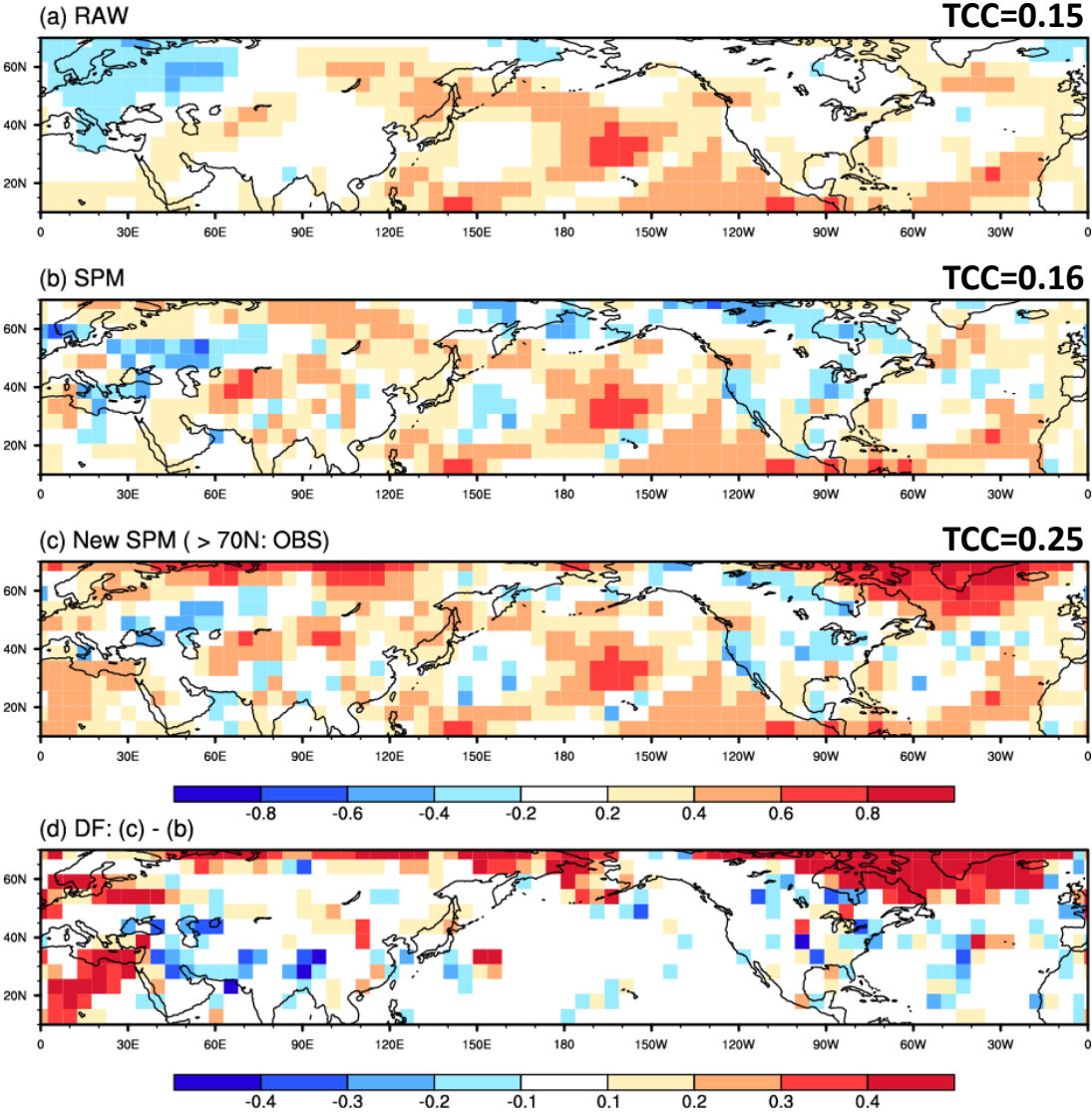
**What if we can predict  
Arctic temperature precisely?  
+  
Statistical post processing**

Replace arctic temperature (north of 75N) with observation in CFS hindcast and see if SPM can transfer this information into lower latitude.

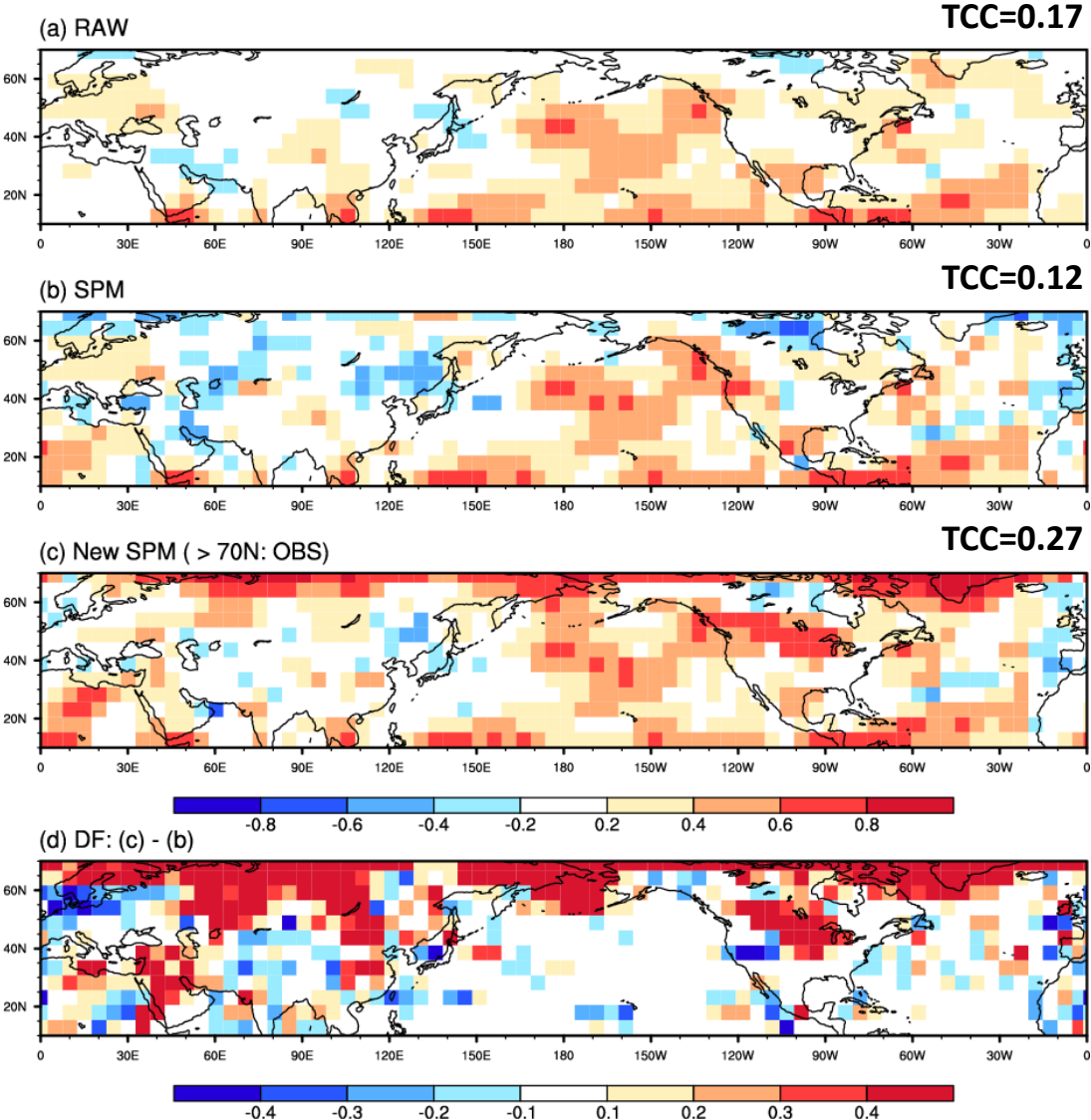
# MME Forecast Skill (DEC, 1981-2010)



# MME Forecast Skill (JAN, 1981-2010)

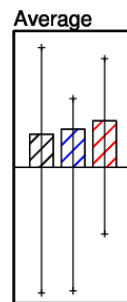
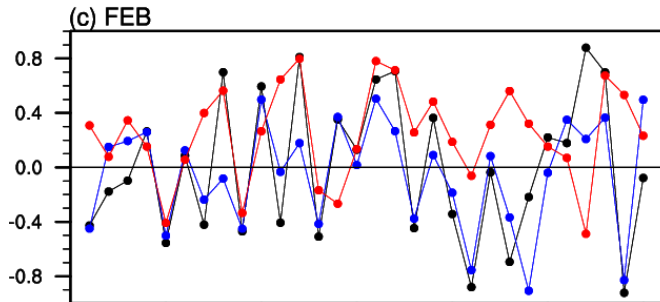
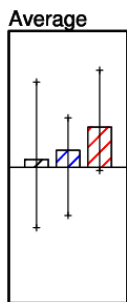
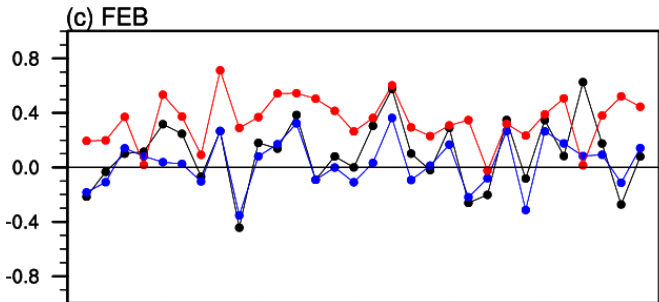
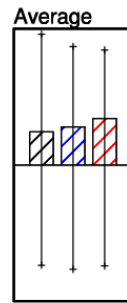
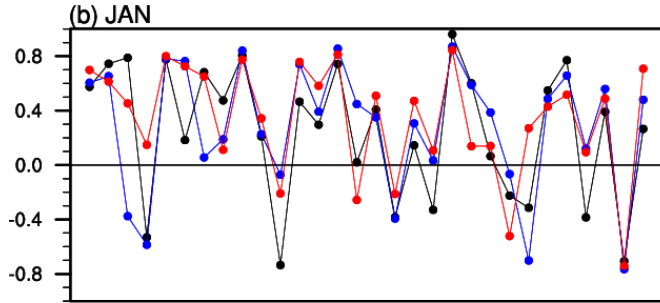
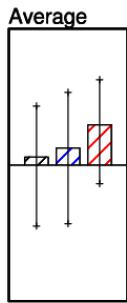
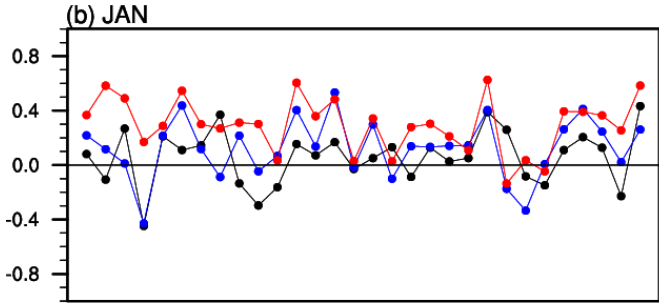
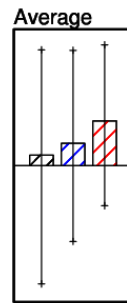
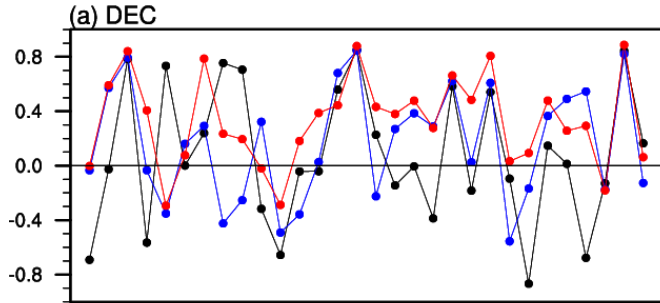
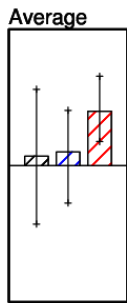
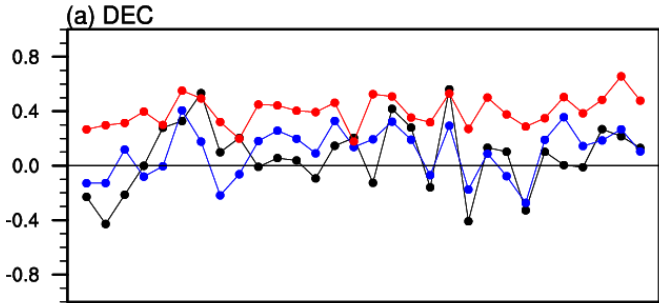


# MME Forecast Skill (FEB, 1981-2010)



# Anomaly Pattern Correlation [10-70oN]

# Anomaly Pattern Correlation [E. Asia]



1980 1985 1990 1995 2000 2005 2010

RAW SPM New SPM

1980 1985 1990 1995 2000 2005 2010

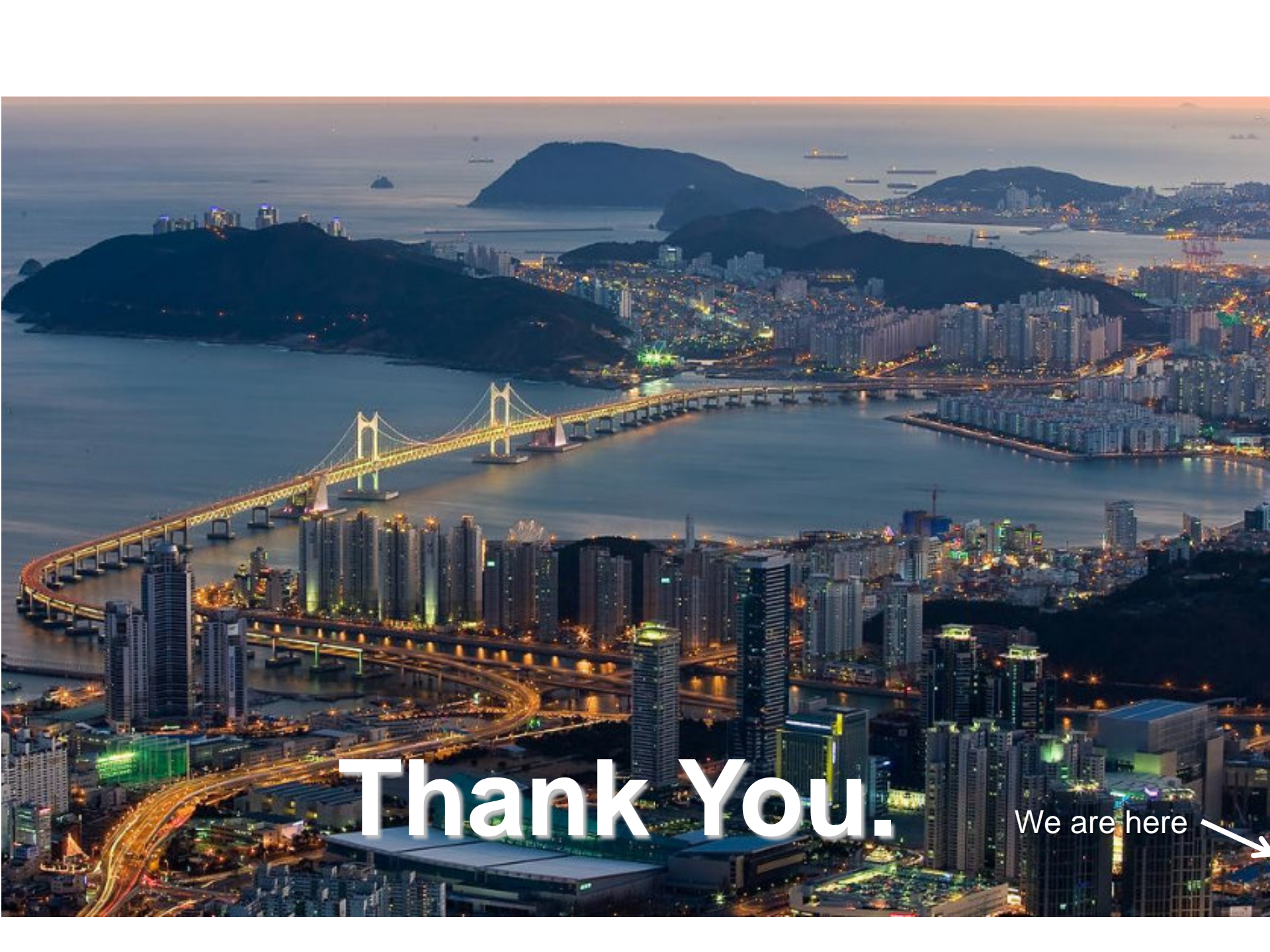
RAW SPM New SPM

● RAW  
● SPM  
● New SPM

# Summary

- APCC MME : the mixture of forecasts from operational centers and research groups (could be the largest collection of forecasts)
  - APCC plays a role as a mid-fielder in Climate Services
- The calibration/correction (SPM) does something noticeable but need to be *calibrated* more for operational use
- Attempts on the more forecast products
- Recent failure of EA forecast might be attributable for Arctic region : chance of additional predictability or not? due to climate change





**Thank You.**

We are here 