Introduction to APEC Climate Center Seasonal Prediction System

- Based on Multi-Model Ensemble -

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Asia Pacific Economic Cooperation Climate Center

ICPT TTA on **"Statistical Methods in Seasonal Prediction"**

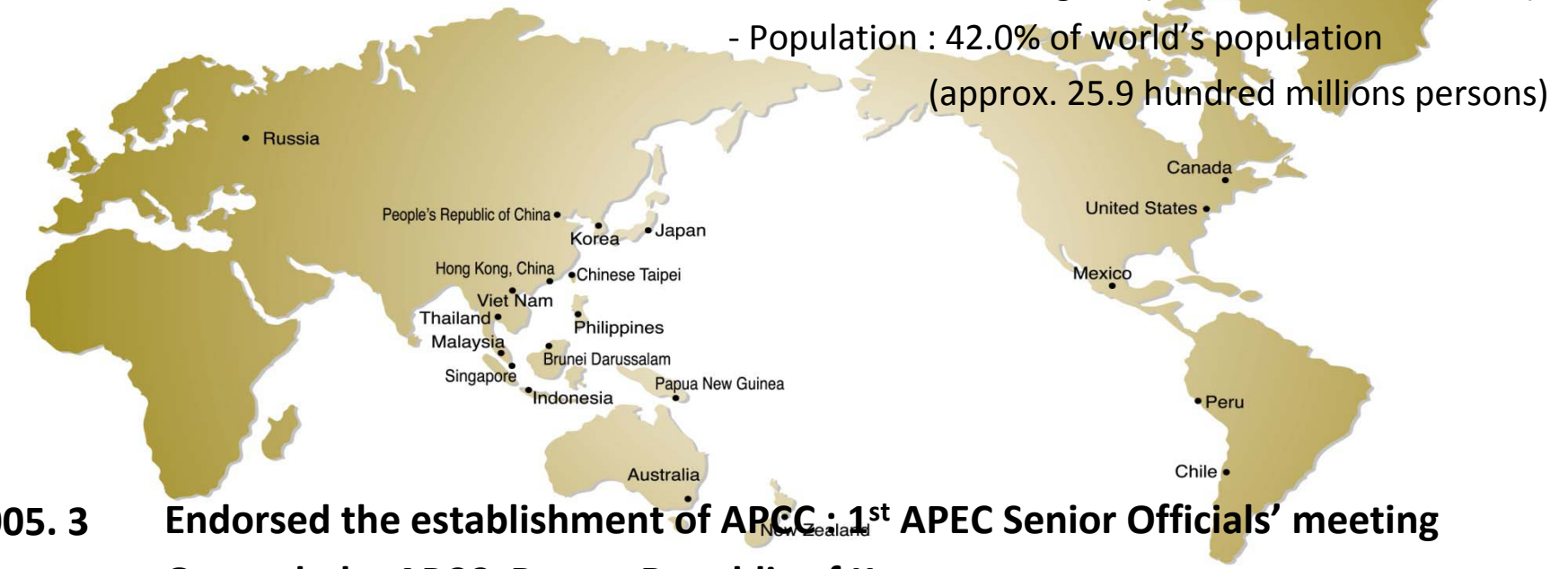
9 August 2010

Asia Pacific Economic Cooperation (APEC)

To meet the Bogor Goals of free and open trade and investment in the Asia-Pacific region

- **Trade and Investment Liberalization**
- **Business Facilitation**
- **Economic and Technical Cooperation**

- Established in 1989, 21 APEC member economies
- 60.4% of World's GDP, 46.9% of World's trade volume
  - Area : 46.8% of the globe(6,261 ten thousand km^2)
  - Population : 42.0% of world's population (approx. 25.9 hundred millions persons)



2005. 3 **Endorsed the establishment of APCC : 1st APEC Senior Officials' meeting**

2005. 9 **Opened the APCC, Busan, Republic of Korea**

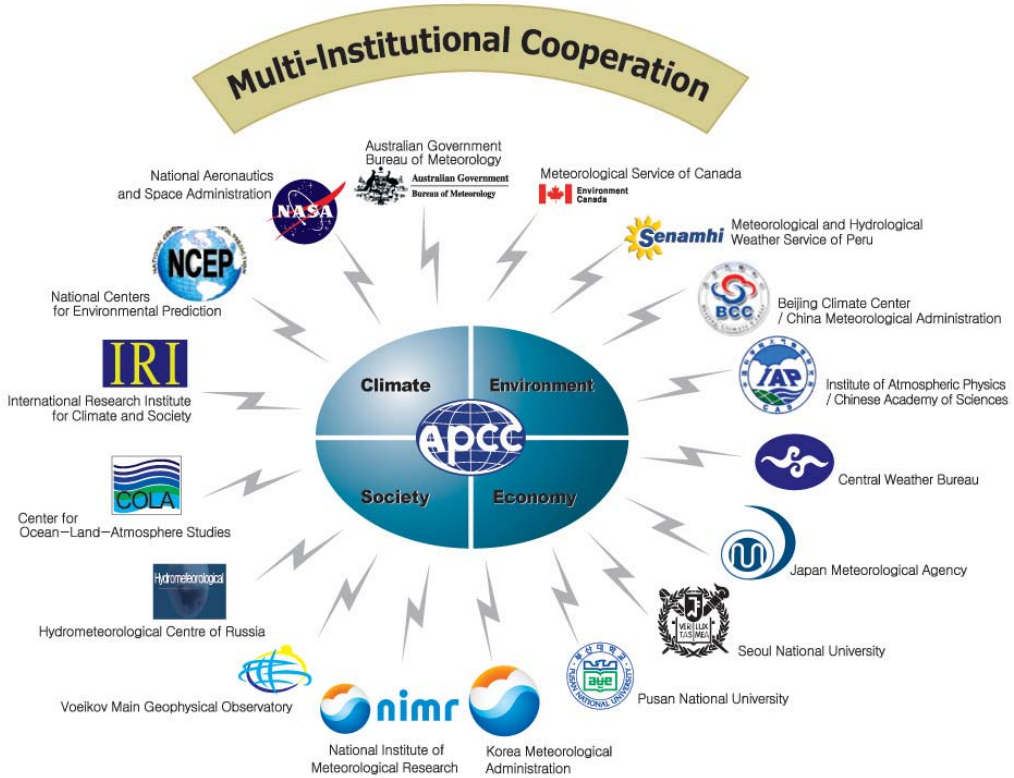
APCC Goals

To set up an institutionalized communication channel for more effective exchanges of regional climate information.

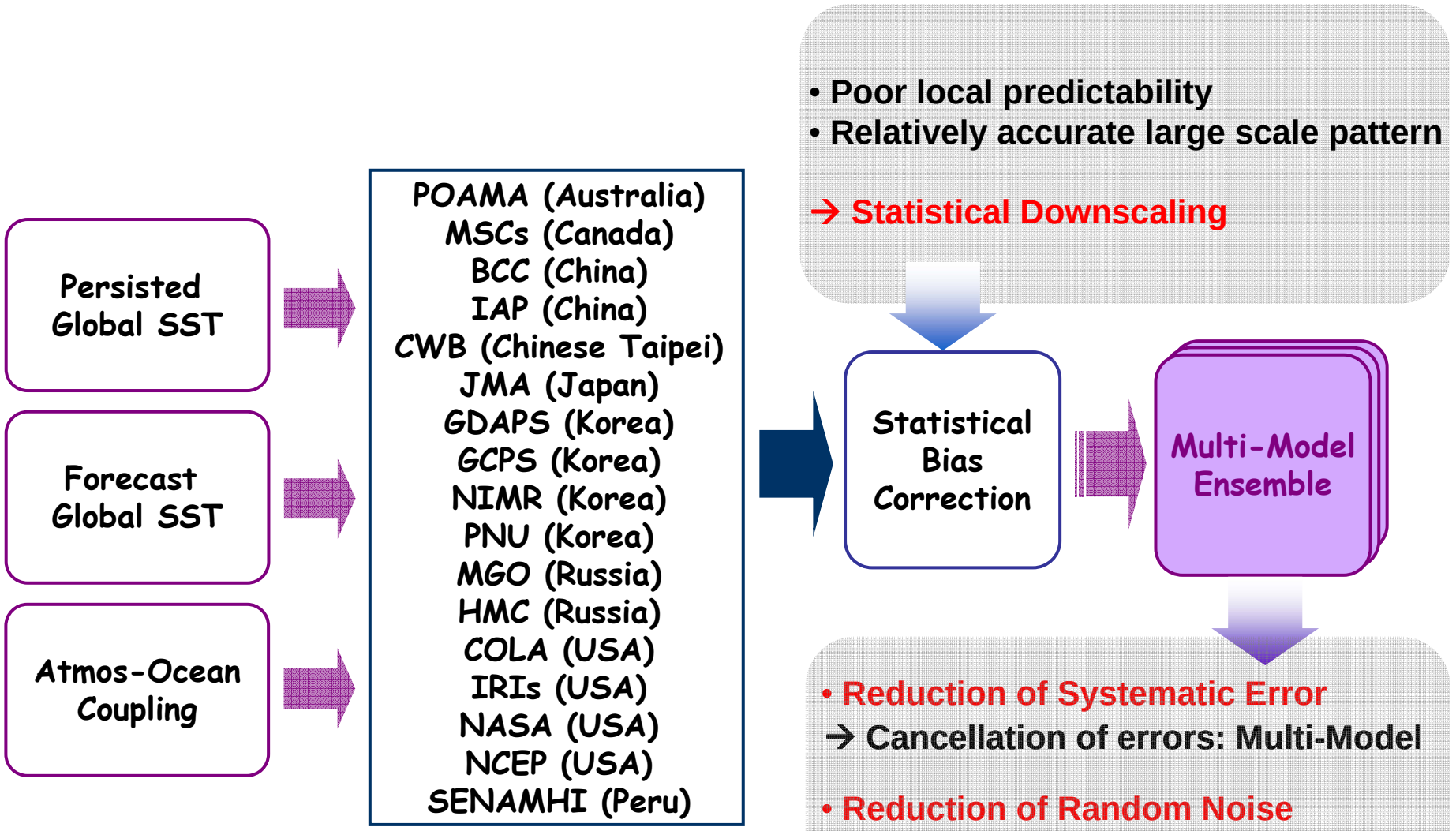
- **Facilitating the sharing of high-cost climate data and information**
- **Capacity building in prediction and sustainable social and economic applications of climate information**
- **Accelerating and extending socio-economic innovation**

APCC MME Forecast

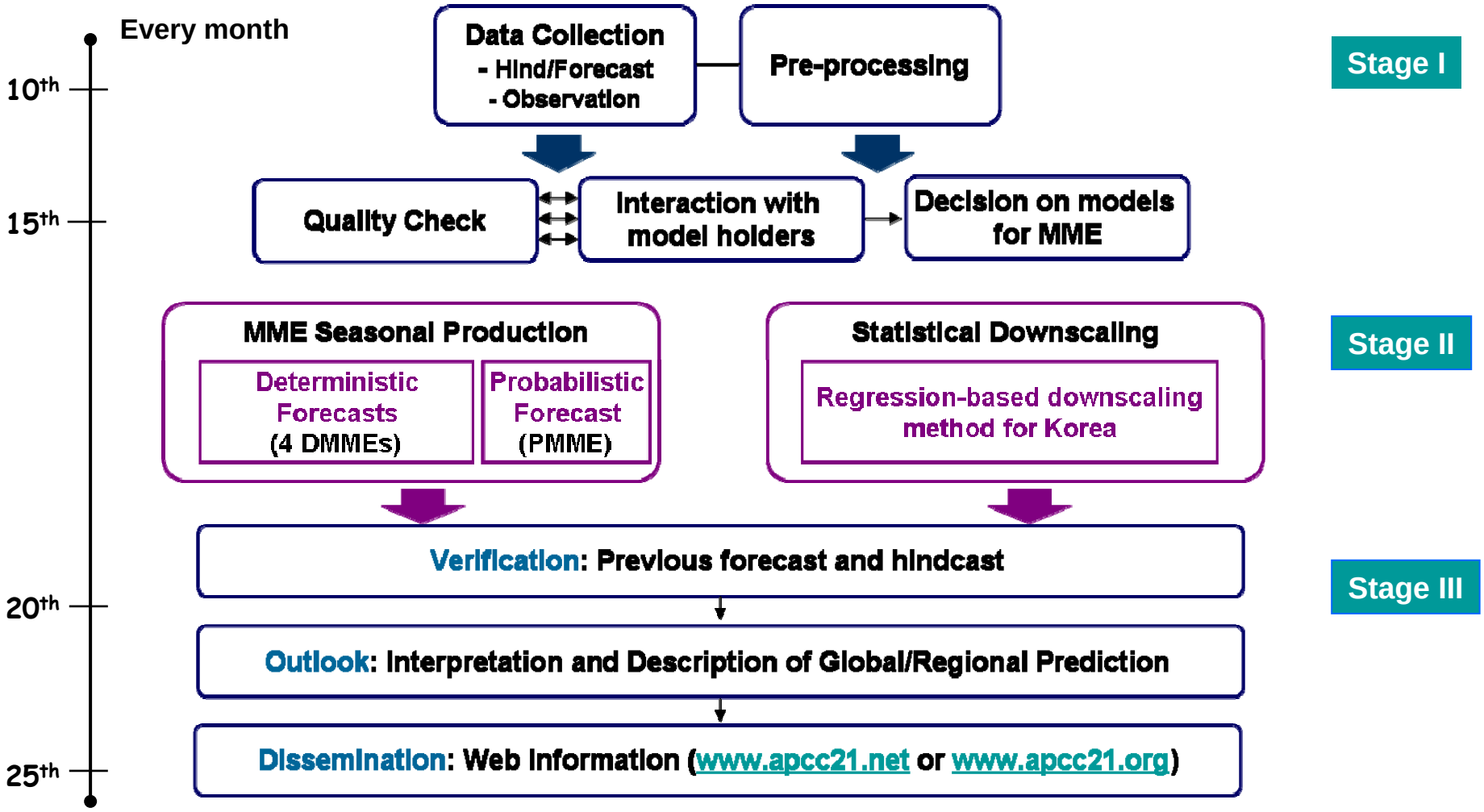
- **17 institutions/operation centers from 9 APEC member economies**
- **Rolling Monthly 3-month MME forecasts and disseminate it to APEC members**
- **Four deterministic and one probabilistic MME forecasts**
- **Precipitation, temperature at 850hPa, and geopotential height at 500hPa**
- **www.apcc21.org: climate monitoring, MME forecast, hind/forecast verification**



APCC Seasonal Climate Prediction System



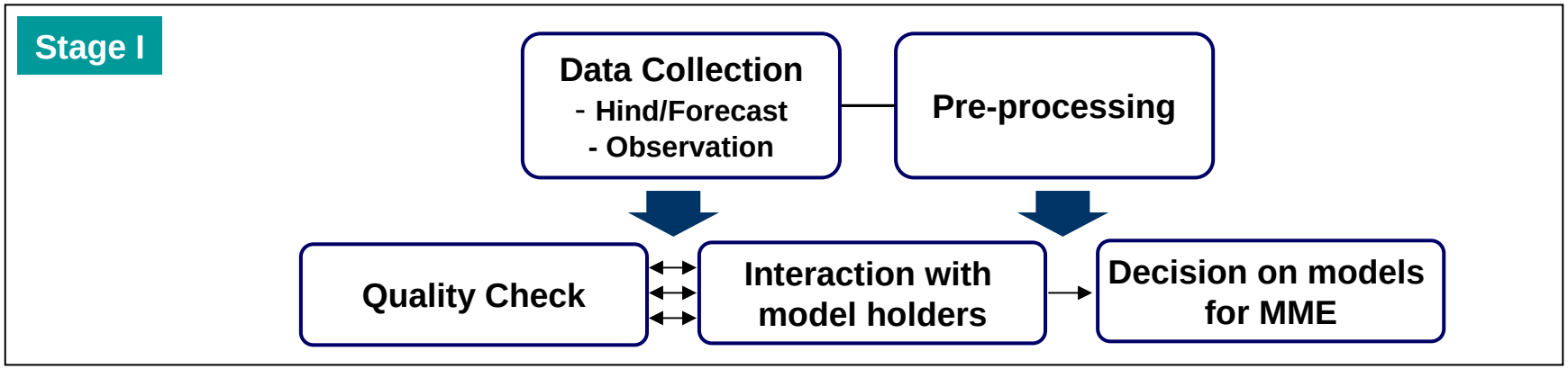
Procedure of APCC MME Forecast



Participating Institutes

Member Economies	Acronym	Organization	Model Resolution
Australia	POAMA	Bureau of Meteorology Research Centre	T47L17
Canada	MSC	Meteorological Service of Canada	1.875 ° × 1.875 ° L50
China	BCC	Beijing Climate Center/CMA	T63L16
	IAP	Institute of Atmospheric Physics	4 ° × 5 ° L2
Chinese Taipei	CWB	Central Weather Bureau	T42L18
Japan	JMA	Japan Meteorological Agency	T63L40
Korea	PNU	Pusan National University	T42L18
	GDAPS/KMA	Korea Meteorological Administration	T106L21
	GCPS/SNU	Seoul National University	T63L21
	METRI/KMA	Meteorological Research Institute	4 ° × 5 ° L17
Russia	MGO	Main Geophysical Observatory	T42L14
	HMC	Hydrometeorological Centre of Russia	1.12 ° × 1.4 ° L28
Peru	SENAMHI	Meteorological and Hydrological Weather Service of Peru	2.8 ° × 2.8 L18 °
USA	IRI	International Research Institute	T42L19
	COLA	Center for Ocean-Land-Atmosphere Studies	T63L18
	NCEP CFS	National Centers for Environmental Prediction	T62L64
	NASA-GSFC	National Aeronautics and Space Administration	2 ° × 2.5 ° L34

Procedure of Seasonal Forecast



- Schedule: 10th ~ 15th every month
- Needs standardization which make same format for individual model data
- Make a decision on the model set to be used in the production of MME seasonal forecasts
- More than 10 models are participated in MME prediction

Preprocessing and Data Conversion

- **Automated Forecast System (AFS)** runs APCC MME seasonal forecast
  - It consists of a number of libraries and scripts used to manage and analyze data in the APCC Data Base
  - These programs are used to make MME and their verification and associated plots
  - Users generally interact with AFS using NCL and Ruby interface

- **Preprocessing and data conversion** is needed to be run in AFS
  - Individual forecast data are standardized and reformatted in combination with hindcast data to match input formats of the AFS (1 model, 1 variable, 1 year)
  - The data type is NetCDF file (with the suffix “.nc”)
  - One file has 3 months data and as much data as ensemble sizes

Preprocessing and Data Conversion

- Dump file information

  > ncdump –h prec.nc

- Resolution: 2.5 x 2.5 degree interval over global domain (144 x 73 grids);

- Writing order: Eastward from 0°to 2.5°W, northward from 90°S to 90°N;

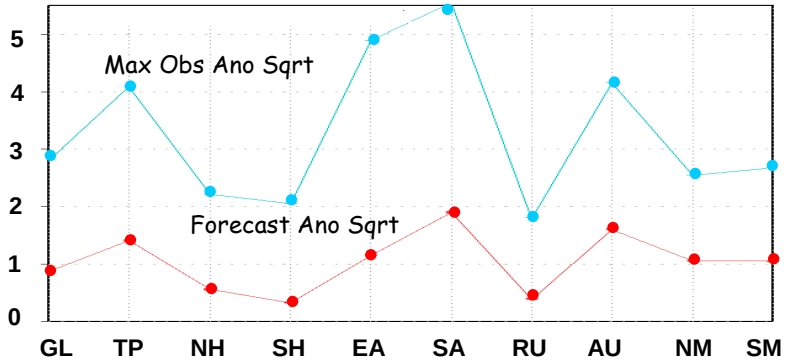
- Writing format: NetCDF format

```
netcdf prec {
dimensions:
        time = UNLIMITED ; // (3 currently)
        level = 15 ;
        lat = 73 ;
        lon = 144 ;
variables:
        double time(time) ;
                time:_FillValue = -9999. ;
                time:original_name = "Lead Time of Forecast in months" ;
                time:units = "days since 1900-01-01" ;
        int level(level) ;
                level:original_units = "Ensemble Member (no units)" ;
                level:units = "m" ;
                level:original_name = "Ensemble Members" ;
        float lat(lat) ;
                lat:units = "degrees_north" ;
                lat:long_name = "latitude" ;
                lat:nlat = 73 ;
        float lon(lon) ;
                lon:units = "degrees_east" ;
                lon:long_name = "longitude" ;
                lon:nlon = 144 ;
        float prec(time, level, lat, lon) ;
                prec:long_name = "Precipitation" ;
                prec:units = "mm/day" ;
                prec:missing_value = 1.e+20f ;
                prec:_FillValue = 1.e+20f ;
// global attributes:
                :creation_date = "Thu Jul 15 15:54:34 KST 2010" ;
                :Conventions = "None" ;
                :title = "Written using AFS function write_TLLL" ;
                :model = "NCEP" ;
}
```

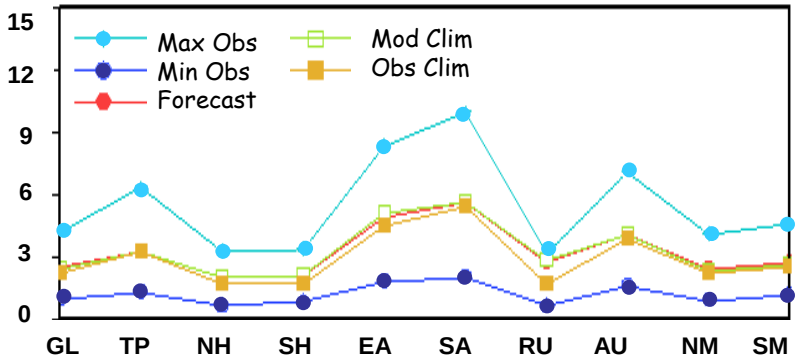
Quality Check (QC)

- ✓ **To detect some artificial mistakes in the data (cased by either by the model itself, or by data transfer procedure)**
- ✓ **QC can be qualitative (“does it look right”) or quantitative (“within which limit”)**

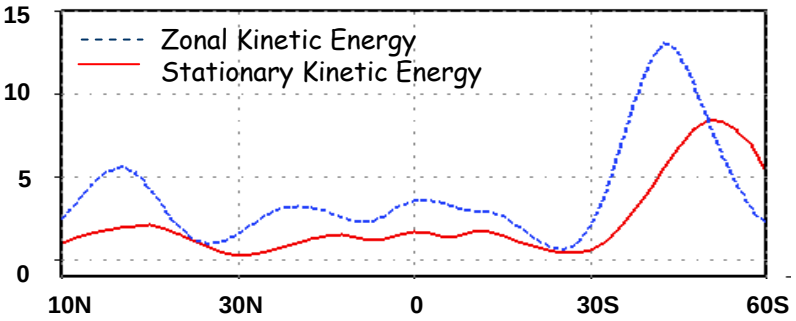
- **Anomaly Square Root Check**



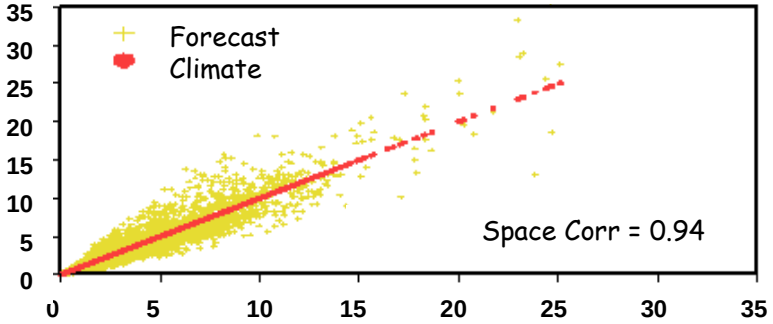
- **Climate and Extreme Value Check**



- **Energetic Check**

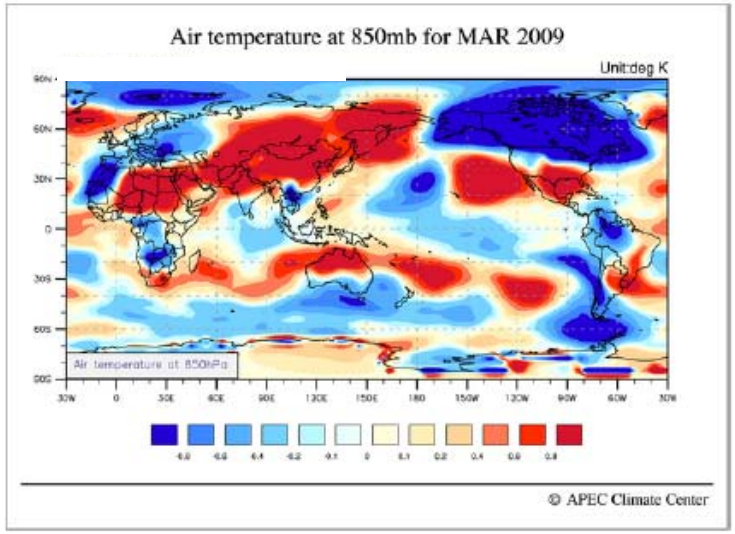


- **Pattern Check**



Decision on models for MME

- **Exceptional case** which any specific model couldn't not participate in APCC MME seasonal forecast
  - 850-hPa Temperature anomalous value (few spots) over the Antarctic region



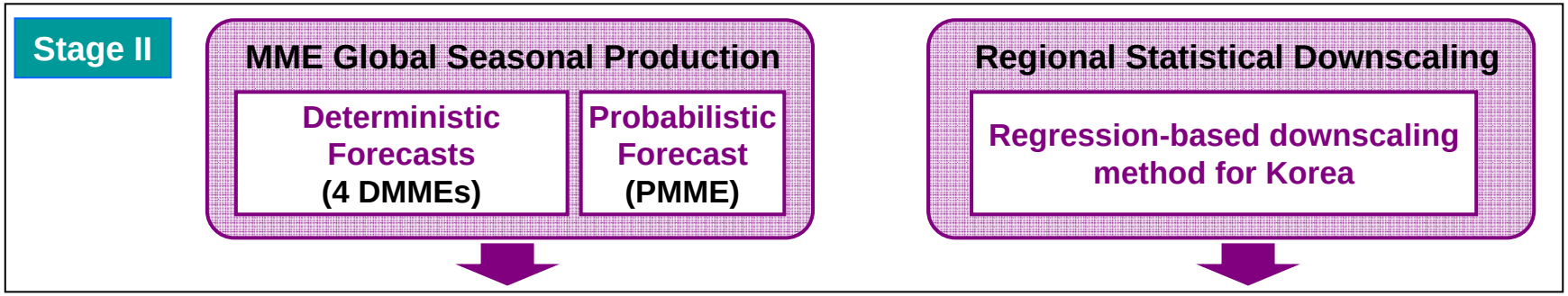
- **Model and Data**

(1) Hindcast Period/Specification
  - Longer (up to 2009) and more overlapping data period are encouraged
  - SMIP/HFP and CMIP-type experiments in hindcast are suggested

(2) Data Provision/Submission
  - Model holders are requested to provide forecast on monthly basis no later than the 15th of each month

(3) Variables
  - At least 11 variables are required

Procedure of Seasonal Forecast



- **Schedule: 15th ~ 20th every month**
- **Deterministic forecast**
  - SCM (Simple Composite Method)
  - MRG (Multiple Regression Method)
  - CPM (Coupled Pattern Projection Method)
  - SSE (Synthetic multi-model Super Ensemble method)
- **Probabilistic forecast**
- **Regional statistical downscaling**

Deterministic MME Method

SCM

Simple Composite Method:

Simple composite of individual forecast with equal weighting.

$$P = \frac{1}{M}\sum_i F_i'$$

MRG

Multiple ReGression method:

Optimally weighted composite of individual forecasts.
The weighting coefficient is obtained by SVD based regression.

$$P = \sum_i a_i F_i'$$

SPM

Stepwise Projection Method :

Simple composite of individual forecasts, after correction by statistical downscaling.

$$P = \frac{1}{M}\sum_i \hat{F}_i'$$

SSE

Synthetic Super Ensemble method:

Weighted combination of statistically corrected multi model output based on minimizing using EOF.

$$P = \frac{1}{M}\sum_i \alpha_i \hat{F}_i'$$

Deterministic MME Schemes

- **SCM (Simple Composite Method)**

  : Simple composite of bias-corrected individual forecast with equal weighting.

$$S_t = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}(F_{i,t} - \overline{F_i})$$

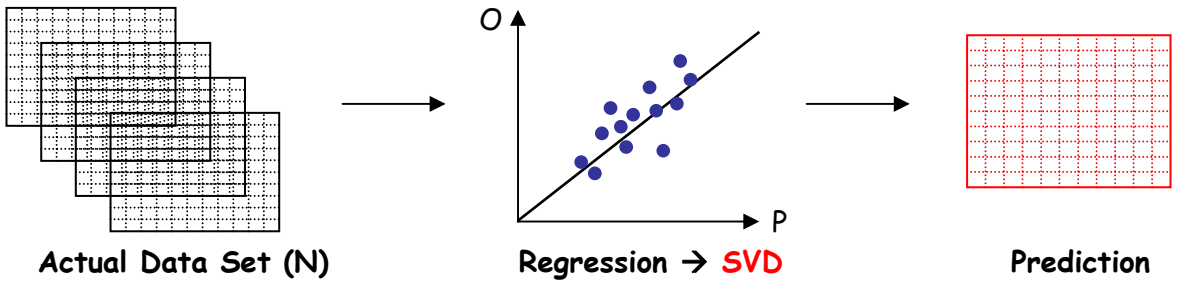
$F_{i,t}$: ith model forecast at time t
$\overline{F_i}, \overline{O}$: Climatology of the ith forecast and obs.
N : the number of forecast models involved

- **MRGM (Multiple Regression Method)**

  : Optimally weighted composite of individual forecasts.
  The weighting coefficient is generated using point-wise regression technique.

$$S_t = \overline{O} + \sum_{i=1}^{N} a_i(F_{i,t} - \overline{F_i})$$

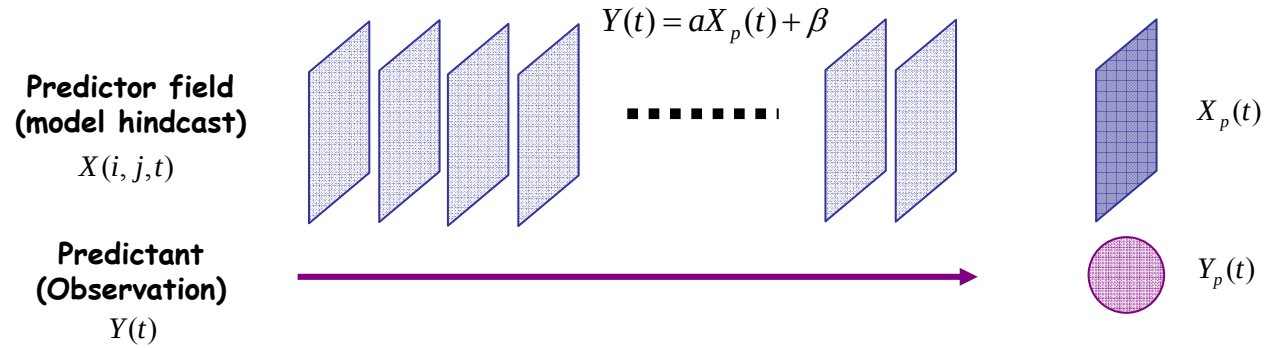
a_i : regression coefficients obtained by SVD



Deterministic MME Schemes

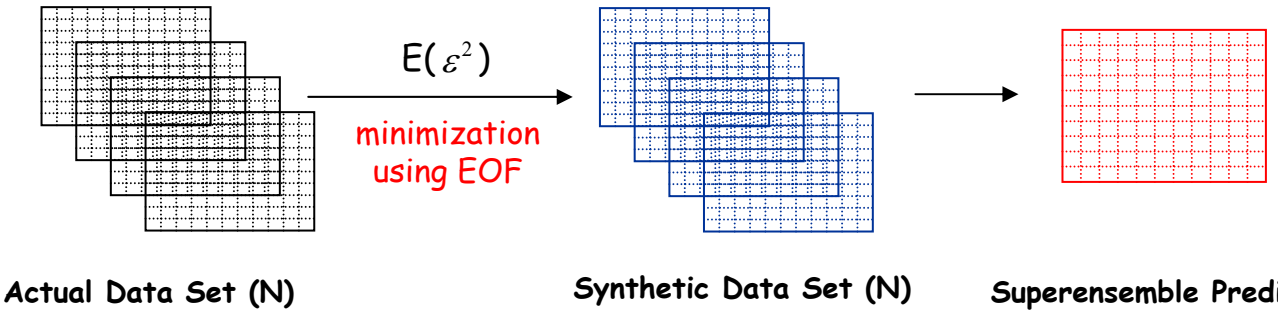
- **CPPM (Coupled Pattern Projection Method)**

  : Statistical downscaling forecast in which an optimal forecast filed is projected onto the observation at the target point



- **SSEM (Synthetic Multi-Model Super Ensemble Method)**

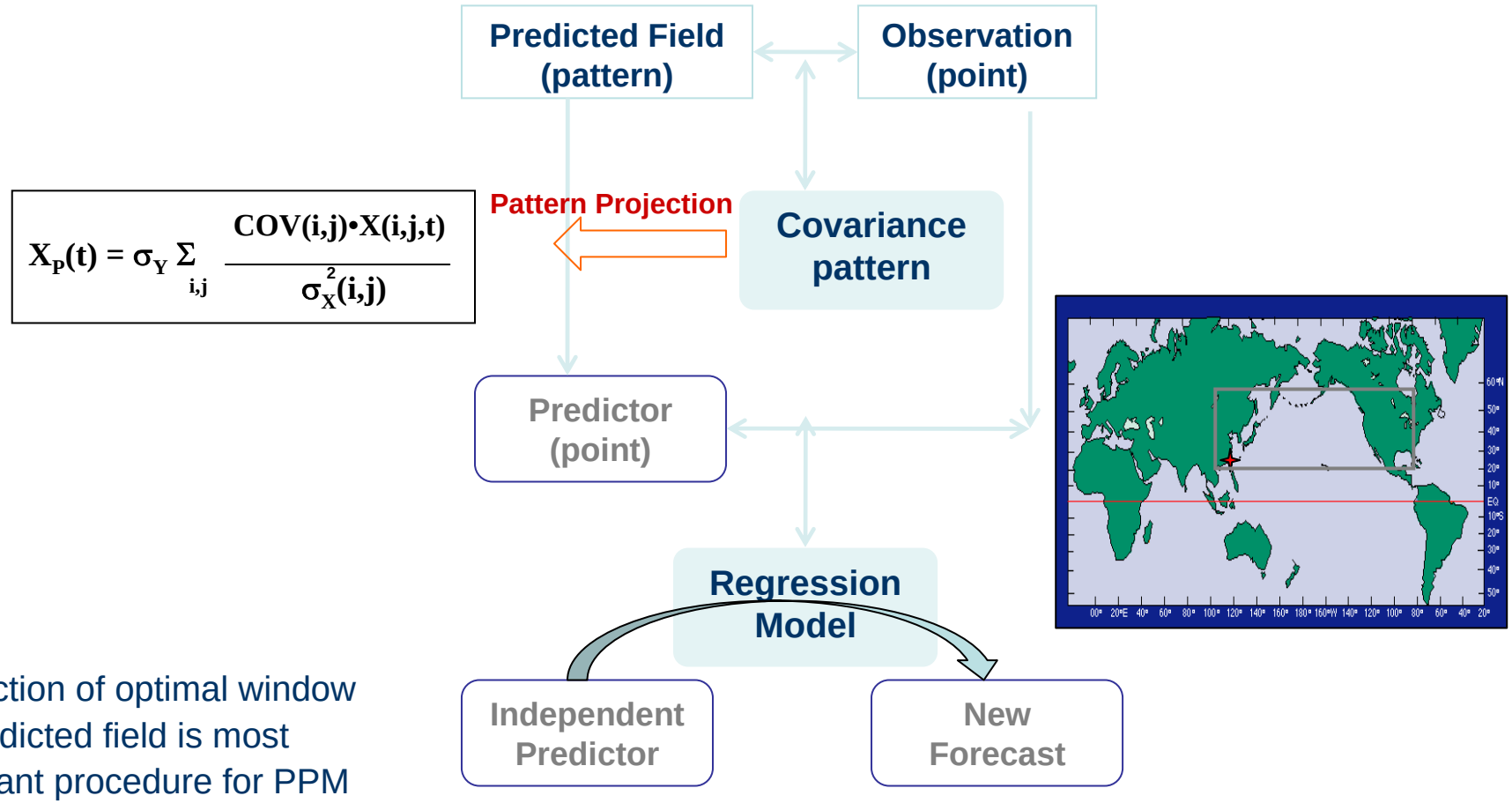
  : Weighted combination of statistically corrected multi-model output.



Pattern Projection Method

✓ **Rationale for using PPM:** Although the precipitation prediction is poor, climate models are able to simulate the large-scale atmospheric circulation.

Procedure of PPM



* Selection of optimal window for predicted field is most important procedure for PPM

Lee (2003), Kang and Shukla (2006)

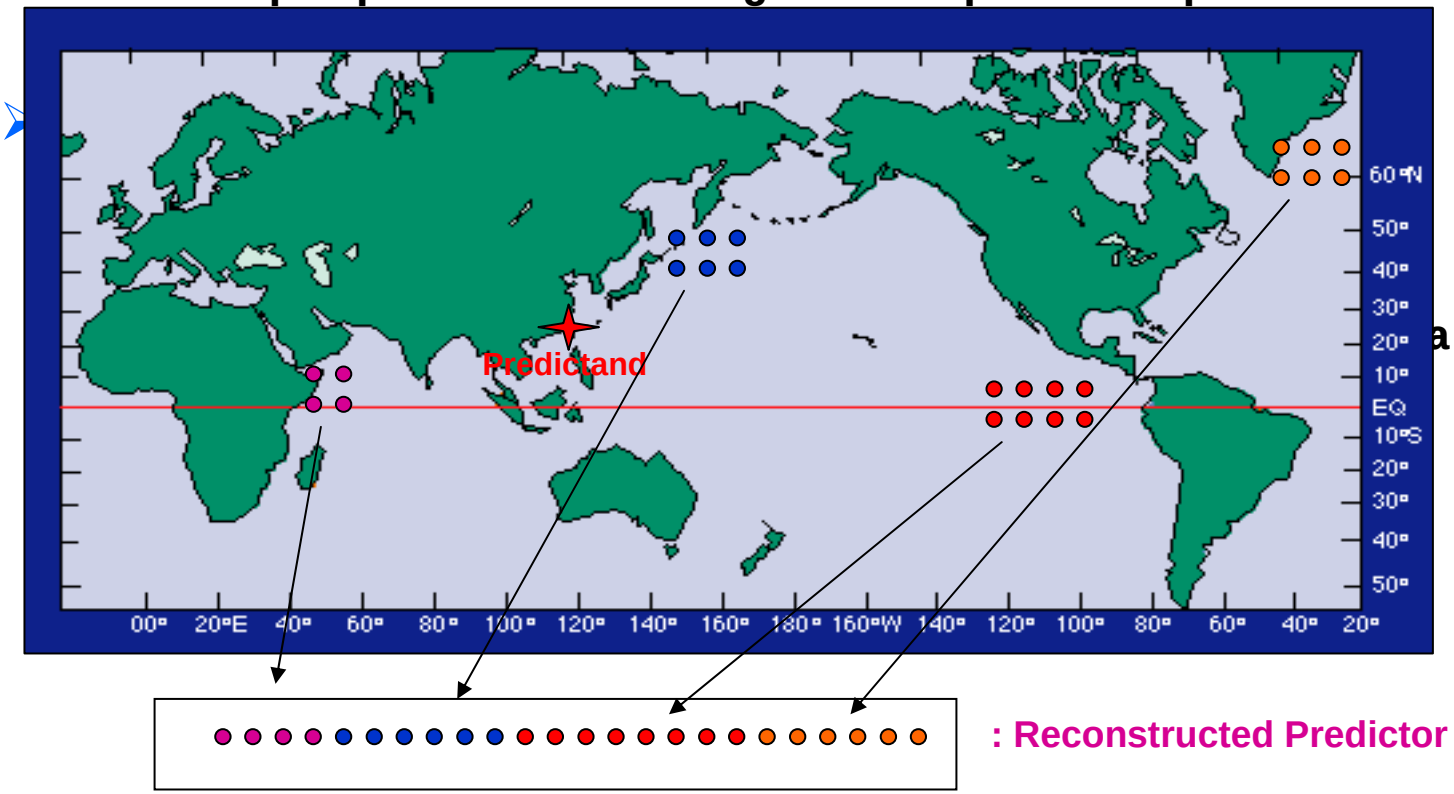
Stepwise Pattern Projection Model (SPPM)

Kug et al. (2007, Mon. Wea. Rev.**)**

➢ First Step : Prior Predictor Selection

- Select qualified predictor grid based on correlation for training period of cross validation

- Gather split predictors and regard as a predictor pattern



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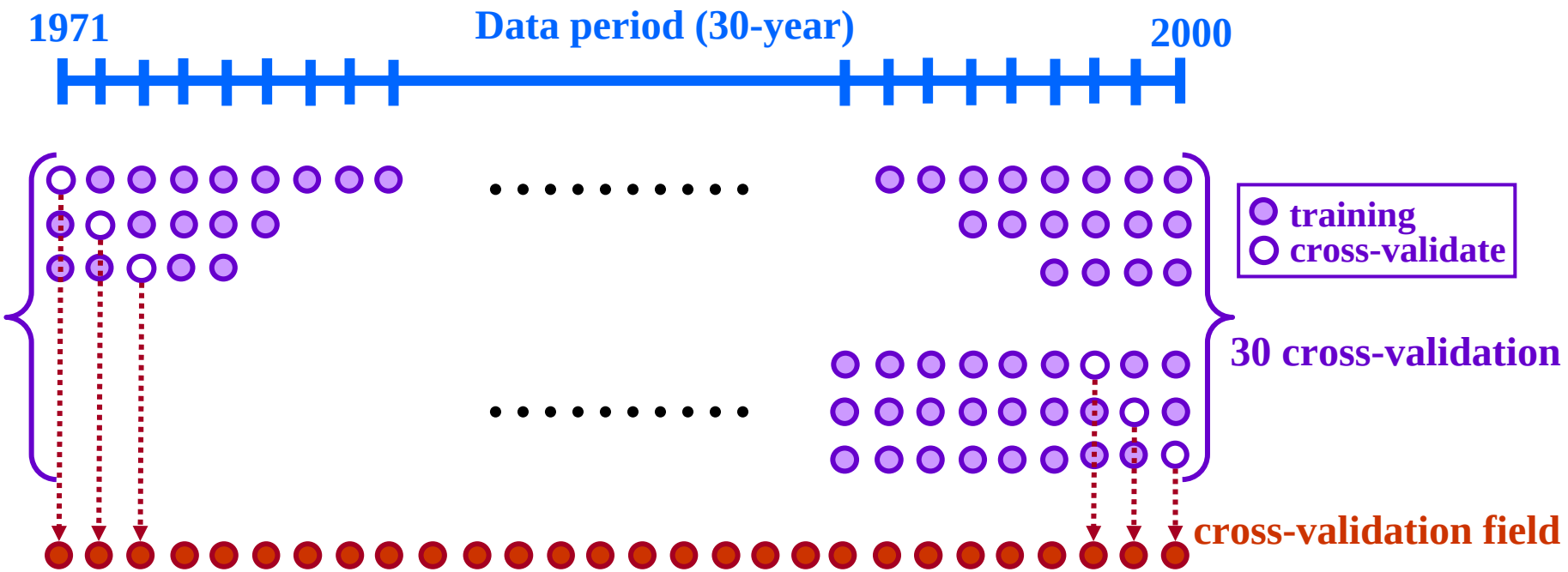
: Reconstructed Predictor Domain

Cross-Validation



- Taking out one sample out of the whole data period.
- Building statistical model with the rest of the period and applying the model to the sample taken out.
- Repeating this procedure until the whole cross-validation field completed.

APCC MME Forecast for 2010ASO
- SCM Method -

Participating Model Description

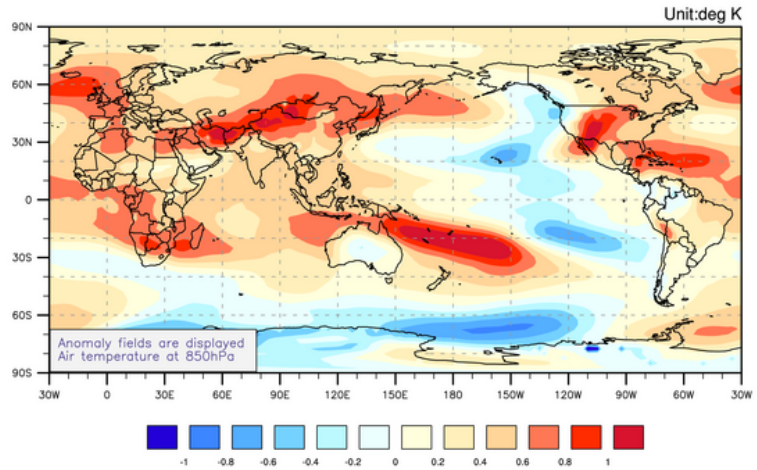
- **9 Models:** **CWB, GCPS, GDAPS, MSC_GM2, MSC_GM3, MSC_SEF, NCEP, NIMR, POAMA**
- **Common Hindcast Period:** **1981-2003 (23 years)**

Name/Economy	Start Year/Month	End Year/Month	Variables	Model Designation	SST Specification (Hindcast/Forecast)	Ensemble (H/F)
CWB Chinese Taipei	1979/Jan.	2005/Dec.	TS, T2M, PREC, MSLP, T850, U850, V850, U200, V200, Z500	CWB T42L18	Predicted SST/ Predicted SST	10/10
GCPS Republic of Korea	1979/Jan.	2009/Present	TS, PREC, MSLP, T850, U850, V850, U200, V200, Z500, OLR	GCPS T63L21	Predicted SST/ Predicted SST	12/12
GDAPS Republic of Korea	1979/Jan.	2009/Present	PREC, MSLP, T850, U850, V850, U200, V200, Z500	GDAPS T106L21	Predicted SST/ Predicted SST	20/20
MSC_GM2 Canada	1969/Jan.	2003/Dec.	T2M, PREC, MSLP, T850, U850, V850, U200, V200, Z500	CCCma AGCM2 T32L10	Persistent ERA40-SST/ Persistent CMC SST	10/10
MSC_GM3 Canada	1969/Jan.	2003/Dec.	T2M, PREC, MSLP, T850, U850, V850, U200, V200, Z500	CCCma AGCM3 T63L32	Persistent ERA40-SST/ Persistent CMC SST	10/10
MSC_SEF Canada	1969/Jan.	2003/Dec.	T2M, PREC, MSLP, T850, U850, V850, U200, V200, Z500	RPN SEF T95L27	Persistent ERA40-SST/ Persistent CMC SST	10/10
NCEP U.S.A.	1982/Jan.	2007/Feb.	T2M, SST, PREC, MSLP, T850, U850, V850, U200, V200, Z500, OLR	NCEP CFS T62L64	Predicted SST/ Predicted SST	15/15
NIMR Republic of Korea	1979/Jan.	2008/Present	PREC, MSLP, T850, U850, V850, U200, V200, Z500	METRI AGCM 5.0 x 4.0, L17	Persistent OISST/ Persistent OISST	10/10
POAMA Australia	1981/Dec.	2003/Feb.	T2M, SST, PREC, MSLP, T850, U850, V850, U200, V200, Z500, OLR	POAMA 1.5 T47L17	Predicted SST/ Predicted SST	15/15

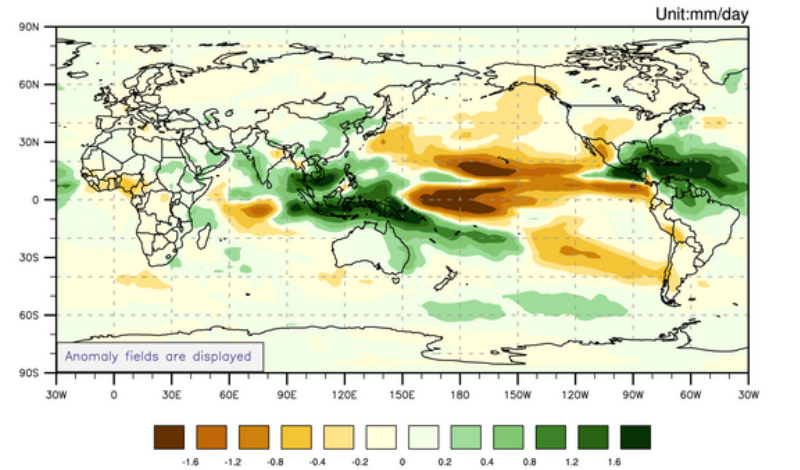
(In alphabetical order)

MME Forecast: Globe

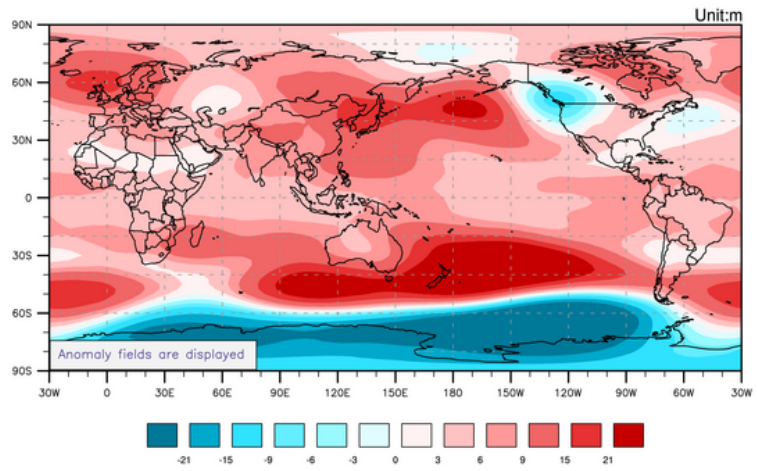
Temperature for August-October 2010



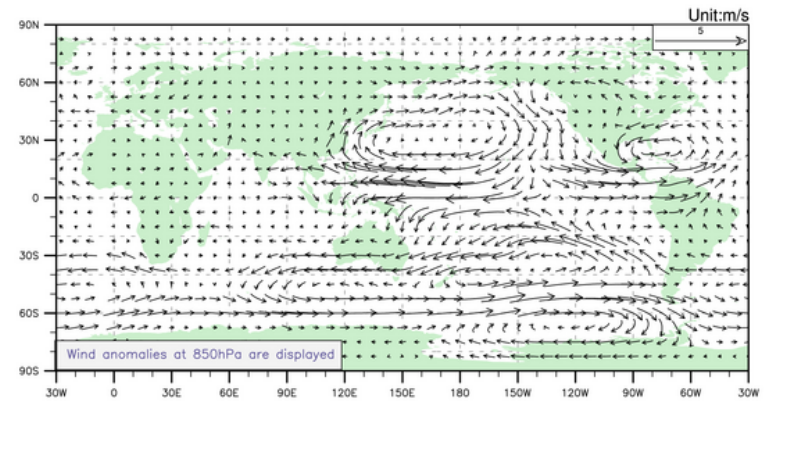
Precipitation for August-October 2010



Geopotential height at 500 mb for August-October 2010



Wind at 850hPa for ASO 2010



APCC Probabilistic MME Prediction

- A **probabilistic multimodel ensemble (PMME) prediction system** has been developed to provide seasonal forecasts at APCC since Jun 2006.

- Currently, APCC PMME issues monthly 3-month forecasts of temperature at 850hPa (T850), precipitation (PREC), and geopotential height at 500hPa (Z500).

(1) Gaussian approximation to estimate tercile-based categorical probabilities (above-, near-, and below-normal)

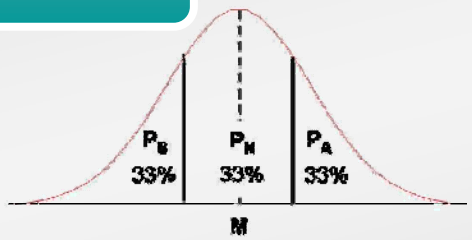
(2) Multi-model combination with model weights proportional to the square root of the ensemble size

(3) Combined map based on three category probabilities applying Pearson's chi-square test

(1) Gaussian Approximation

Defining terciles

Normal fitting method



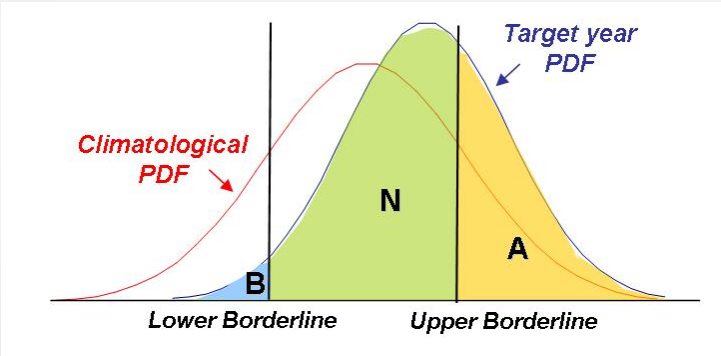
- For the middle/upper tercile boundary :
  mean plus 0.43 times the standard deviation
  → $\mu + 0.43\sigma$
- For the lower/middle tercile boundary :
  mean minus 0.43 times the standard deviation
  → $\mu - 0.43\sigma$

Forecast probability

A Probability of Above-normal

N Probability of Near-normal

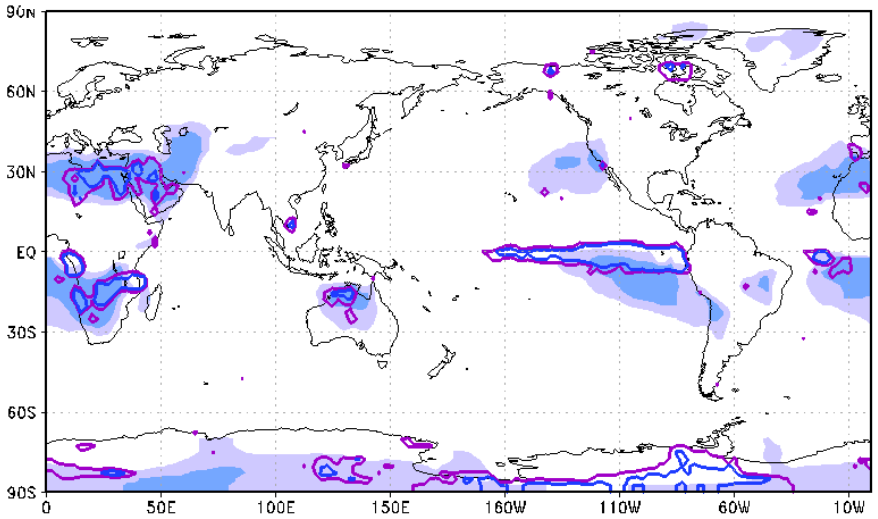
B Probability of Below-normal



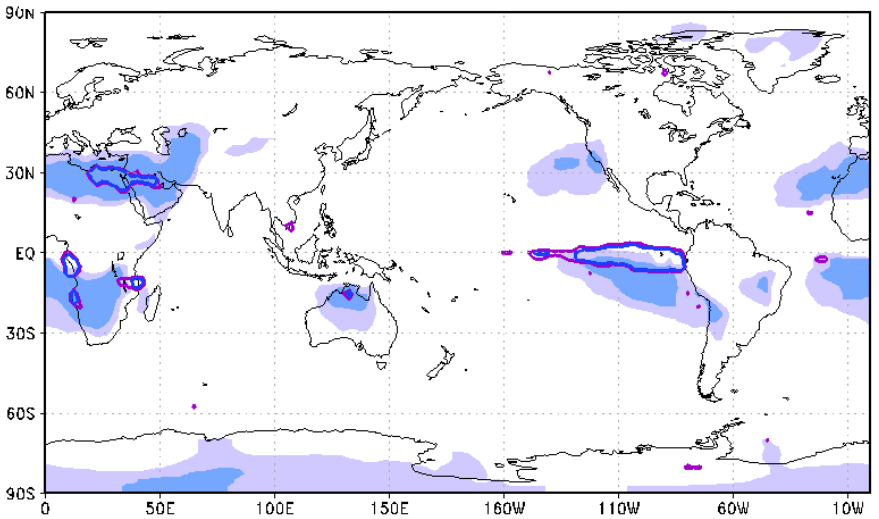
APCC PMME Method

Test for Distribution Adequacy (Summer, PREC, OBS)

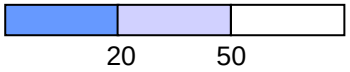
(a) Gaussian and Empirical PDF



(b) Gamma and Empirical PDF



Total Mean Precipitation (mm)



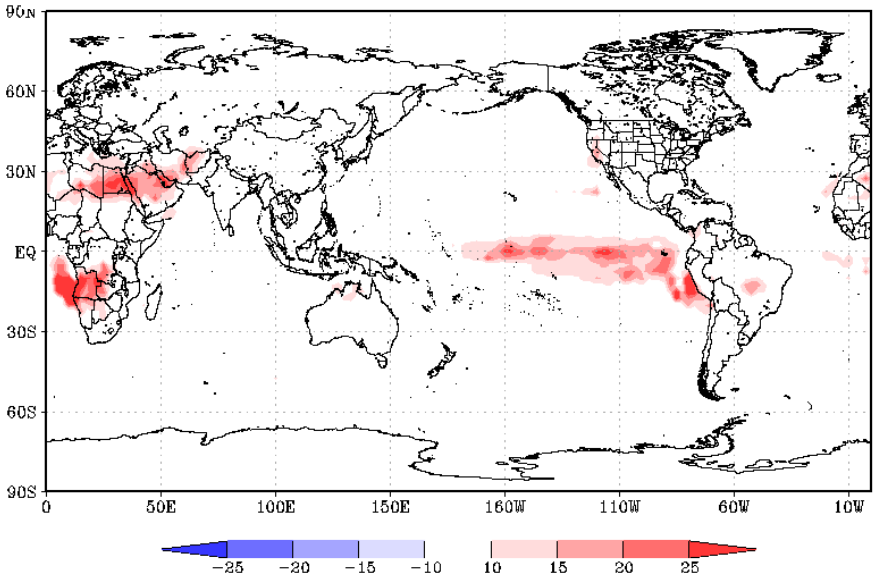
5% Significance Level
10% Significance Level

Kolmogorov-Smirnov (KS) test of goodness of fit for summer precipitation (a) Gaussian and Empirical PDF and (b) Gamma and Empirical PDF. Contours border the regions where theoretical PDF differs from Empirical PDF at 5% (blue) and 10% (pink) significance levels. Shaded are the areas where total mean precipitation less than 50mm.

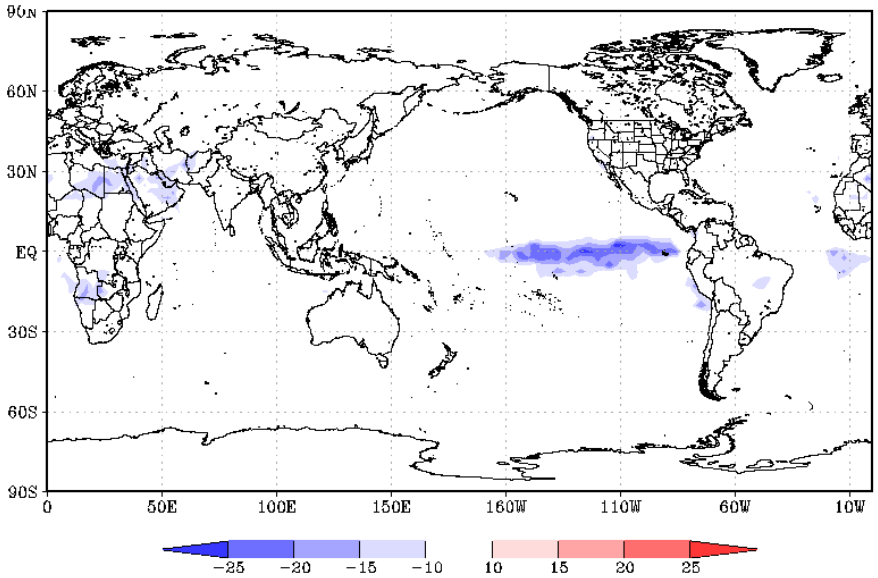
APCC PMME Method

Max. Diff. (Gamma – Normal) between Forecast Probabilities

(a) Above-Normal



(b) Below-Normal



Maximal difference (Gamma minus Gaussian) throughout 1983-2003 between in precipitation forecast probabilities estimated on the basis of Gamma and Gaussian PDFs for summer precipitation for the categories (a) above normal and (b) below normal.

Gaussian PDF for PREC

(1) Goodness-of-fit Test for Normality of Precipitation

- Empirical summer precipitation PDF does not differ significantly from Gaussian, given 21-year series size and the 5% significance level.

(2) Max. Diff. (Gamma – Normal) between Forecast Probabilities

- The possible error in forecast probability due to use of Gaussian PDF instead of gamma does not exceed 10% for the whole globe.

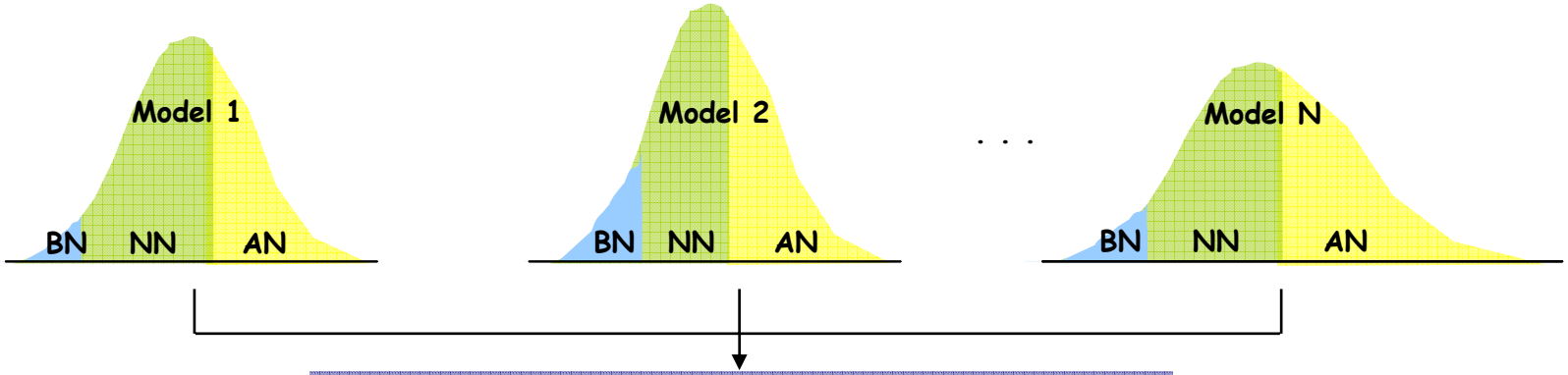
(3) Gaussian approximation-based method

- More technologically simple and less time consuming than others *(e.g., gamma fitting method, non-parametric approach etc)* that is important in operations.

→ Gaussian approximation of PREC is appropriate for most part of the globe !!!

(2) Multi-Model Combination

Combining individual model predictions



" Probabilistic Multi-Model Ensemble "

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

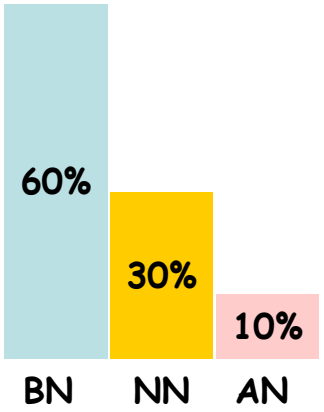
model weight **forecast probability of an event**

$$P(E) = \frac{1}{\sum_{i=1}^{M} \sqrt{n_i}} \sum_{i=1}^{M} \sqrt{n_i} P(E / Model_i)$$

→ **Weight for each model is proportional to the square root of the ensemble size of *Model*$_i$**

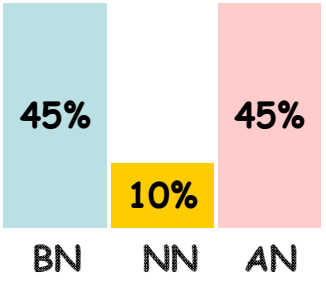
(3) Combined Map

(EX1)



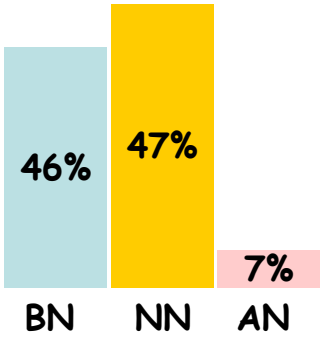
" Below Normal "

(EX2)



" ??? "

(EX3)



" Near Normal ??? "

" Chi-square Test "

$$\chi^2 = \sum_{i=1}^{k} (O_i - E_i)^2 / E_i$$

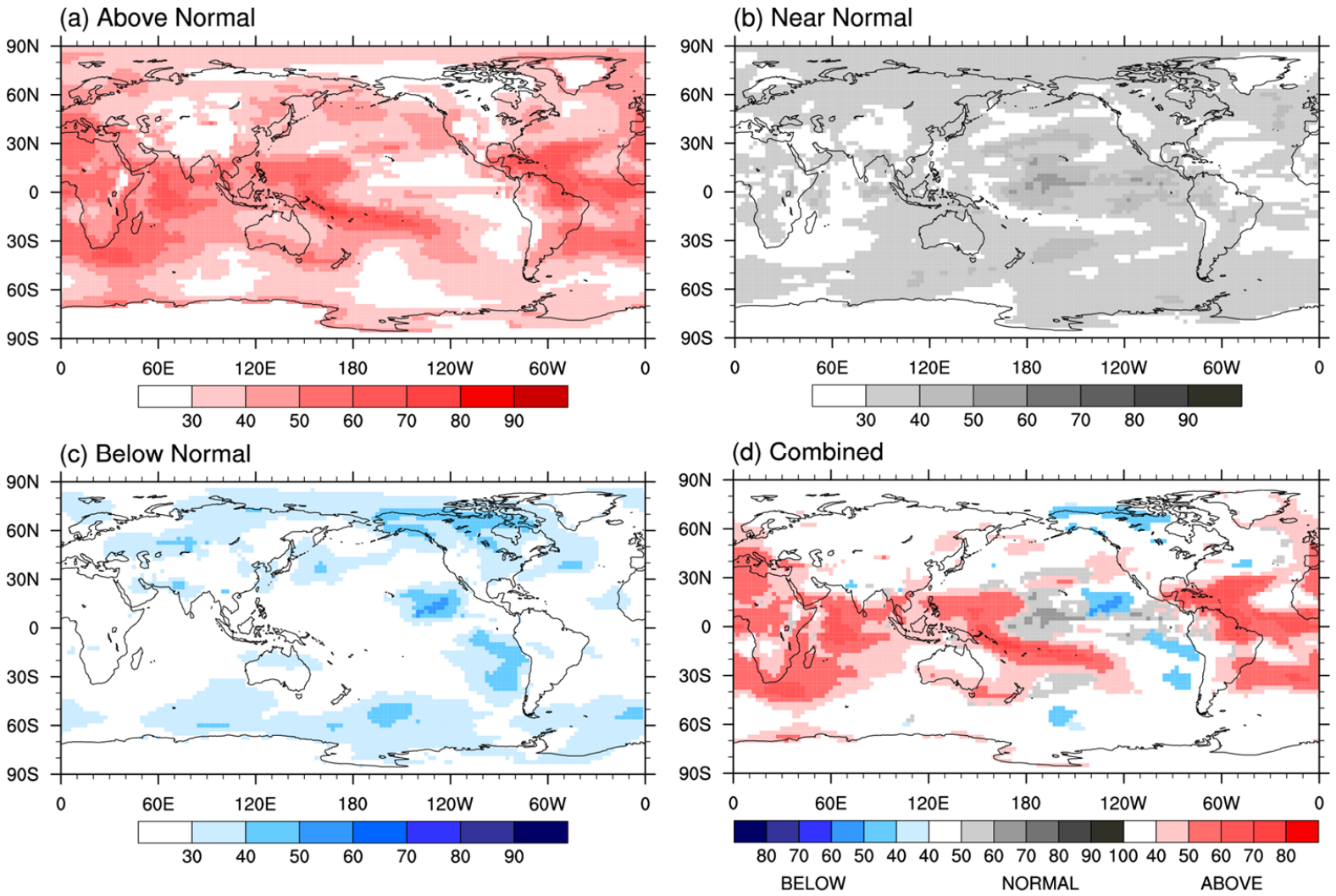
k : number of categories
O : observed frequencies in forecast
E : expected frequencies

If differences are not significant at 5% sig. level.

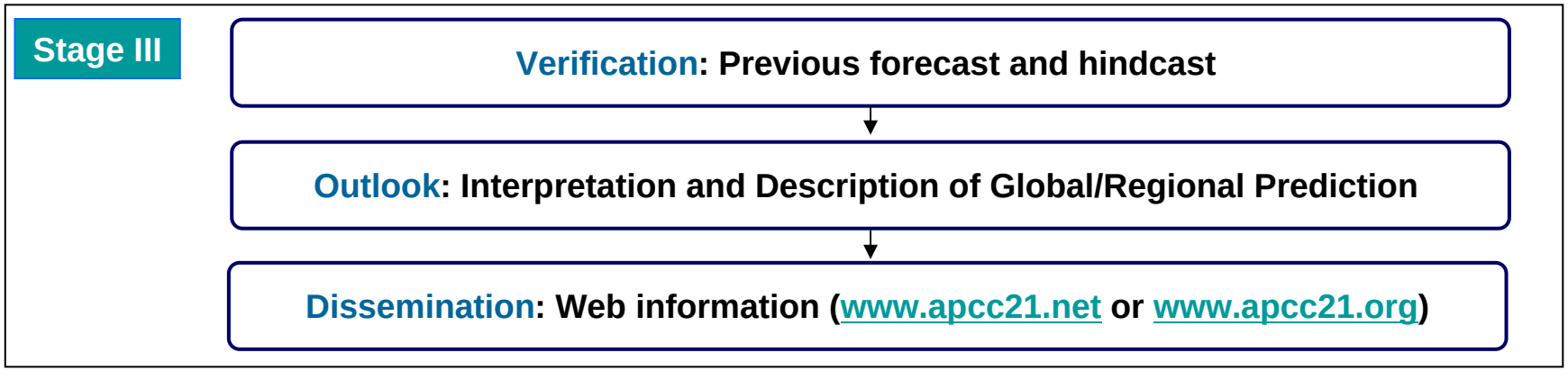
→ **UNCERTAINTY!!!!**

Probabilistic MME Forecasts

Temperature at 850hPa for 2006 JJA



Procedure of Seasonal Forecast



- **Schedule: 20th ~ 25th every month**
- **Verification: in terms of skill scores recommended by WMO SVS-LRF**
  (Standard Verification System for Long-Range Forecast)
- **Outlook: release official APCC outlook 5 days prior to the forecast period, after discussion with WG/SAC**
- **These all information can be available on the APCC web-site.**
- **Anyone can access APCC monthly global MME 3-month forecast through our website around 25th**

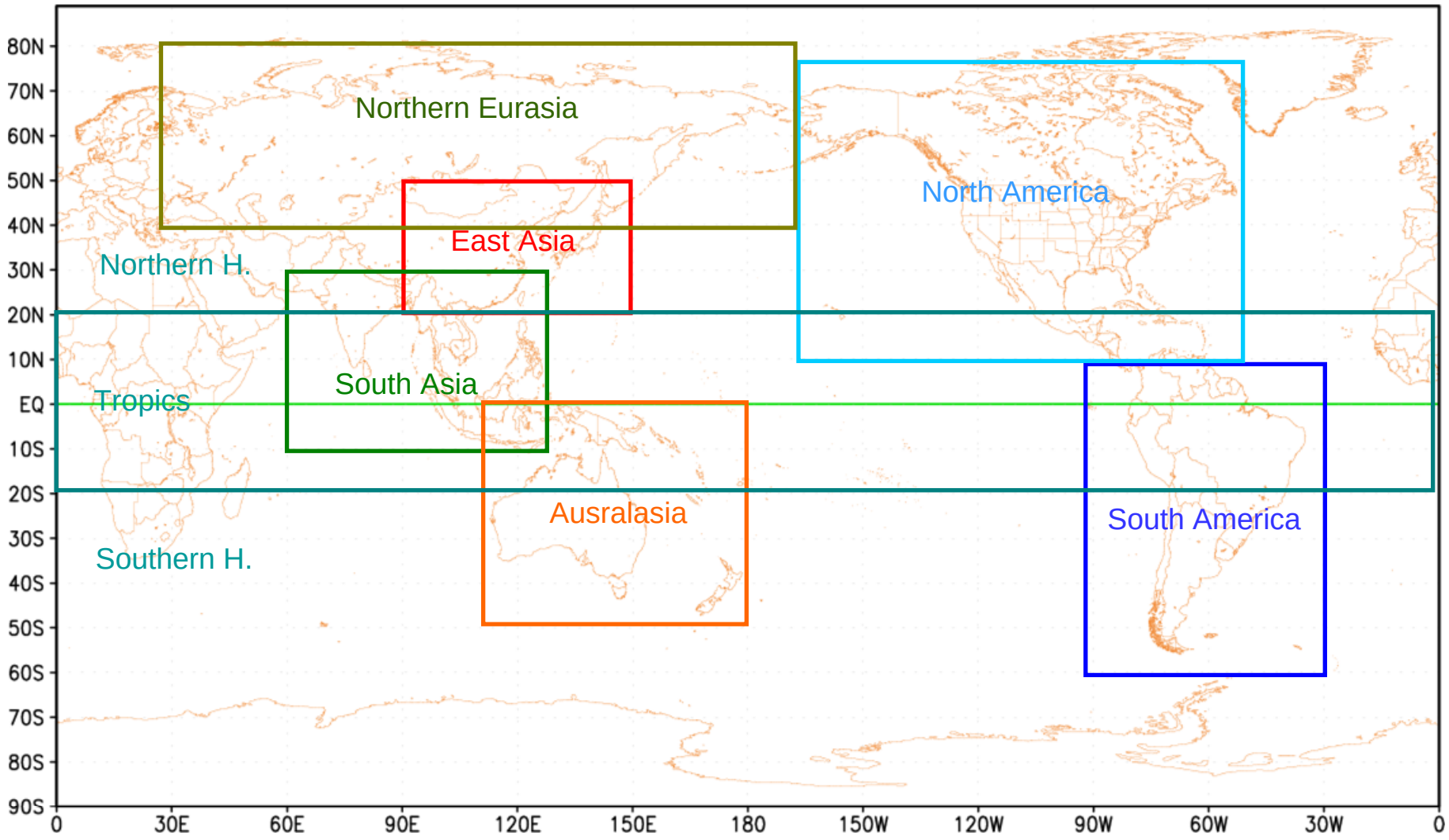
** WG: Working Group*
** SAC: Science Advisory Committee*

Upgrading of the SVS

- APCC pursues the WMO-prescribed SVS measures.
- We are upgrading our efforts of verification. We have upgraded our verification almost to level 3 suggested by WMO.

Level 1	Parameters	Verification Regions	Deterministic Forecasts	Probabilistic Forecasts
	T2m anomaly Precipitation anomaly	Tropics Northern Extra-Tropics Southern Extra-Tropics	MSSS (bulk number)	ROC curves, ROC areas Reliability diagrams Frequency histograms
	Niño3.4 Index	N/A	MSSS (bulk number)	ROC curves, ROC areas Reliability diagrams Frequency histograms
Level 2	**Parameters**	**Verification Regions**	**Deterministic Forecasts**	**Probabilistic Forecasts**
	T2m anomaly, SST anomaly Precipitation anomaly	grid point verification on a 2.5° by 2.5° grid	MSSS and its three term decomposition at each grid point	ROC areas at each grid point
Level 3	**Parameters**	**Verification Regions**	**Deterministic Forecasts**	**Probabilistic Forecasts**
	T2m anomaly, SST anomaly Precipitation anomaly	grid point verification on a 2.5° by 2.5° grid	3 by 3 contingency tables at each grid point	ROC reliability tables at each grid point

Defined Area

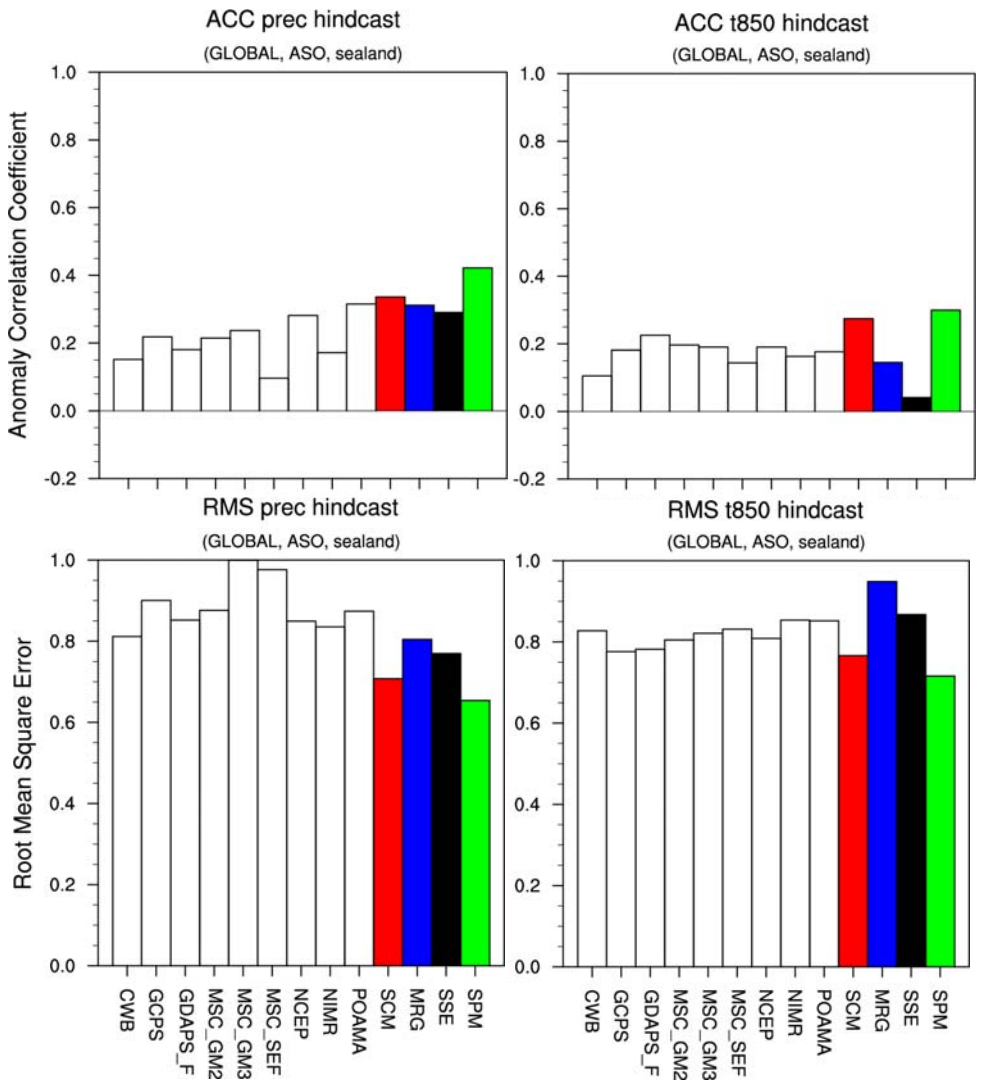


ACC and RMSE

Prec **T850**

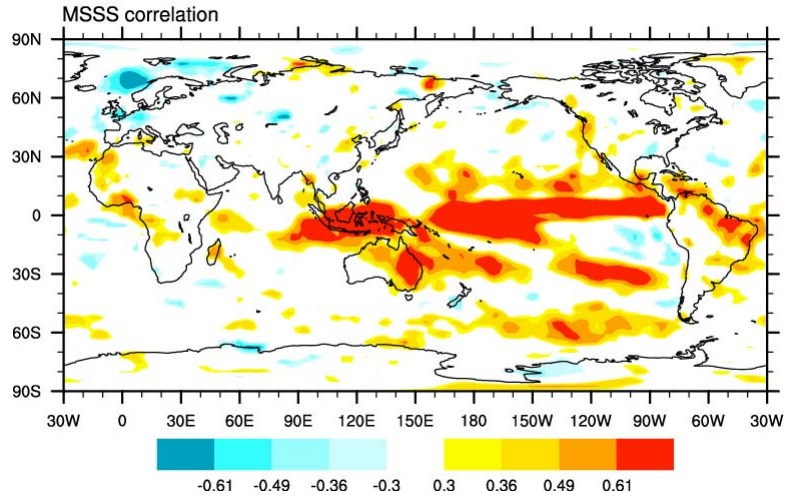
ACC

RMSE

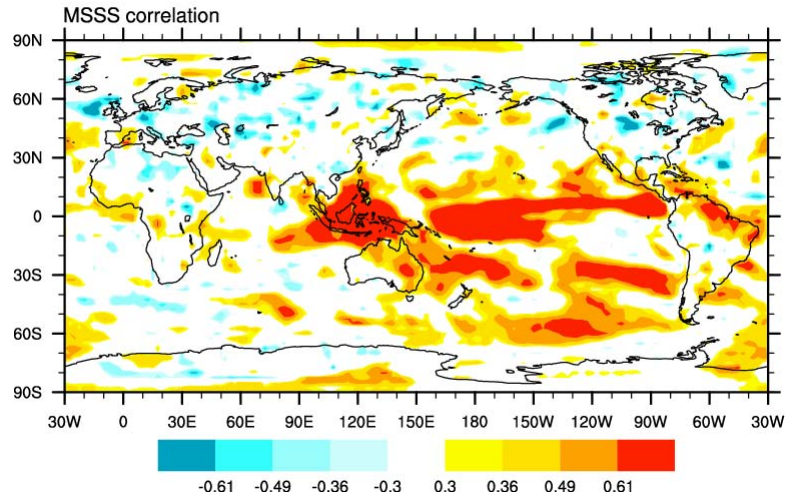


MSSS correlation (Prec)

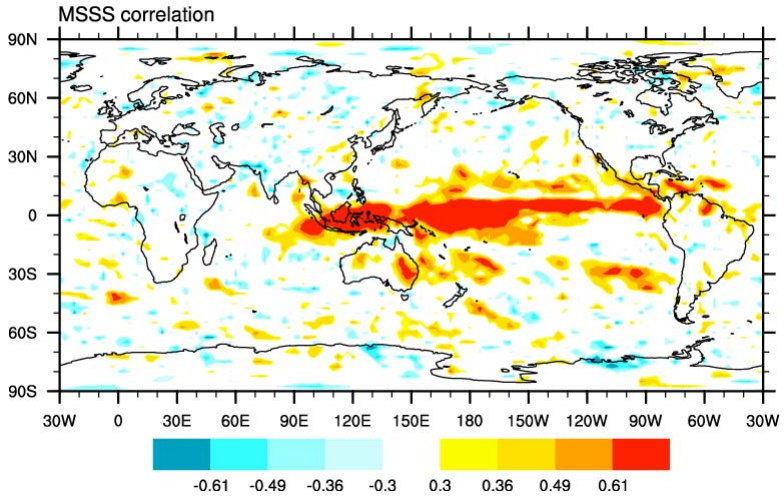
SCM



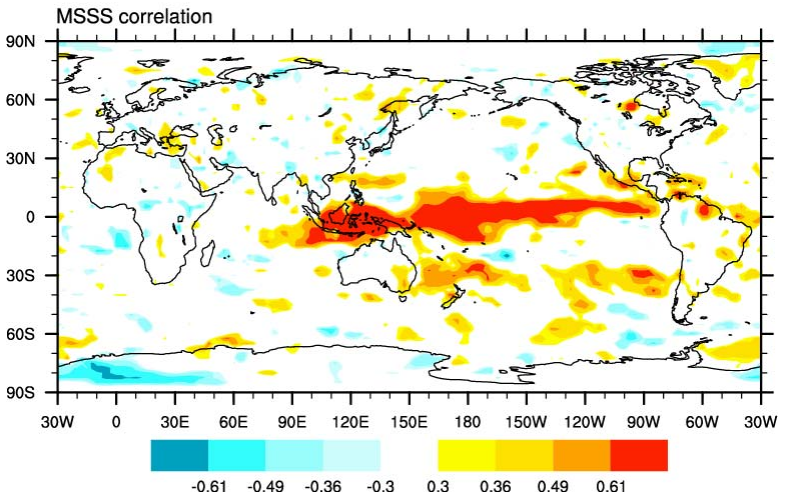
SPM



MRG

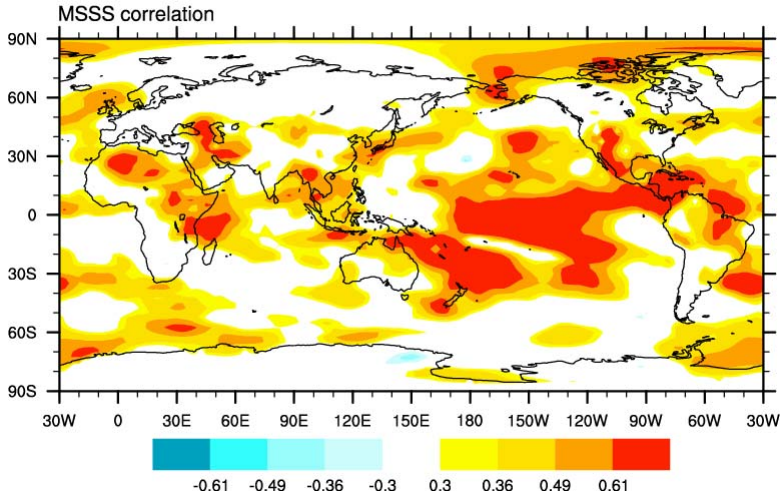


SSE

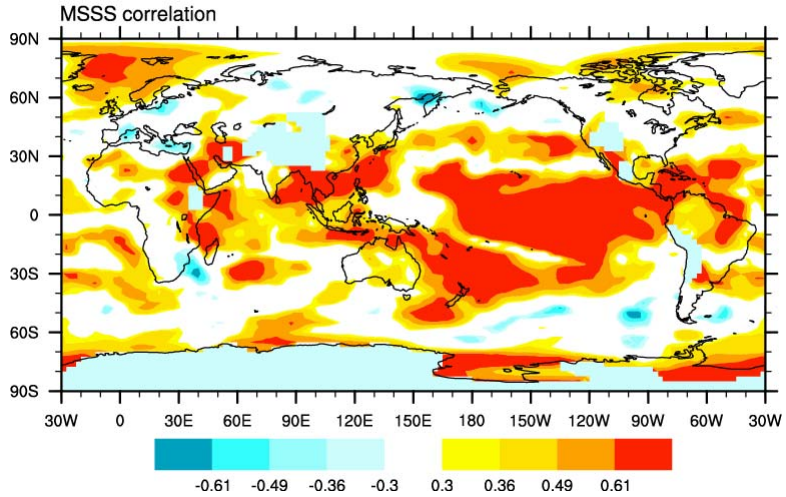


MSSS correlation (T850)

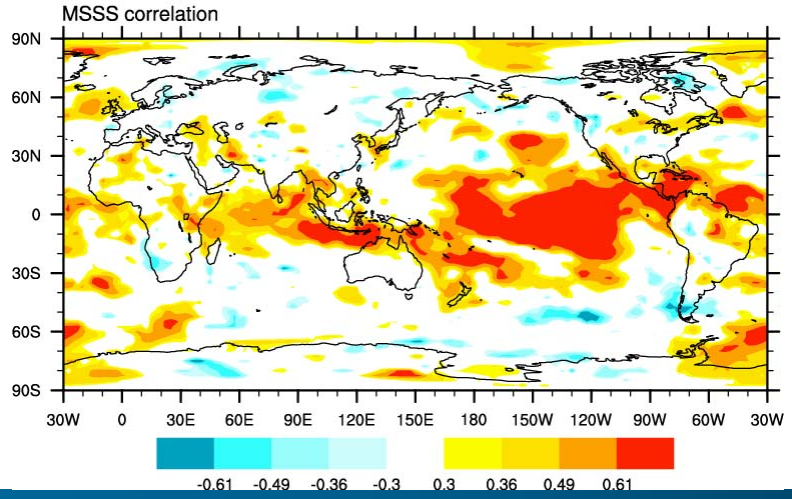
SCM



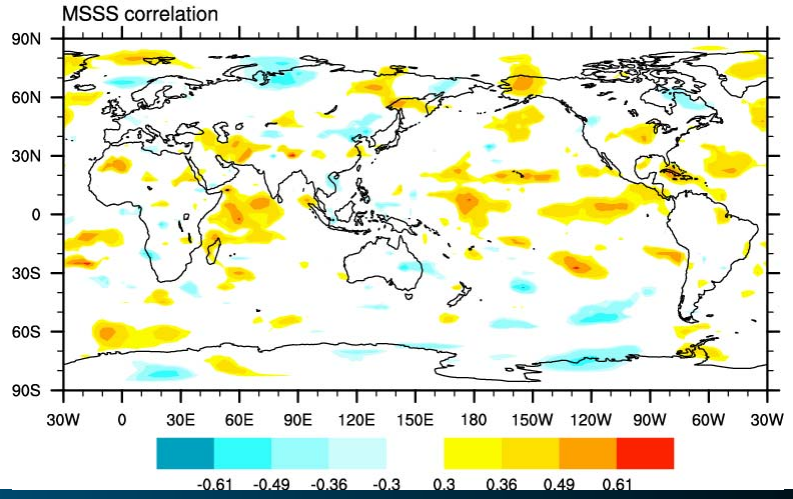
SPM



MRG

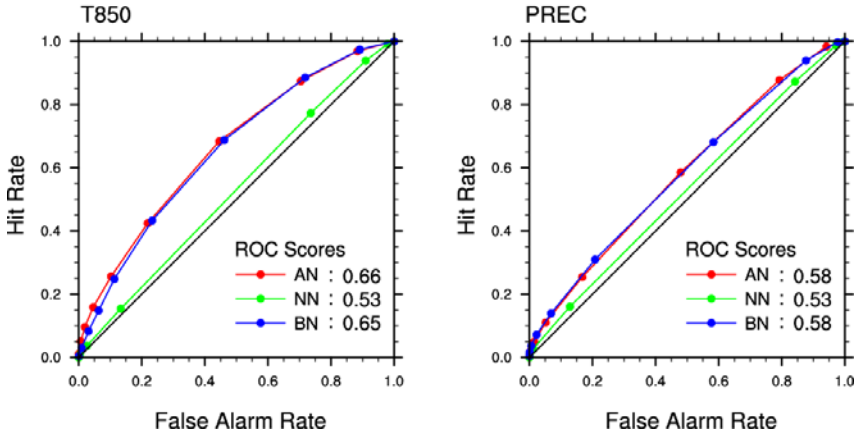


SSE

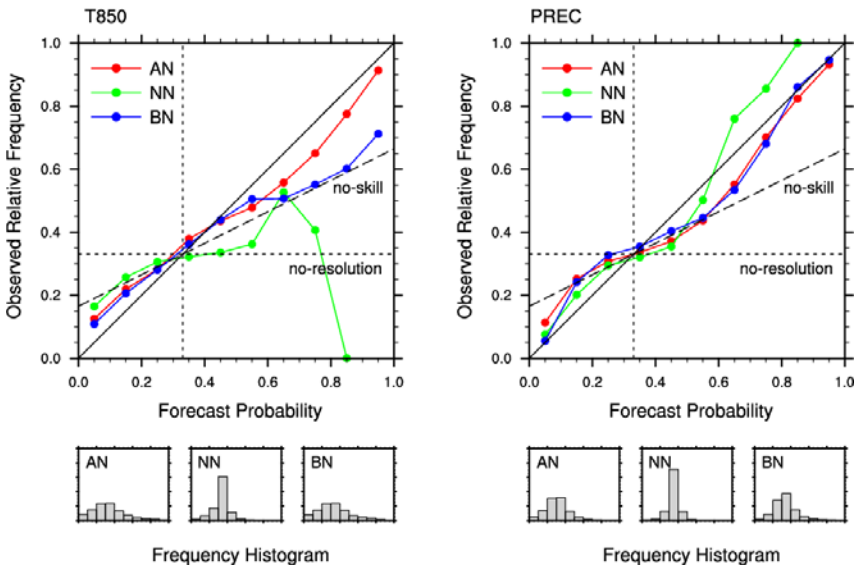


ROC Curve and Reliability Diagram

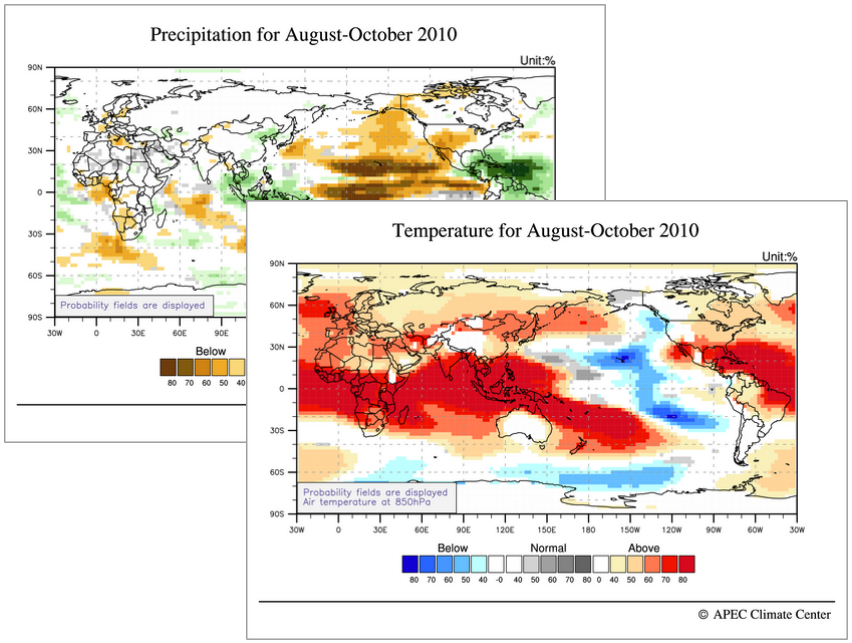
ROC Curve : ASO (1981-2003)



Reliability Diagram : ASO (1981-2003)



Forecast graphics and Outlook



- Interpretation and description of global and regional prediction are made depending on the above forecasts
- These forecast information are uploaded in APCC website, and sent out by 25th of each month to 21 NMHSs and larger climate prediction community

The APEC CLIMATE CENTER
Climate Outlook for August-October 2010

BUSAN, 26 July 2010 - Synthesis of the latest model forecasts for August-October 2010 at the APEC Climate Center (APCC), located at Busan, Korea, indicates above normal rainfall over Southeast Asia adjoining eastern Australia and southern Polynesian Islands, equatorial Latin America, the Florida key region and the tropical Atlantic Ocean. Suppressed rainfall is predicted over the central to eastern Pacific and south east Pacific adjoining the southern South America. Above normal temperature is predicted over most of the Globe while below-normal temperature is expected in the central to eastern Pacific regions.

Current Climate Conditions

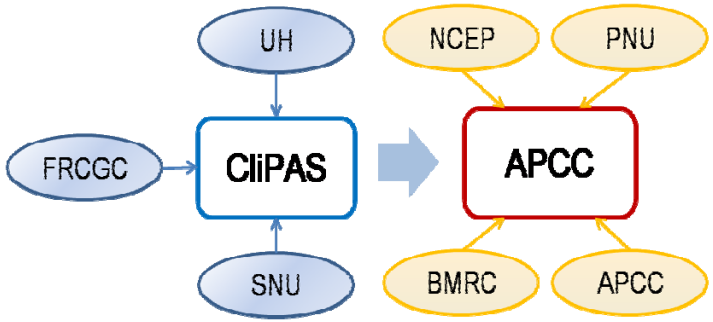
During the period from May through the first half of July 2010, anomalously warm conditions were found over the Arctic, Eastern Europe, Middle East, central Asia, eastern Eurasia, Alaska, and eastern North America. Warm anomalies were also observed over northwestern and southeastern parts of Africa, central India and the north-to-central part of Brazil. On the other hand, cold anomalies were observed over a few places of African continent, Western Europe, western Russia, Australia, western USA, south part of South America and the eastern Pacific Ocean. The monthly patterns of May and June are similar to the seasonal one. In the first half of July, there was warm condition in northern Australia while the climate condition in most of Africa, Indian subcontinent and the eastern Pacific Ocean was colder than ……..

Forecast

Seasonal Temperature Outlook:
The APCC forecast for August-October 2010 indicates persistent warm conditions over most of the Globe, including Africa, Eurasia, North America and Maritime Continent adjoining northern Australia and Polynesian regions, and most of the Indian and Atlantic Oceans. Below-normal temperature is expected in the central to eastern Pacific. The central Australia, the western edge of North America, and northern South America may experience slightly colder-than-normal conditions. (The monthly pattern of individual months of August, September and October …..

APCC Homepage (www.apcc21.org)

6-Month 1-Tier MME Prediction



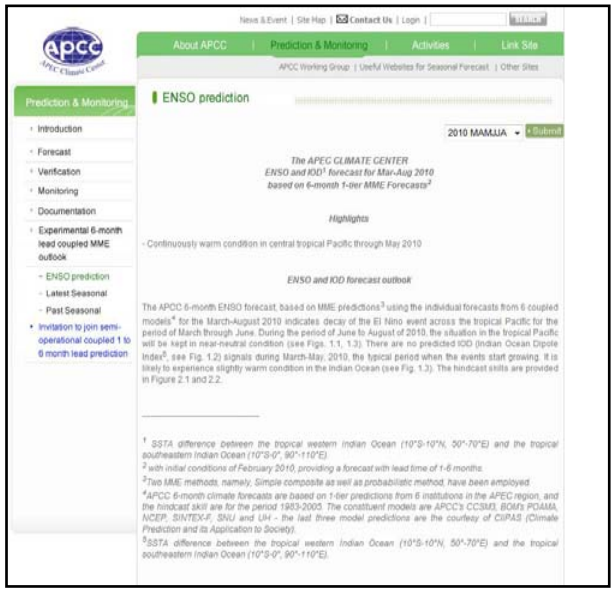
Experimental 6-month Coupled MME Prediction

- 6-month forecasts and hindcasts four times an year (NCEP, BMRC, PNU, FRCGC, UH, SNU and APCC models)
- Forecast and hindcast verification carried out every season since the fall of 2008.
- Experimental 1-6 month lead climate bulletin launched since spring 2009.
- 1-6 month lead ENSO and IOD prediction

* CliPAS: Climate Prediction and Its Application to Society

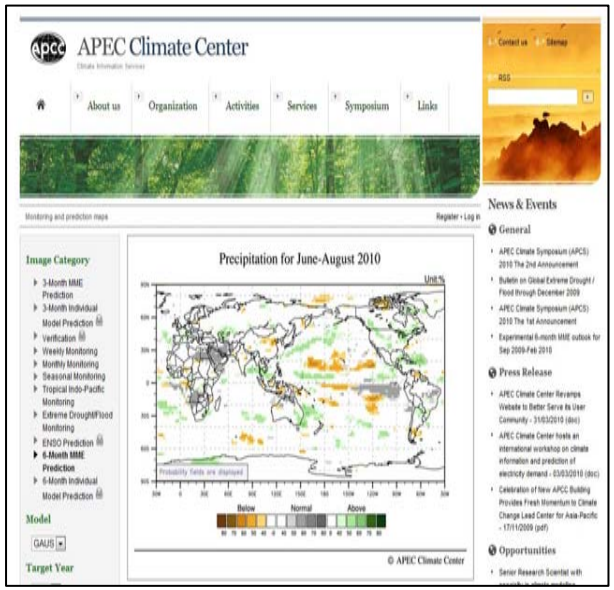
◆ Web Distribution of Climate Outlook for 6-month MME Forecast

Old version

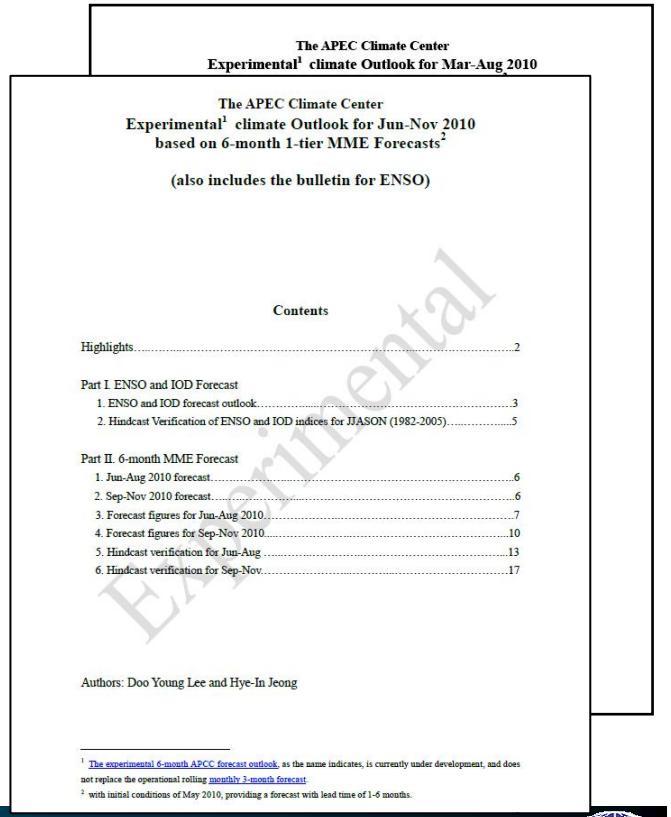


http://www.apcc21.net/climate/climate05_03.php

New version



http://www.apcc21.org/en/services



The APEC Climate Center
Experimental[1] climate Outlook for Mar-Aug 2010

The APEC Climate Center
Experimental[1] climate Outlook for Jun-Nov 2010
based on 6-month 1-tier MME Forecasts[2]

(also includes the bulletin for ENSO)

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6. Hindcast verification for Sep-Nov 17

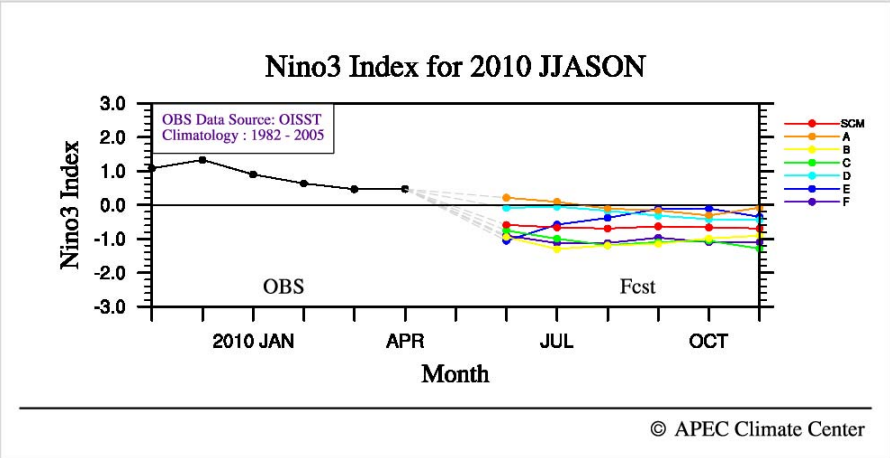
Experimental

Authors: Doo Young Lee and Hye-In Jeong

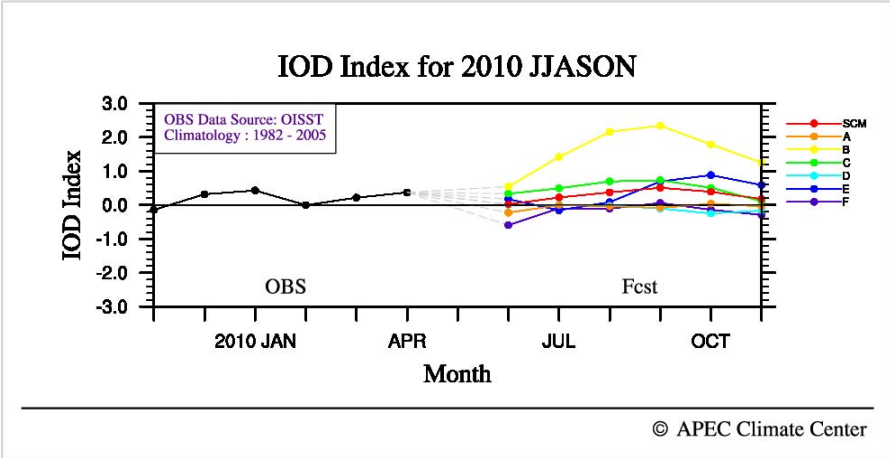
[1] The experimental 6-month APCC forecast outlook, as the name indicates, is currently under development, and does not replace the operational rolling monthly 3-month forecast.
[2] with initial conditions of May 2010, providing a forecast with lead time of 1-6 months.

6-Month 1-Tier MME Prediction

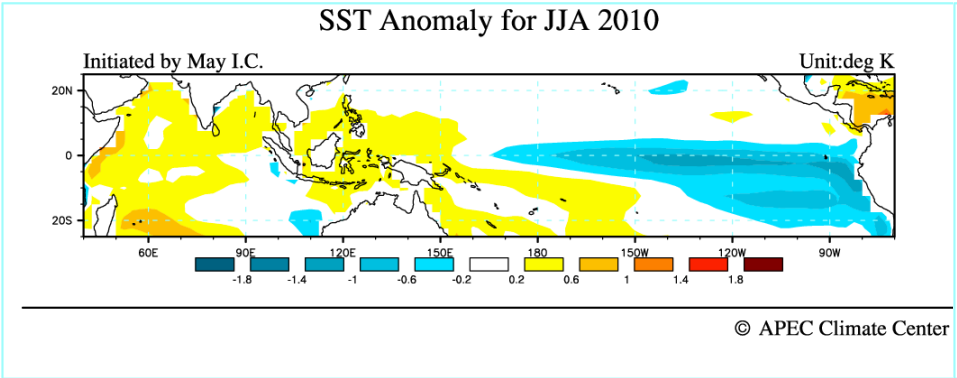
Predicted Niño3 Index

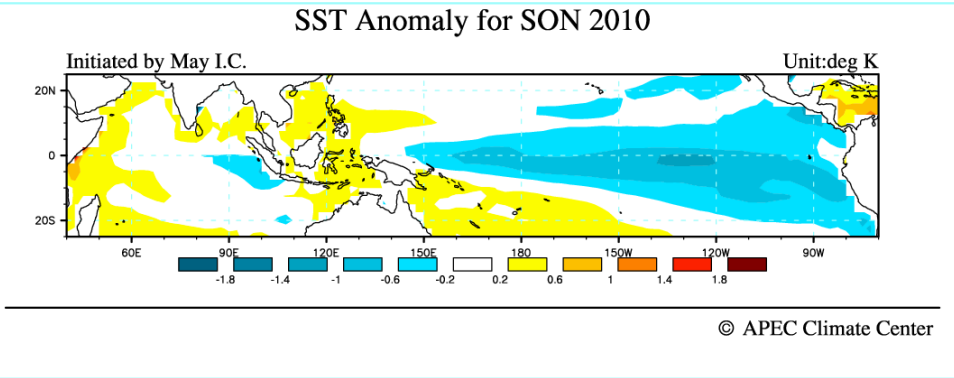


Indian Ocean Dipole mode index



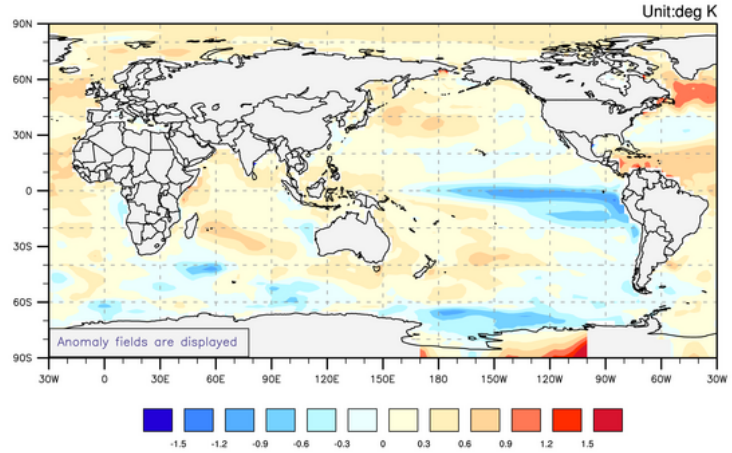
Spatial distributions of forecasted SST Anomalies (SCM) over the tropical Indo-Pacific



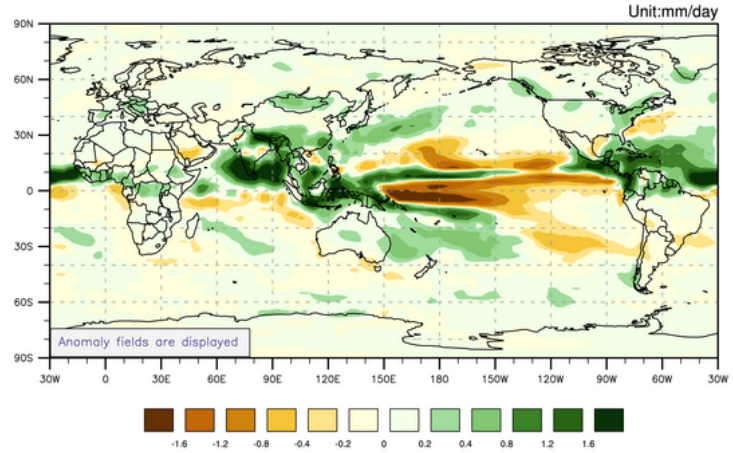


6-Month 1-Tier MME Prediction (JJASON)

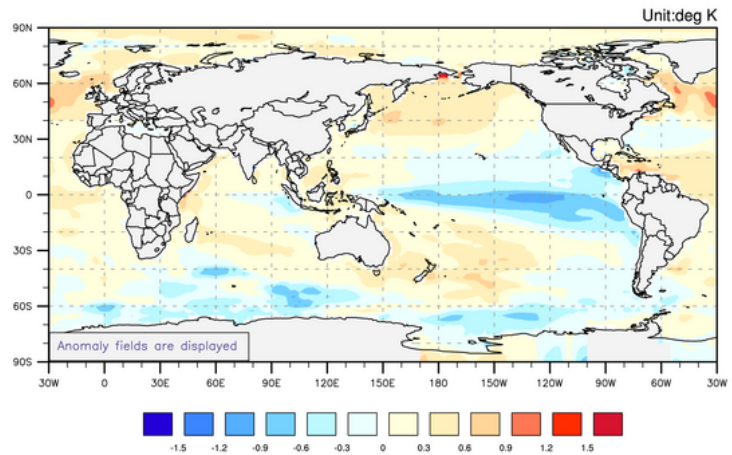
Sea Surface temperature for June-August 2010



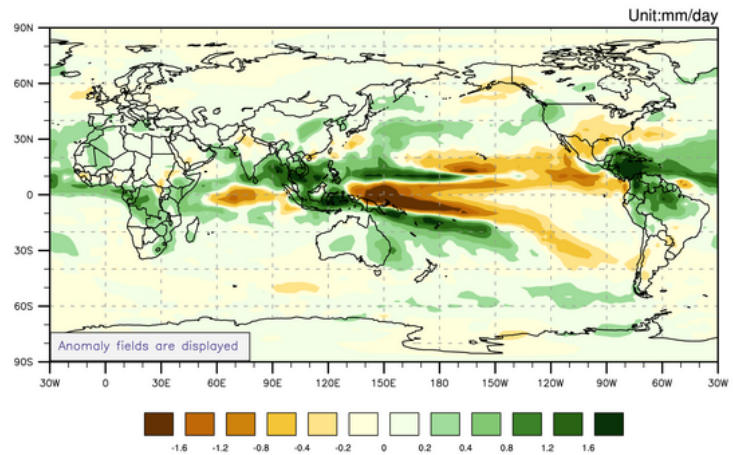
Precipitation for June-August 2010



Sea Surface temperature for Sepember-November 2010



Precipitation for Sepember-November 2010



APCC Forecast Outlook

- The forecast outlook is available at
  http://www.apcc21.net or http://www.apcc21.org.

- To subscribe it, please contact
  Dr. R. H. Kripalani (krip@apcc21.net), Soo-Jin Sohn (jeenie7@apcc21.net)
  and Young-Mi Min (ymmin@apcc21.net)

- We hope that the above information is of use to you,
  and would appreciate any suggestions and comments.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야경투시도
Thank You
APEC Climate Center
(http://www.apcc21.net)
주경투시도