



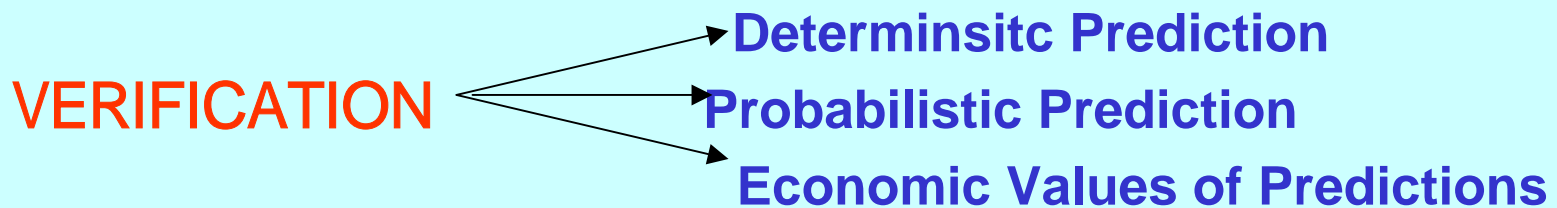
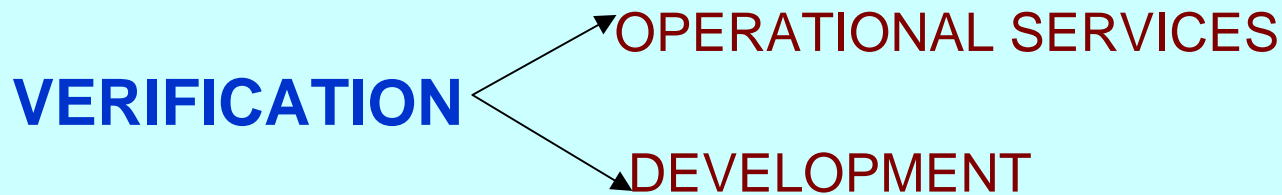
The Verification System for Multi-Model Ensemble Seasonal Predictions at APCN

Sarat C. Kar¹, Hongwen Kang¹, Anahit Hovsepyan¹,
W.T. Yun² and C.K. Park²

¹APCN Secretariat,

²Korea Meteorological Administration,
Seoul, Korea

APCN MULTI-MODEL ENSEMBLE PREDICTION SYSTEM



Verification Statistics for Hindcast Data & for Predictions

Idea at APCN:

Development of a Verification Procedure as per WMO (CBS) Requirement, in addition, develop our own Diagnostic Strategy

Develop Procedures to utilize the Lessons learnt from Verification to Improve APCN MME Prediction

WMO CBS: SVS for Long-range Forecasts

It is recommended that three levels of verification be done:

Level 1: Large scale aggregated overall measures of forecast performance (MSSS)

Tropics: from 20°S to 20°N all inclusive.

Northern Extra-Tropics: from 20°N to 90°N, all inclusive.

Southern Extra-Tropics: from 20°S to 90°S, all inclusive.

Level 2: Verification at grid points

MSSS and its three decomposed terms,

Mean & Variance of Observation and Forecasts

Correlation of Observation and Forecasts

Level 3: Grid point by grid point Contingency Tables for more extensive verification

On 2.5x2.5 degrees Grid

Development of APCN Standardized Verification Procedure

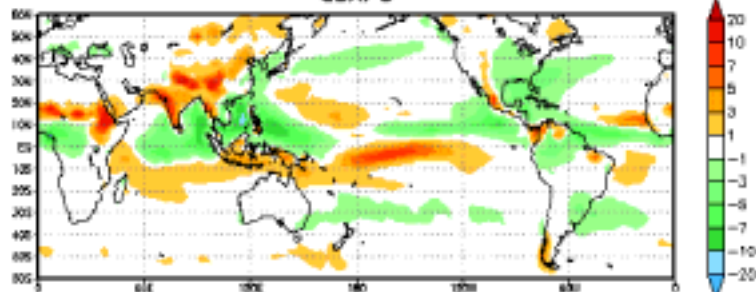


- Development of a Generalized Program
- Development of a Generalized Shell Script
- Works for any Model & for any Variable
- Model Output Structure is Provided from Outside,
So the Verification Program is not changed.

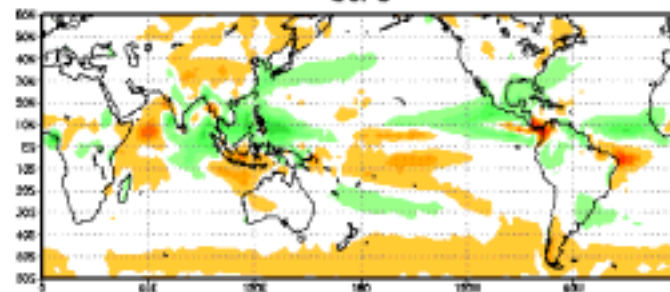
Verification Code is written such that new Verification parameters e.g. Probability Skill etc. can be added on to it

BIAS Precip. JJA Hindcast (1979-1999)

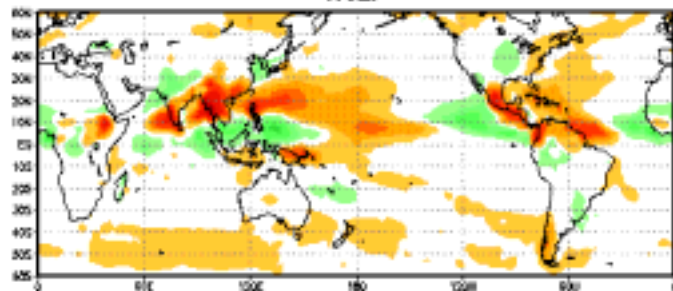
GDAPS



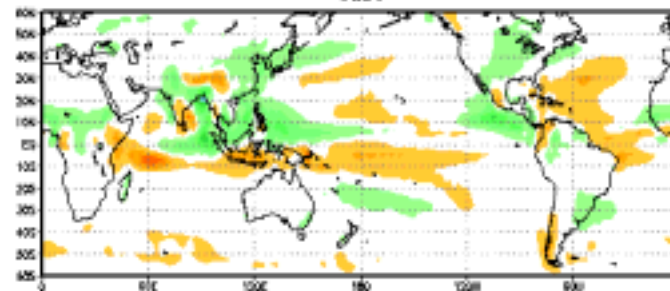
GCPS



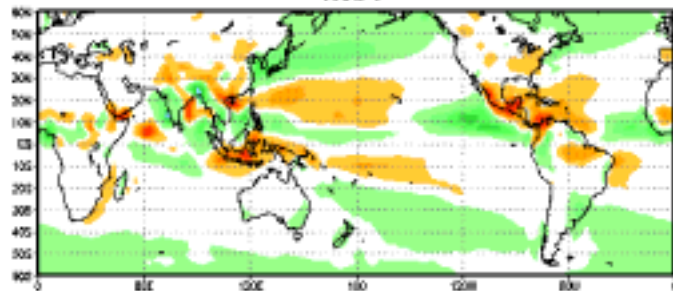
NCEP



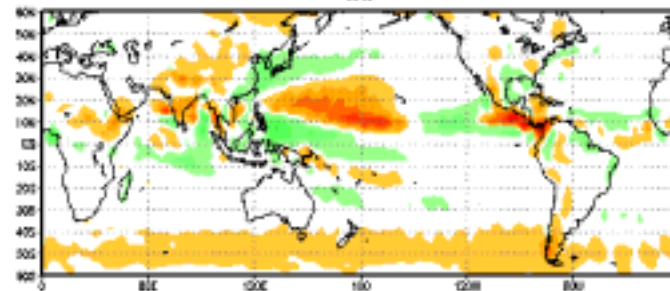
JMA



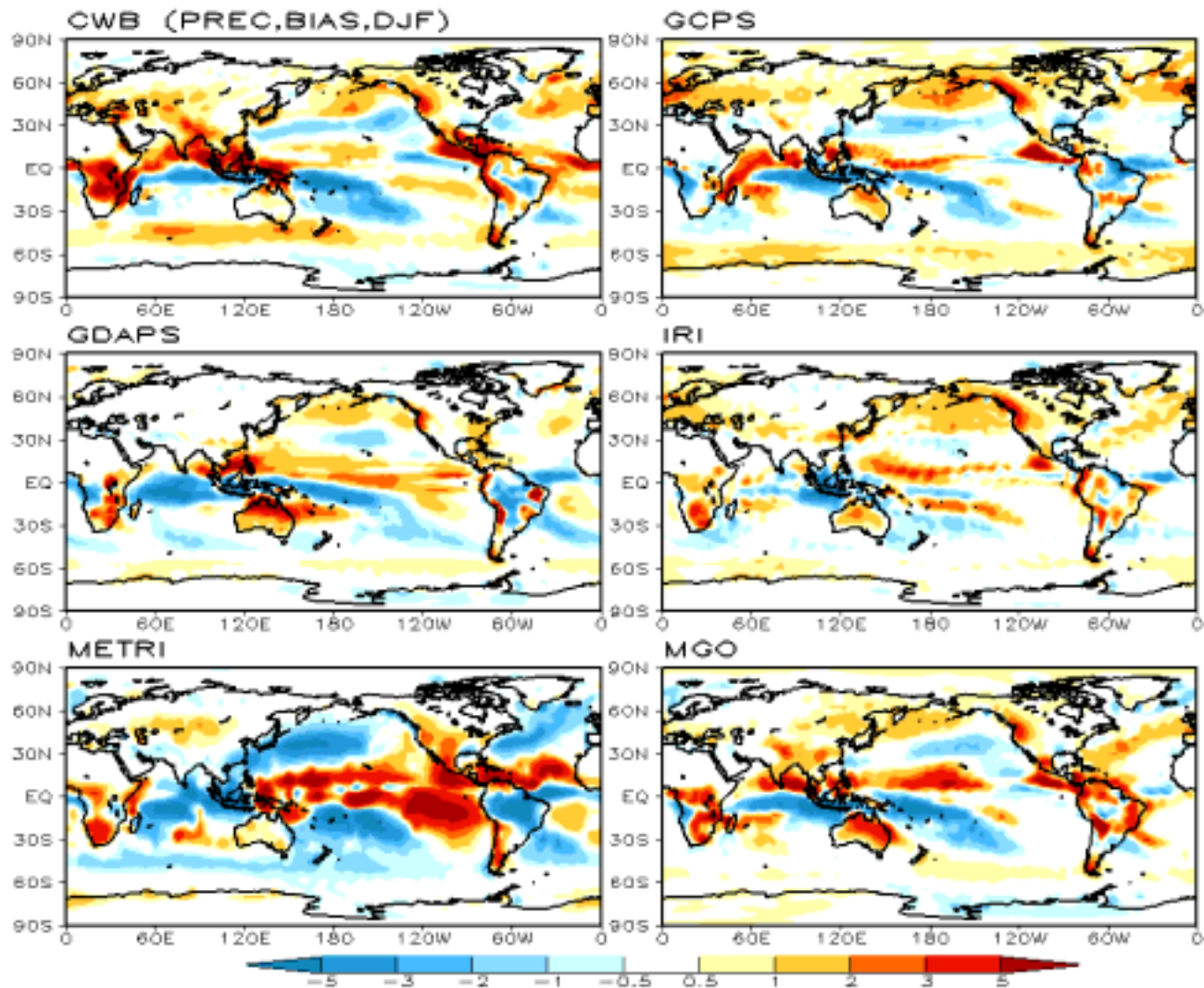
NSIPP



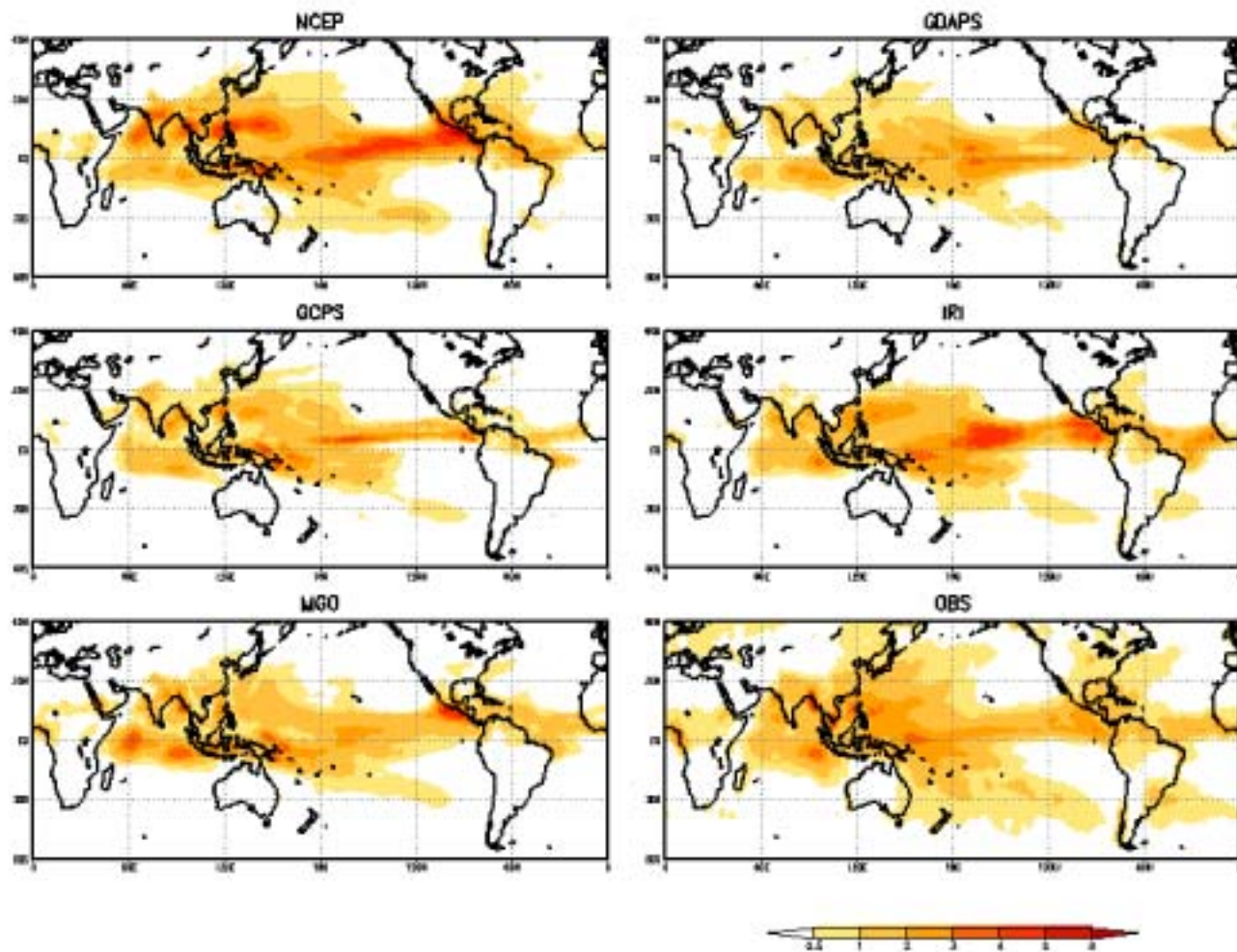
IRI



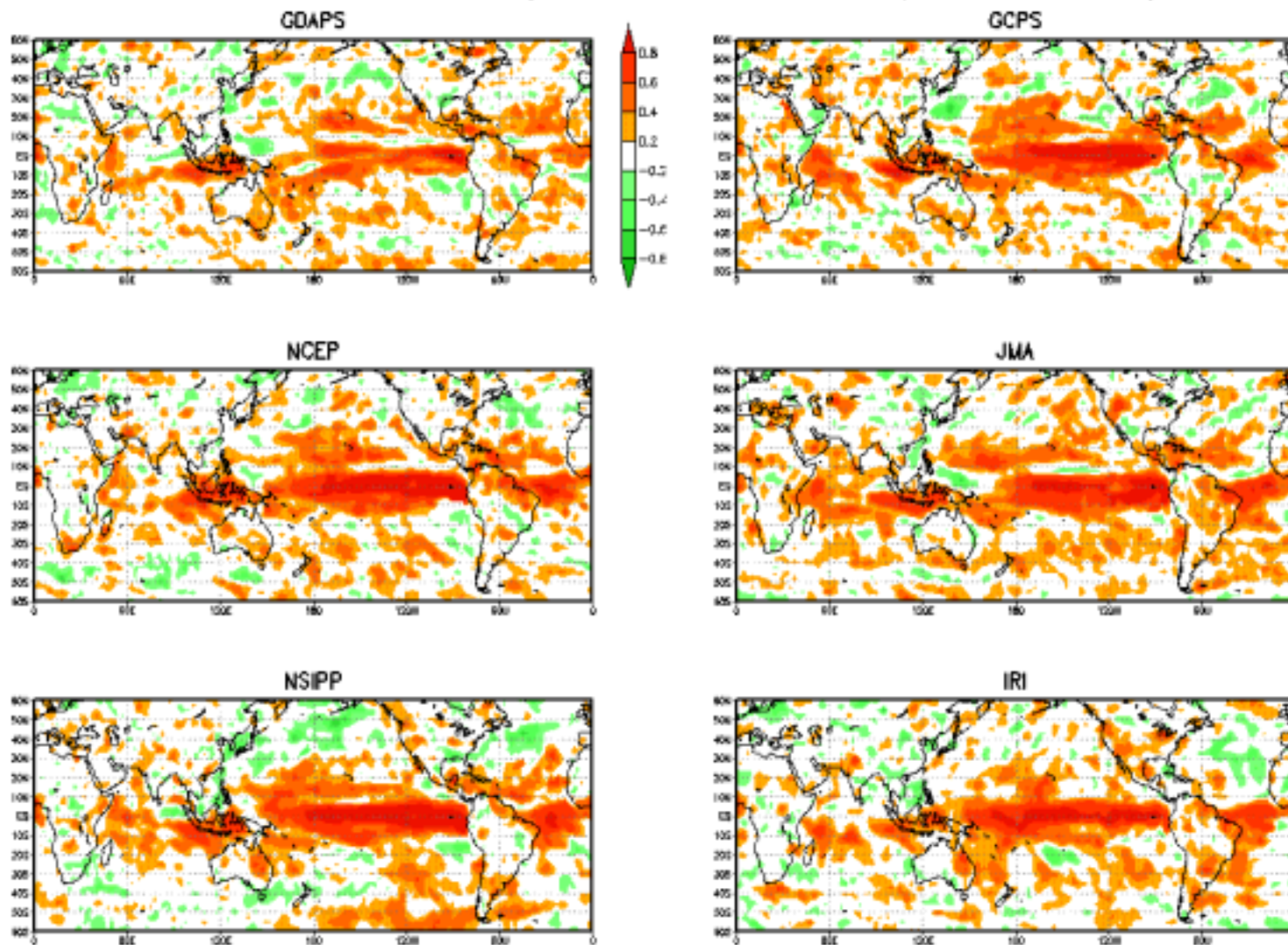
BIAS PRECIP DJF



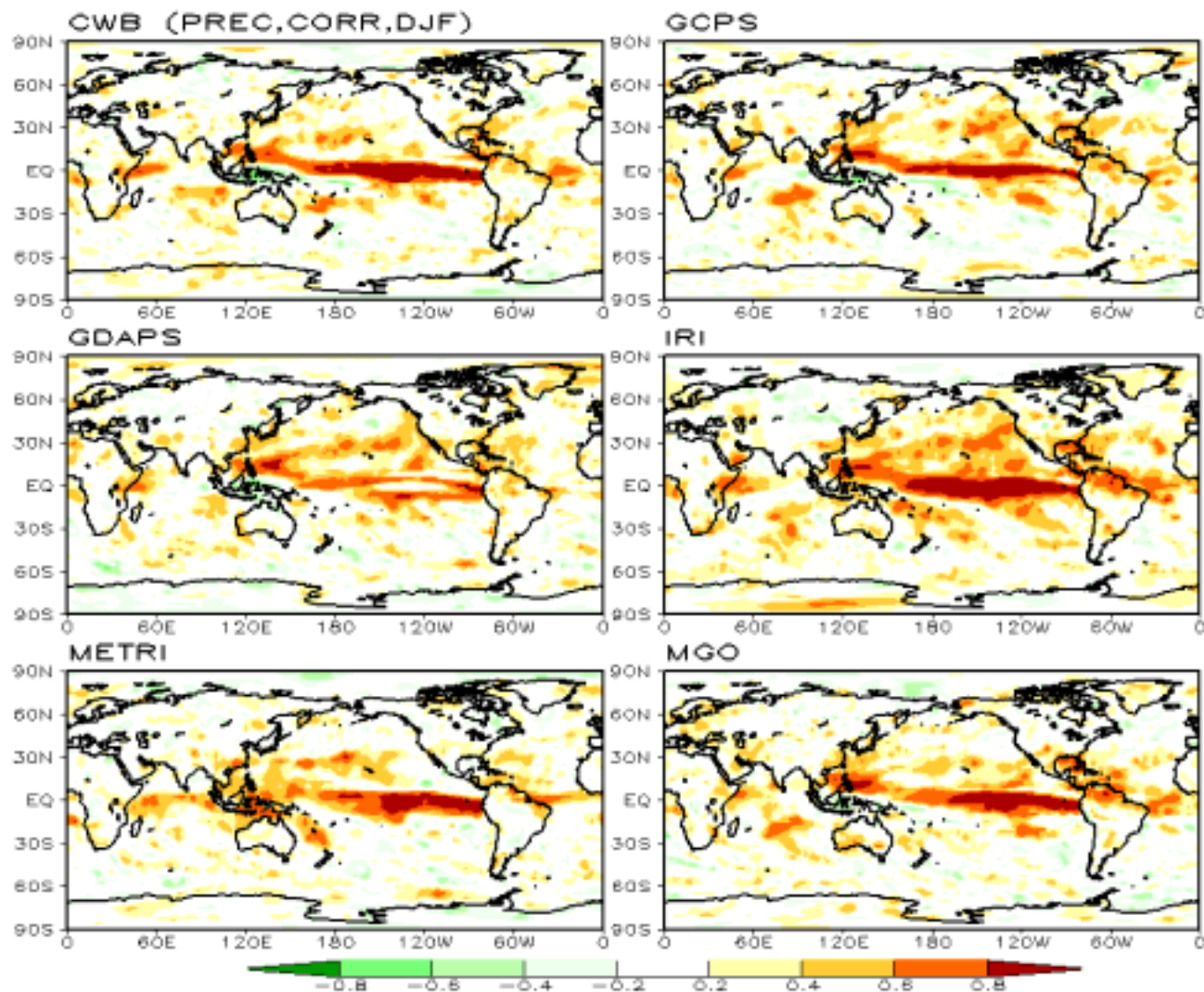
Inter-Annual Variability (Std. Dev) Precip. JJA



Correlation Precip. JJA Hindcast (1979–1999)

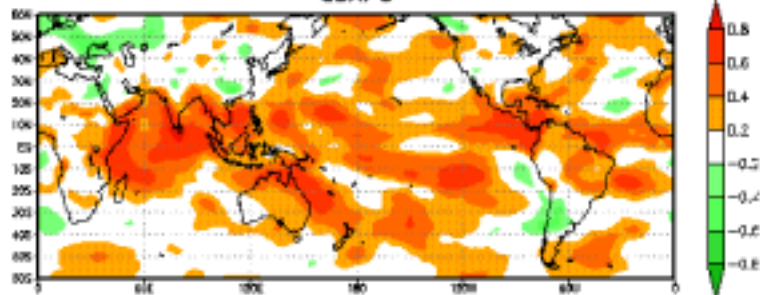


CORR PRECIP DJF

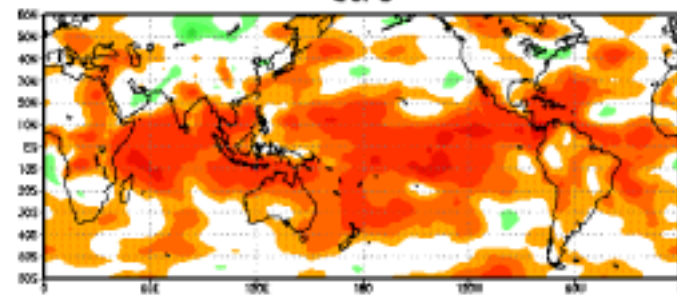


Correlation T850 JJA Hindcast (1979–1999)

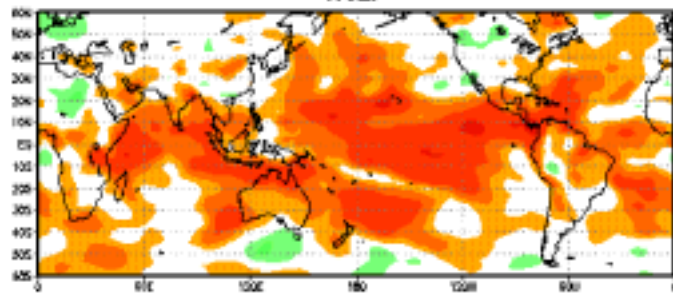
GDAPS



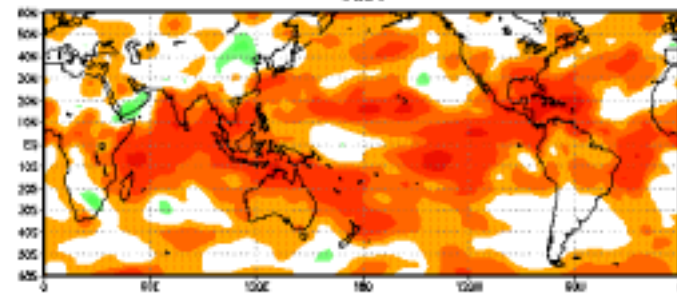
GCPS



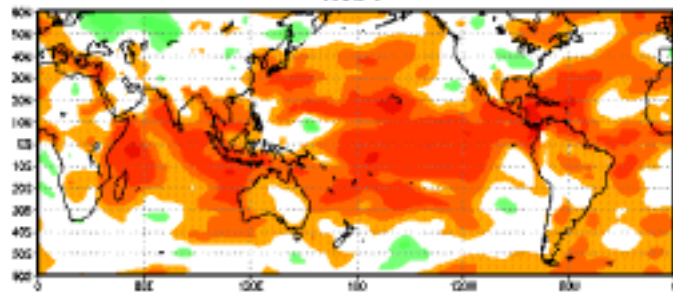
NCEP



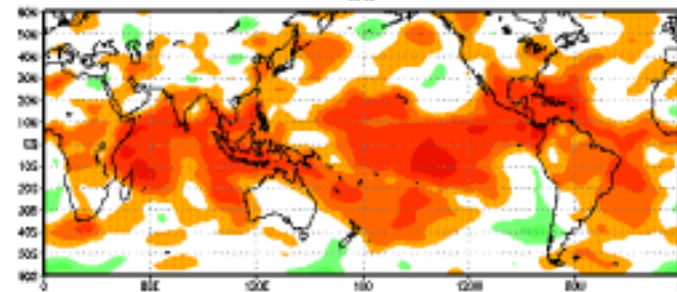
JMA



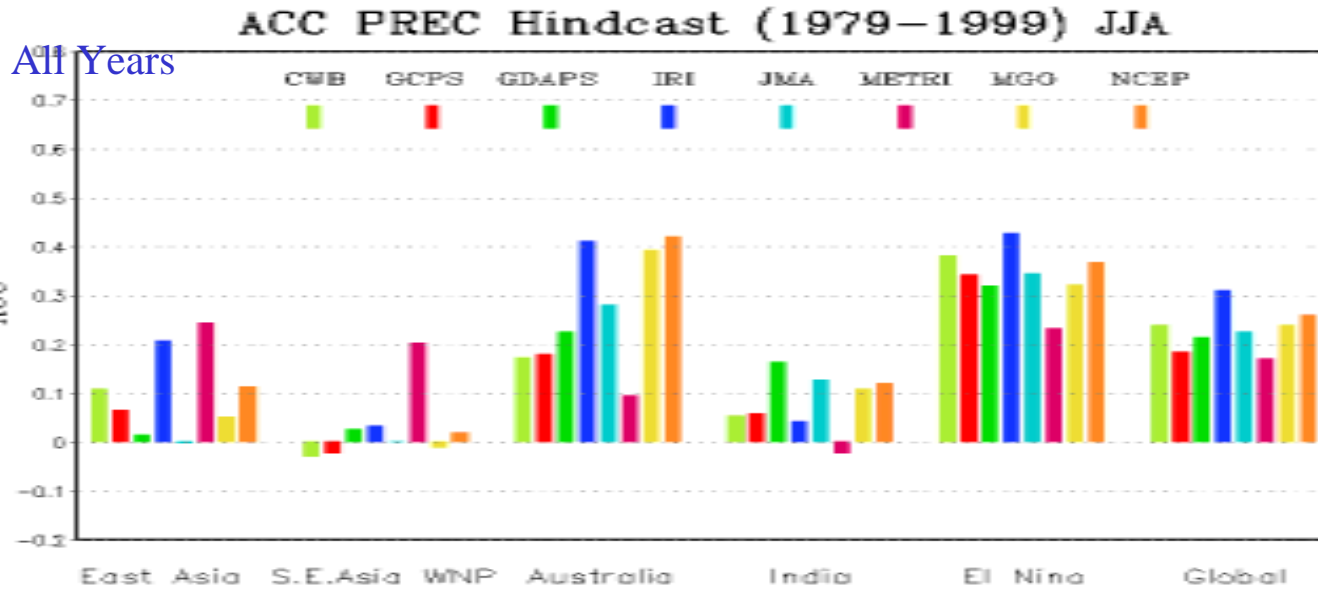
NSIPP



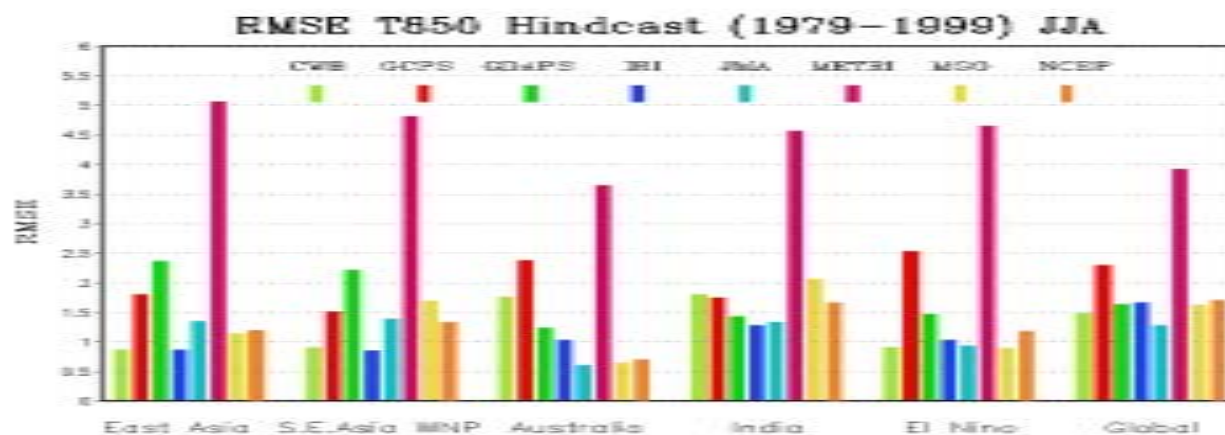
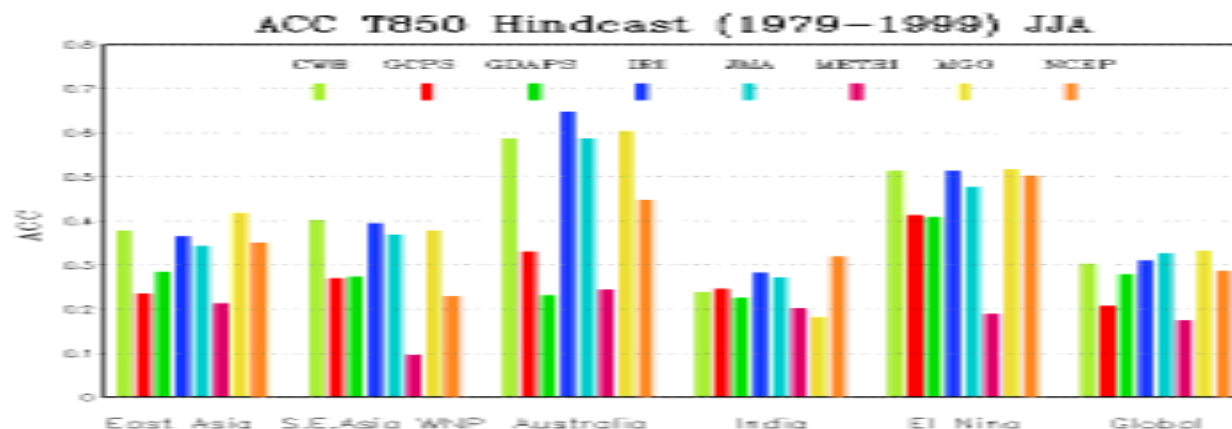
IRI



ACC PRECIP JJA

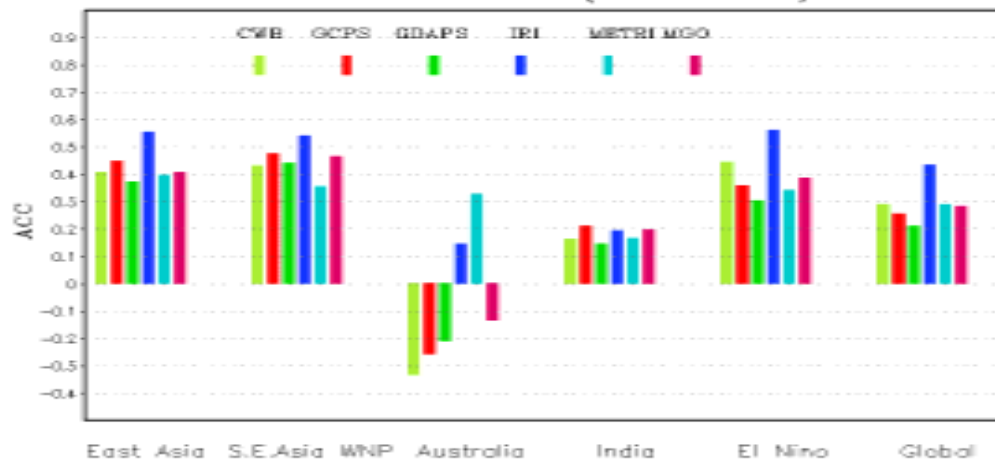


ACC & RMSE for T850 JJA

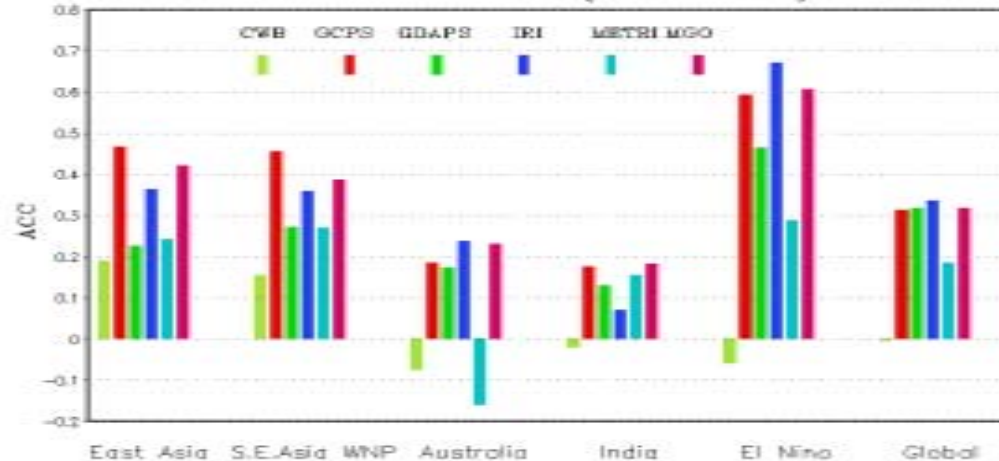


ACC PRECIP DJF

ACC PREC Hindcast (1979–1999) DJF



ACC T850 Hindcast (1979–1999) DJF



Let x_{ij} and f_{ij} ($i=1, \dots, n$) denote time series of observations and continuous deterministic forecasts respectively for a grid point or station j over the period of verification (POV).

The mean squared error of the forecasts is:

The mean squared error of 'climatology' forecasts (Murphy, 1988) is:

The Mean Squared Skill Score (MSSS) for j is defined as one minus the ratio of the squared error of the forecasts to the squared error for forecasts of 'climatology':

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^n x_{ij}, \bar{f}_j = \frac{1}{n} \sum_{i=1}^n f_{ij}$$

$$s_{xj}^2 = \frac{1}{n} \sum_{i=1}^n (x_{ij} - \bar{x}_j)^2, s_{fj}^2 = \frac{1}{n} \sum_{i=1}^n (f_{ij} - \bar{f}_j)^2$$

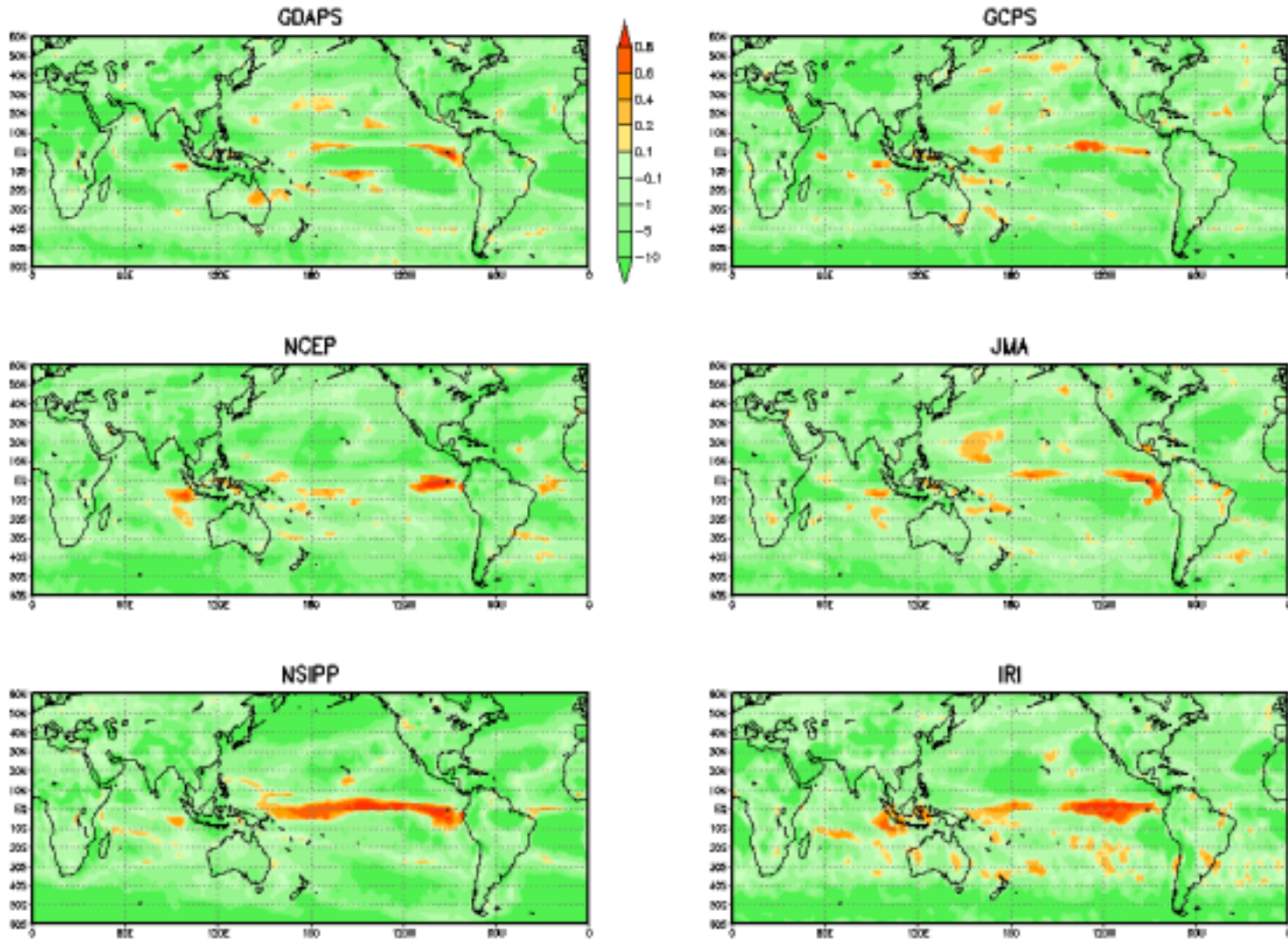
$$MSE_j = \frac{1}{n} \sum_{i=1}^n (f_{ij} - x_{ij})^2$$

$$MSE_{cj} = (n - 1/n)^2 s_{xj}^2$$

$$MSSS_j = 1 - \frac{MSE_j}{MSE_{cj}}$$

$$MSSS = 1 - \frac{\sum_j w_j MSE_j}{\sum_j w_j MSE_{cj}}$$

MSS Precip. JJA Hindcast (1979–1999)



Decomposition of MSSS $MSSS(f, x_{clim}, x) = r_{fx}^2 - [r_{fx} - (s_f / s_x)]^2 - [(f_{clim} - x_{clim}) / s_x]^2$

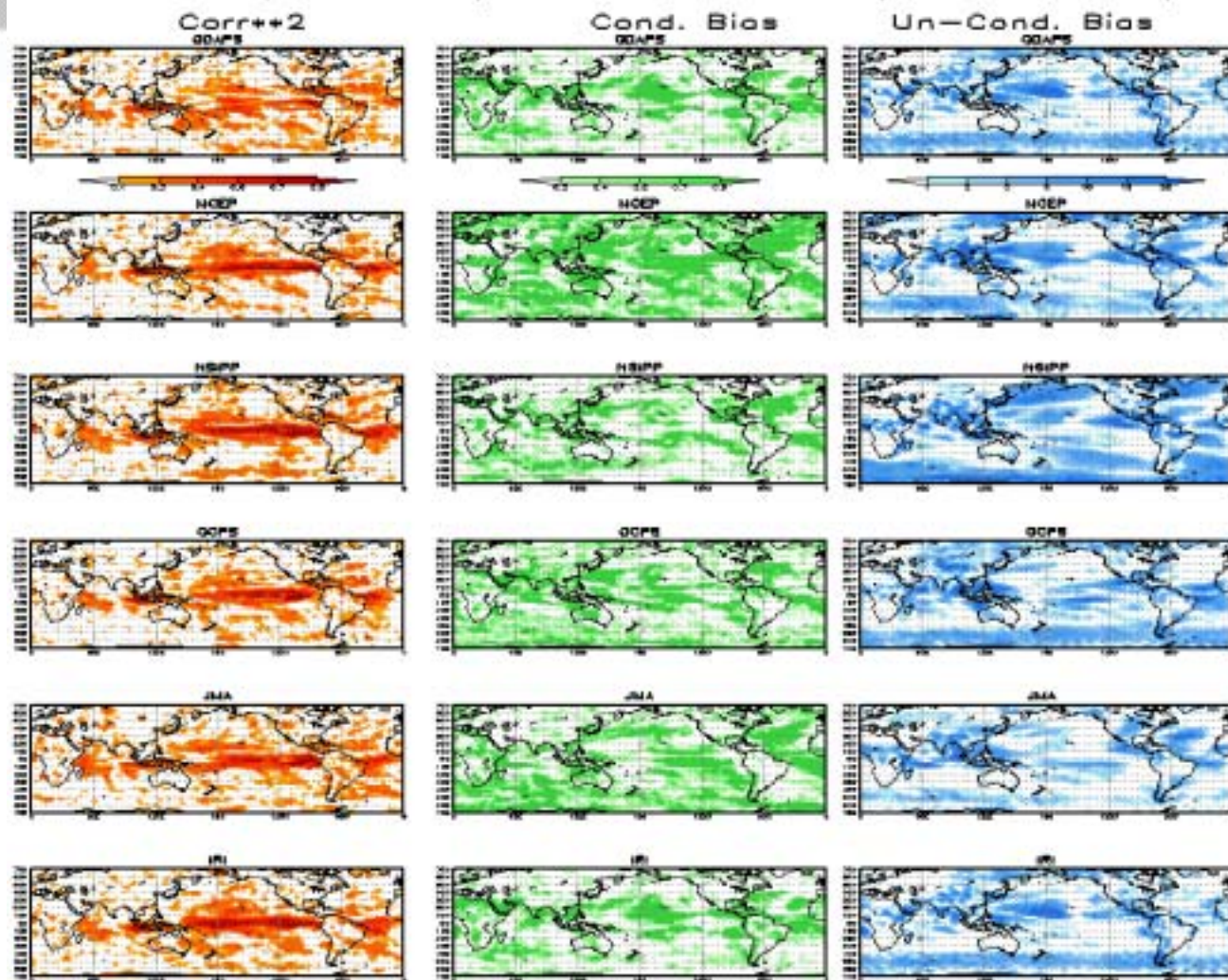
S_f^2 Sample variance of the Forecasts

S_x^2 Sample variance of the Observations

r_{fx} Sample Coefficient of Correlation between Forecasts and Observations

Composition of MSSS

MSSS Compo. Precip. JJA Hindcast (1979–1999)



sts

		observations		
		occurrences	non-occurrences	
forecasts	occurrences	O_1	NO_1	$O_1 + NO_1$
	non-occurrences	O_2	NO_2	$O_2 + NO_2$
		$O_1 + O_2$	$NO_1 + NO_2$	T

$O_1 = \sum W_i (OF)_i$ represents the correct forecasts or hits

$NO_1 = \sum W_i (NOF)_i$ represents the false alarms

$O_2 = \sum W_i (ONF)_i$ represents the misses

$NO_2 = \sum W_i (NONF)_i$ represents the correct rejections

(OF) being 1 when the event occurrence is observed and forecast; 0 otherwise
(ONF) being 1 when the event occurrence is observed but not forecast; 0 otherwise
(NOF) being 1 when the event occurrence is not observed but was forecast; 0 otherwise
(NONF) being 1 when the event occurrence is not observed and not forecast; 0 otherwise

Hit Rate (HR)

$$HR = \frac{O_1}{(O_1 + O_2)}$$

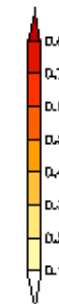
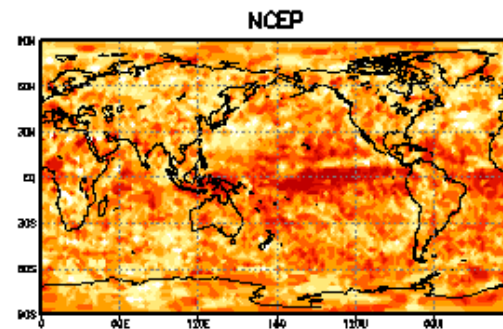
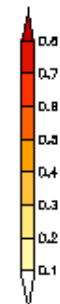
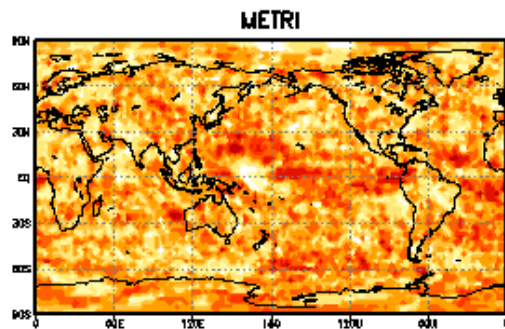
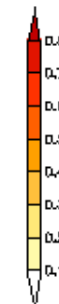
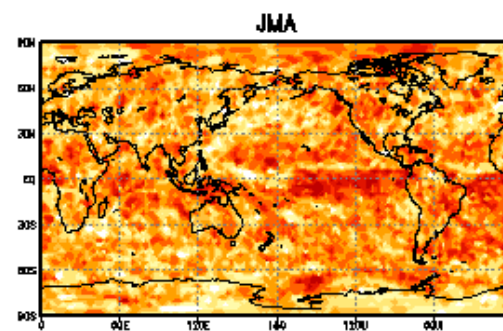
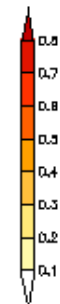
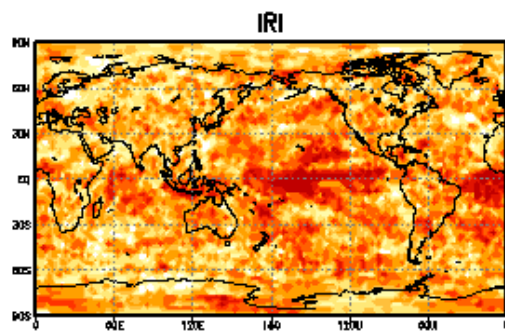
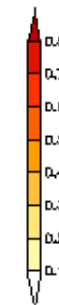
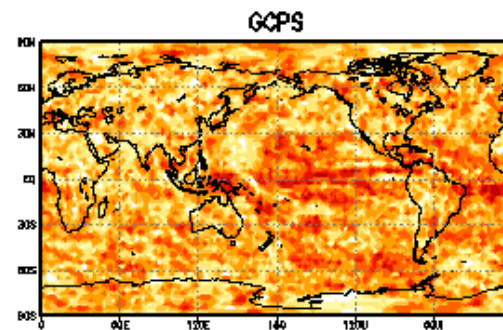
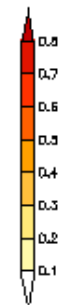
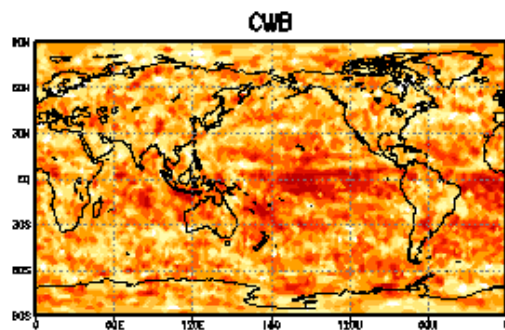
False Alarm Rate (FAR)

$$FAR = \frac{NO_1}{(NO_1 + NO_2)}$$

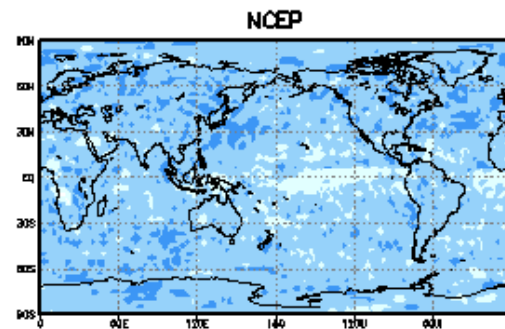
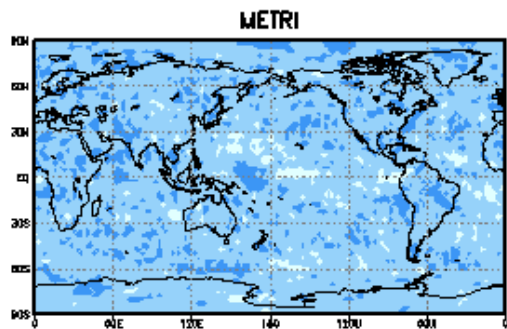
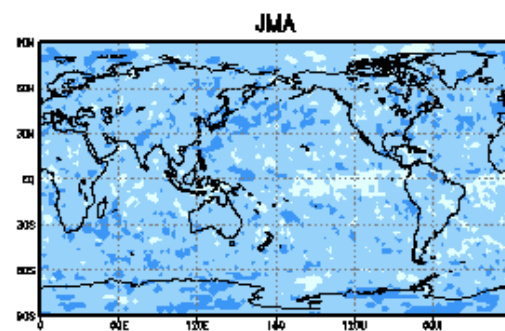
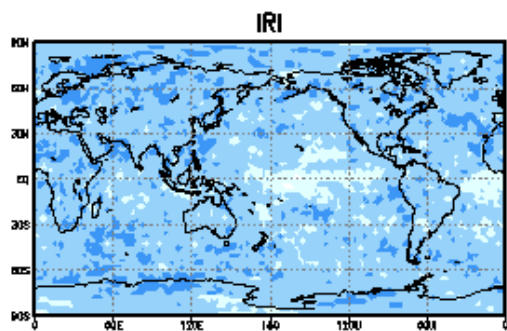
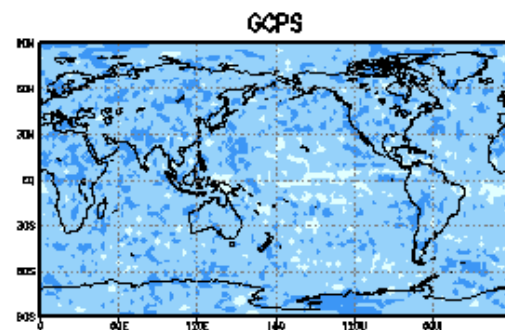
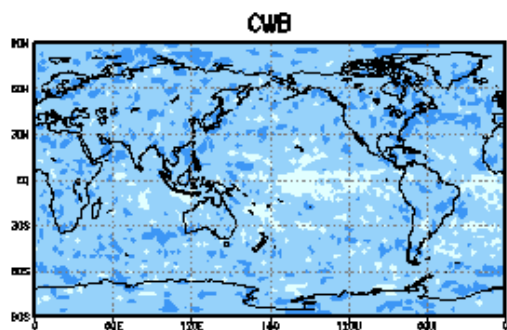
Hanssen and Kuipers score (KS)

$$KS = HR - FAR = \frac{O_1 NO_2 - O_2 NO_1}{(O_1 + O_2)(NO_1 + NO_2)}$$

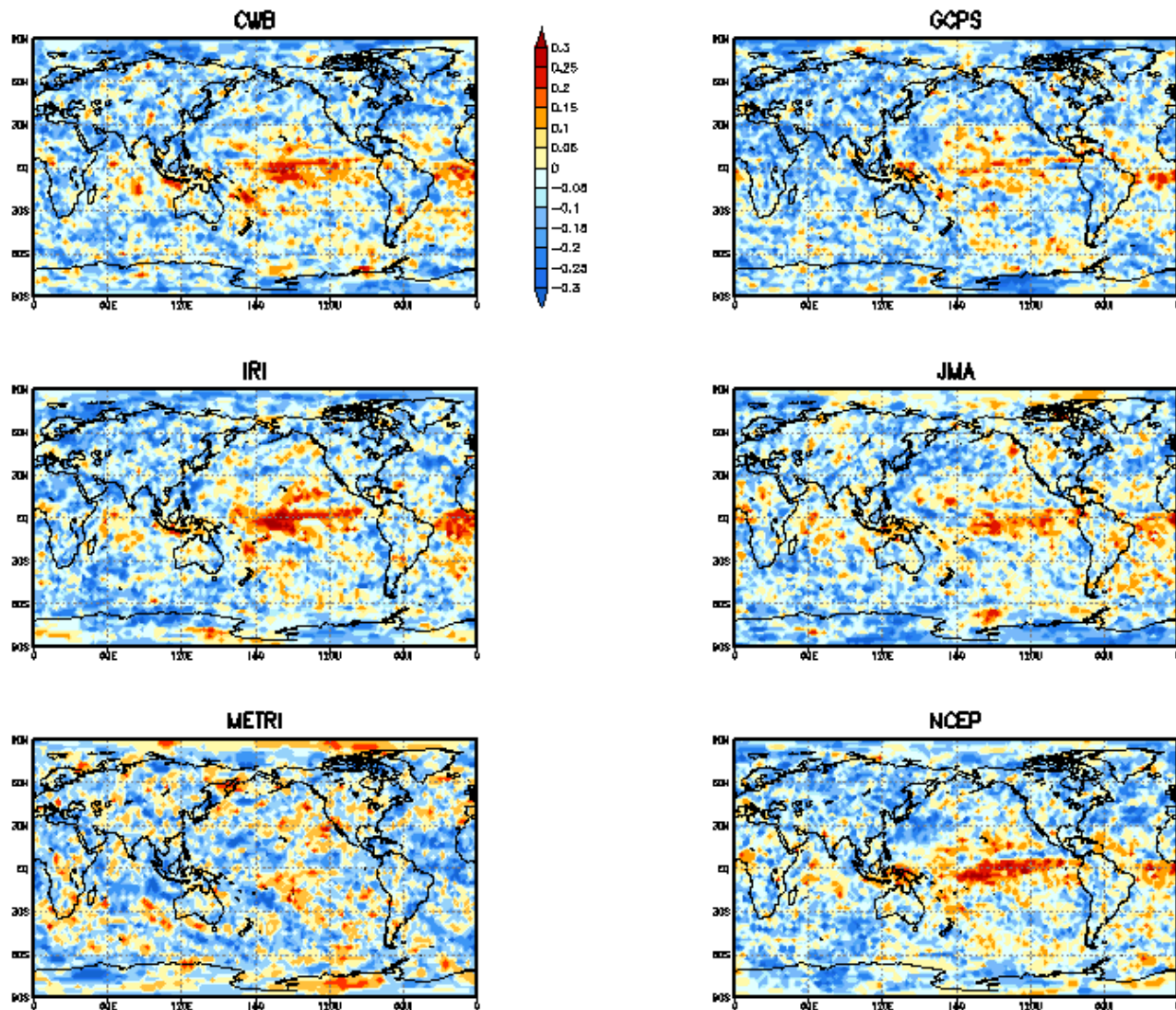
HIT RATE (Above Normal) Precip JJA



False Alarm Rate (Above Normal) Precip JJA



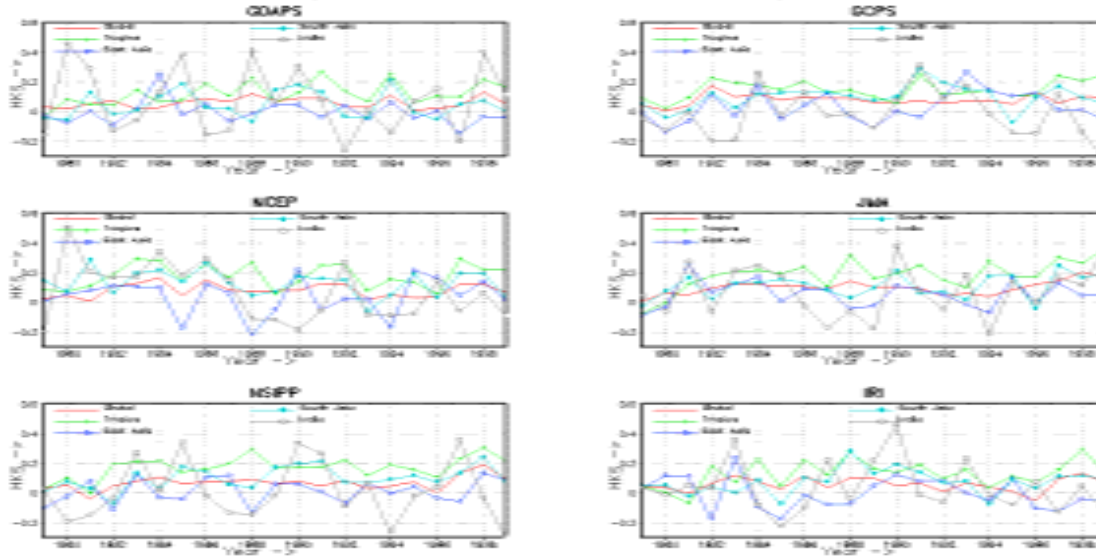
Hit Rate - False Alarm Rate (Above Normal) Precip JJA



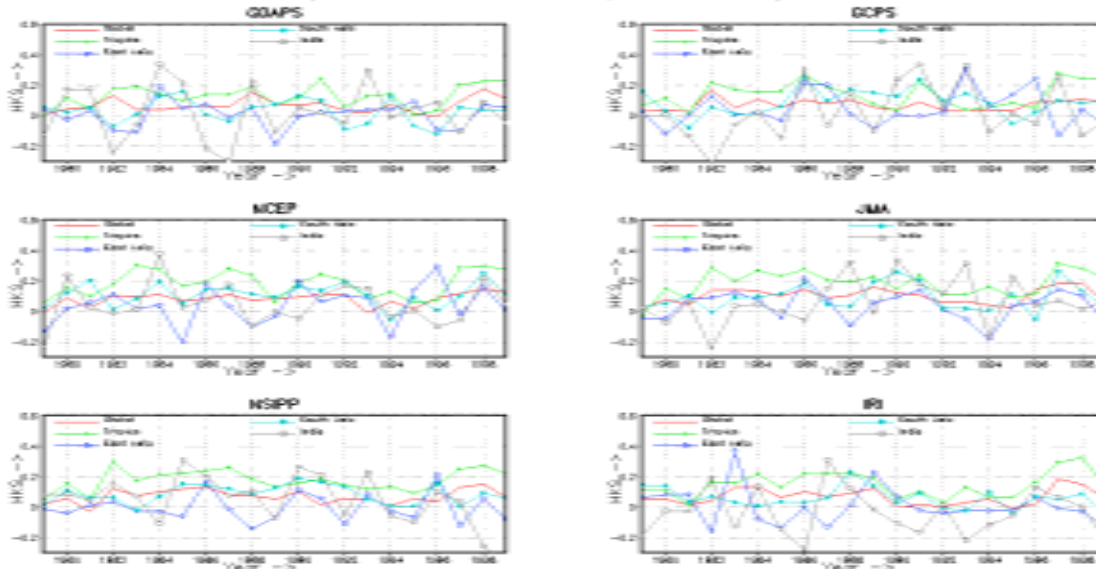
H.K. Skill Score Precip JJA



HKS Score Precip. JJA Hindcast (1979-99) Below Normal



HKS Score Precip. JJA Hindcast (1979-99) Above Normal



ROC Contingency Table

Precip GDAPS JJA 1985 Indian Region



Above Normal

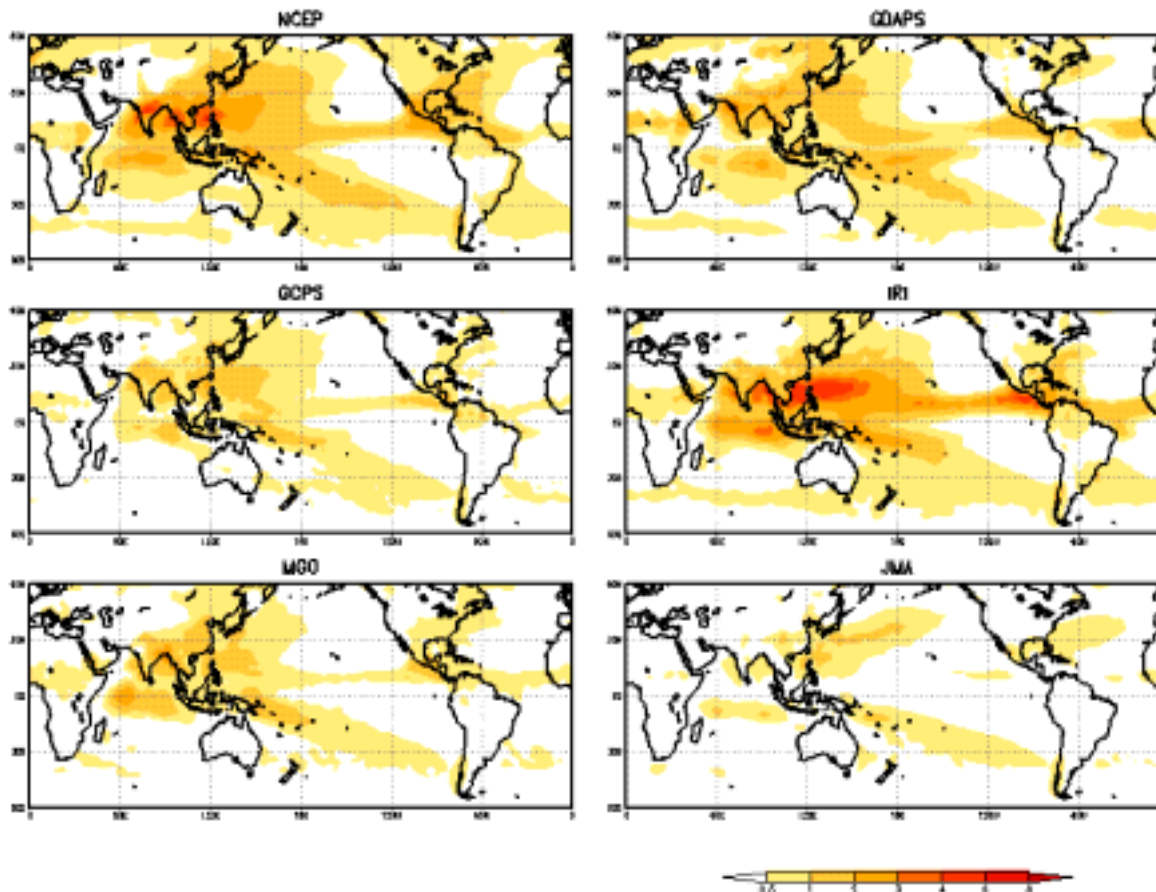
		Observations		
		Occurrences	Non - occurrences	
Forecast	Occurrences	9	11	20
	Non - occurrence	17	66	83
	s	26	77	103

Below Normal

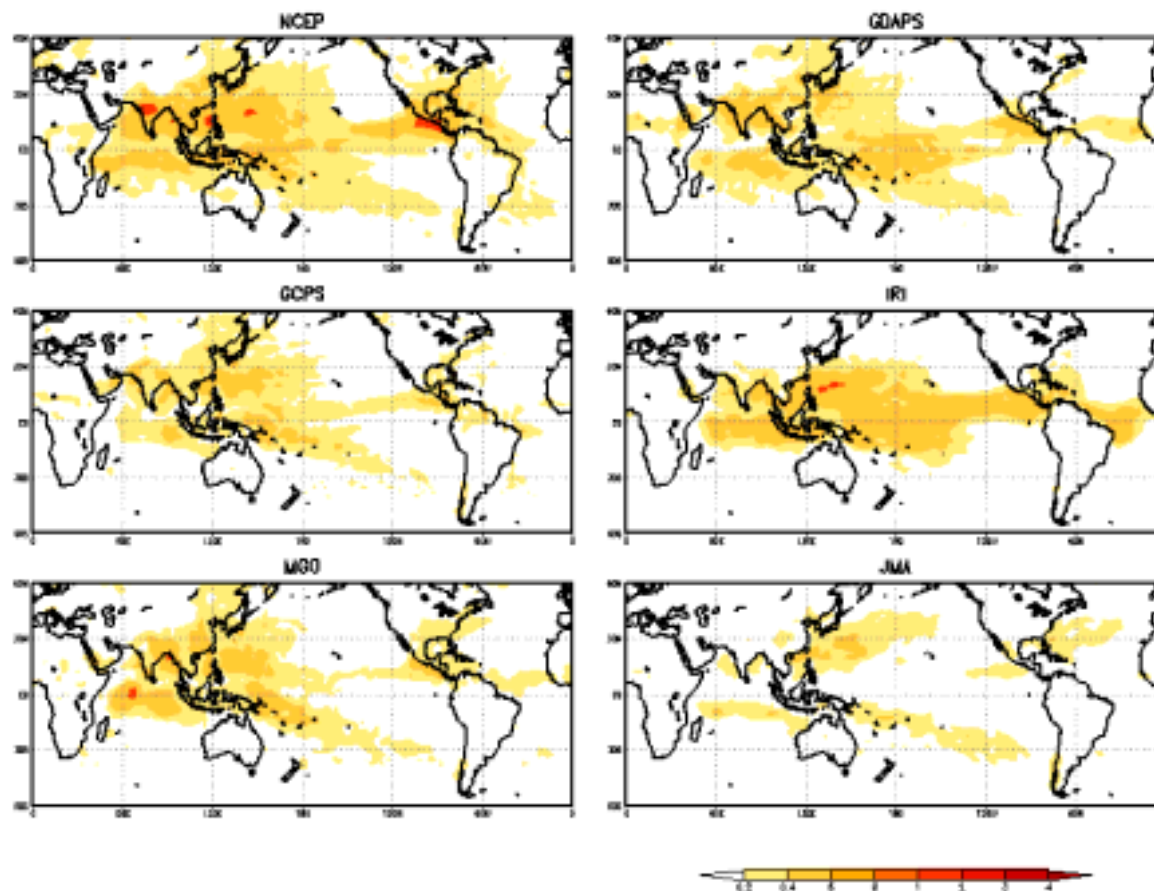
		Observations		
		Occurrences	Non - occurrences	
Forecast	Occurrences	19	15	34
	Non - occurrence	23	46	69
	s	42	61	103

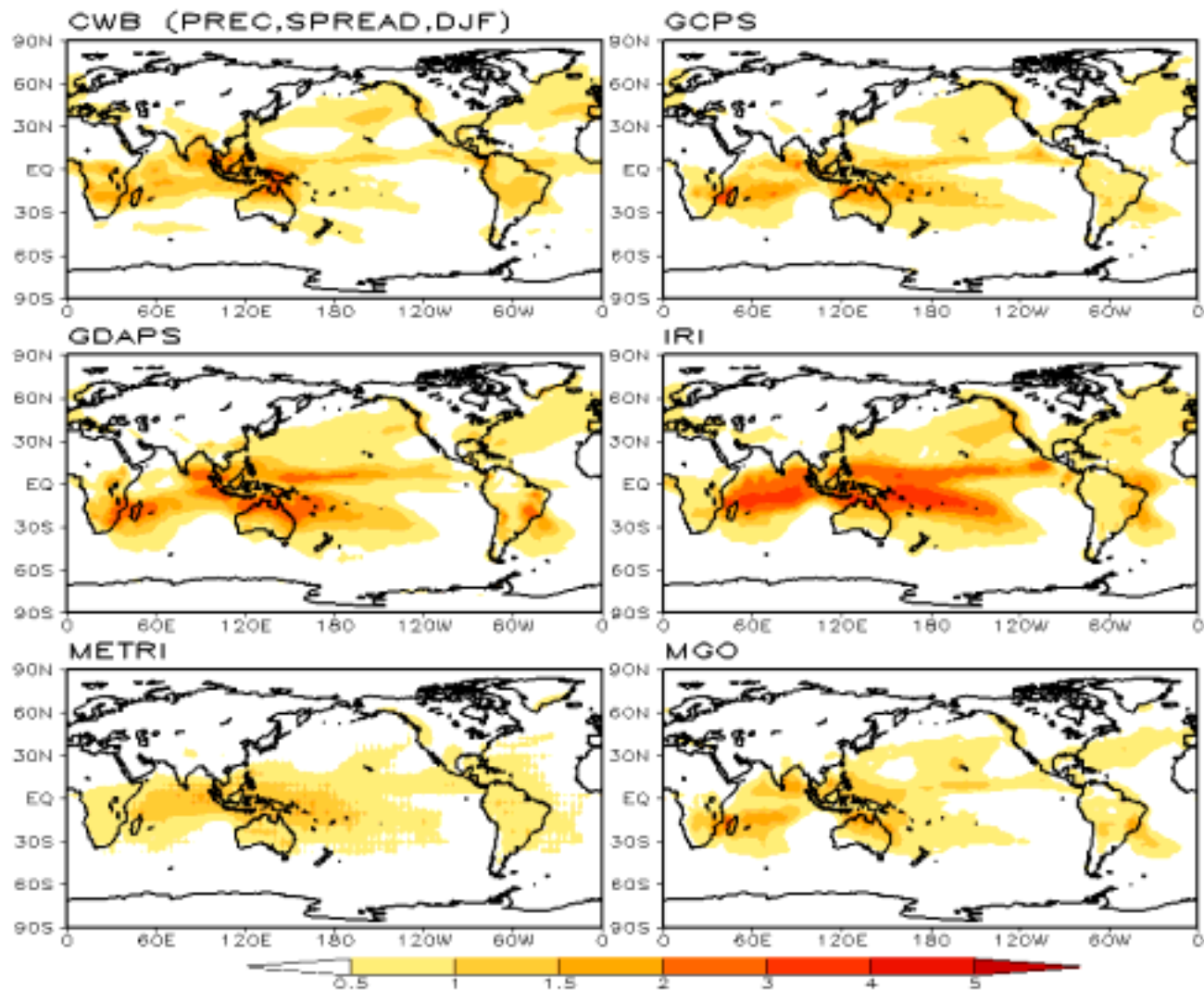
ENSEMBLE SPREAD & PREDICTABILITY

Ensemble Spread Precip. JJA

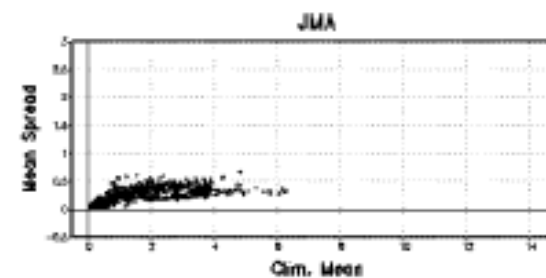
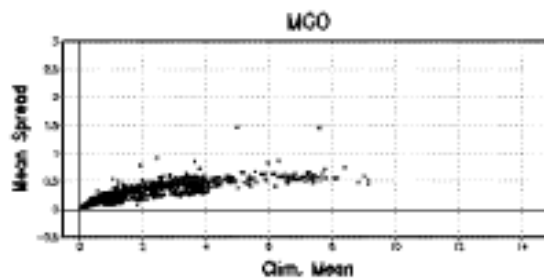
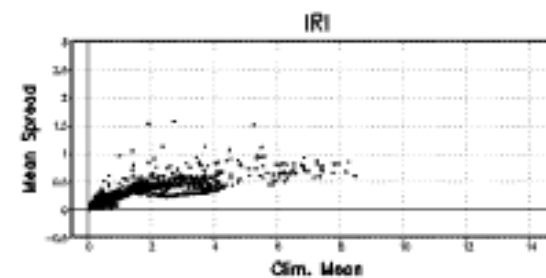
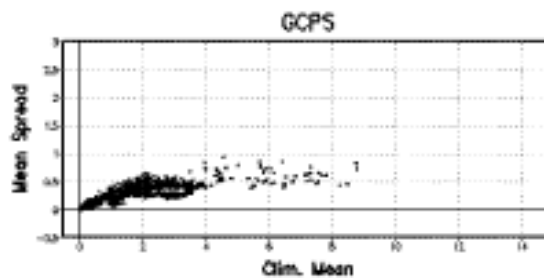
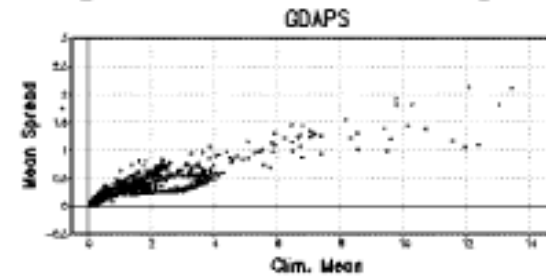
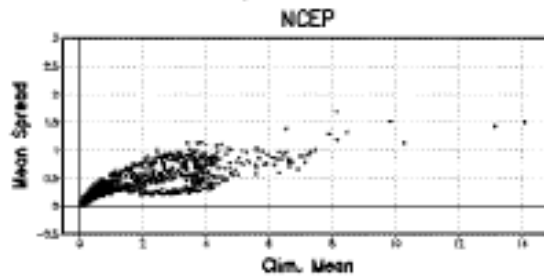


Ensemble Spread (Std. Dev.) Precip. JJA

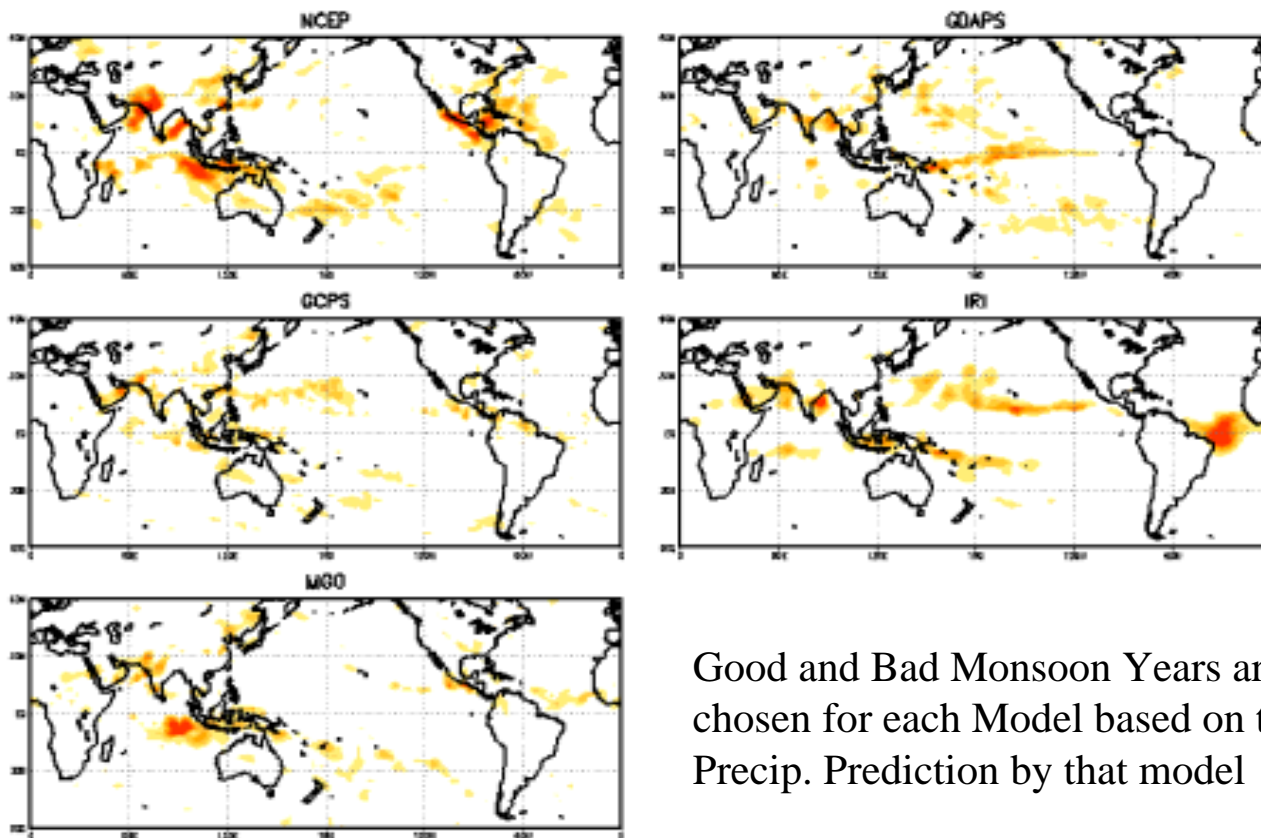




Mean Spread vs Clim. Mean [40E-160E,20S-40N]

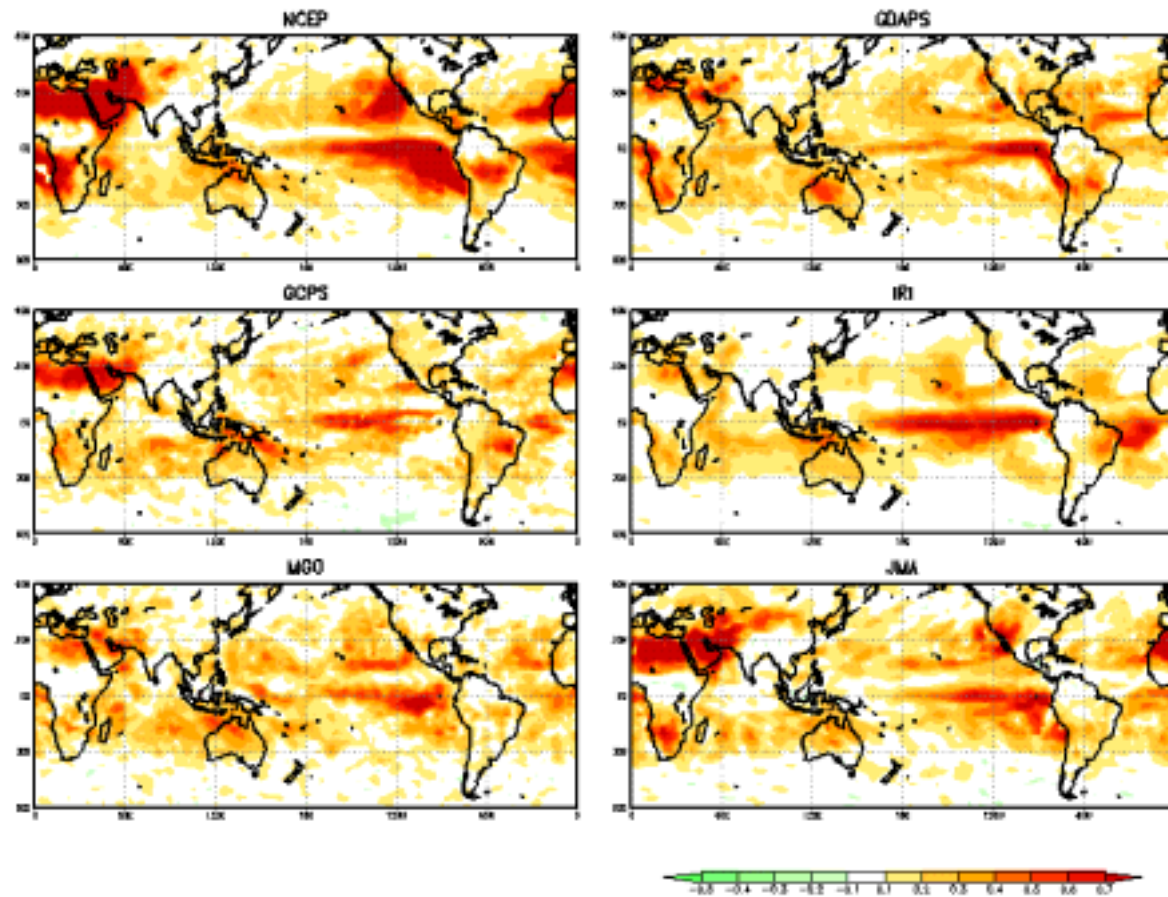


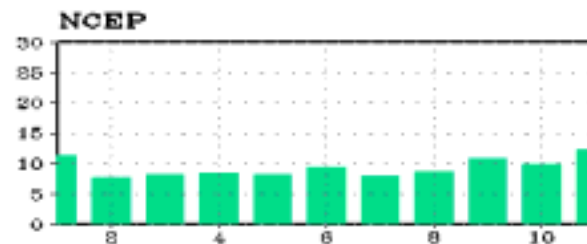
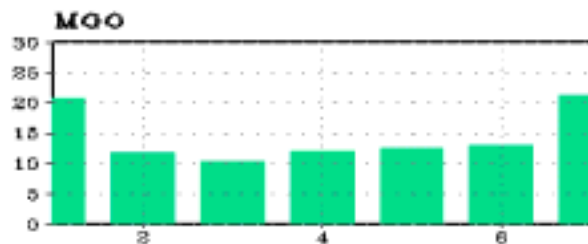
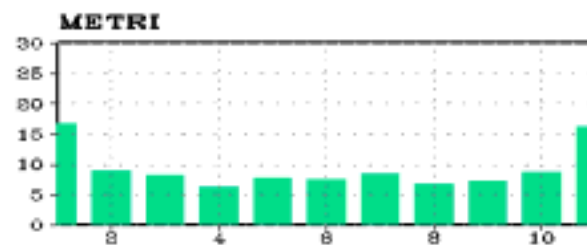
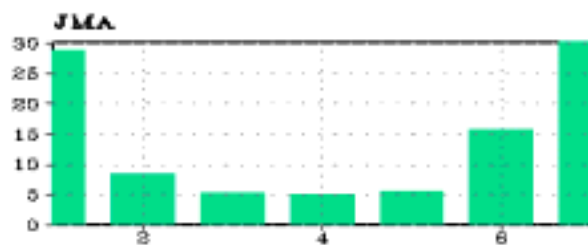
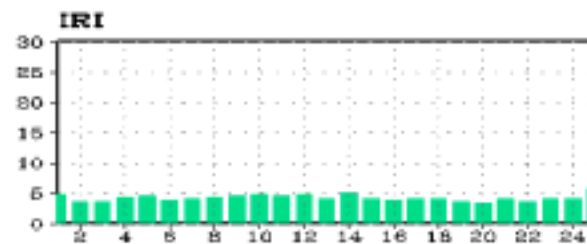
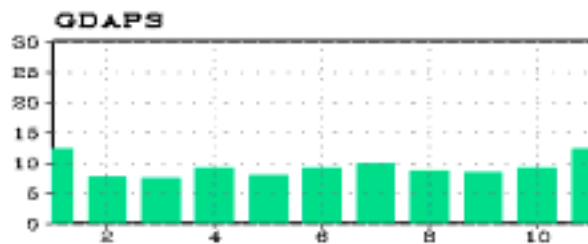
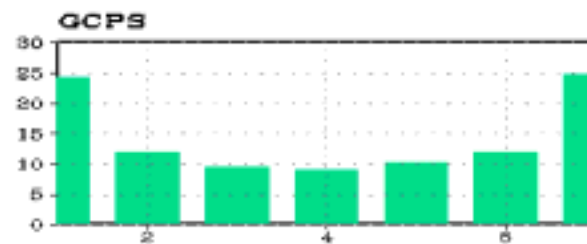
Diff: Ens. Spread Precip. Good-Bad India JJA



Good and Bad Monsoon Years are chosen for each Model based on the Precip. Prediction by that model

CORR: Ensemble Mean Anom & Spread Precip. JJA





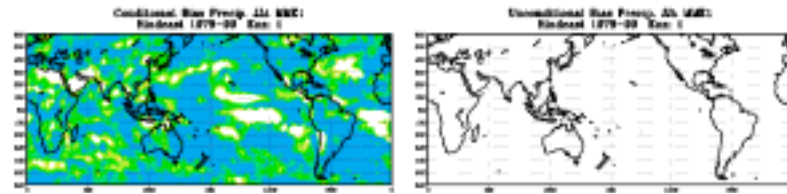
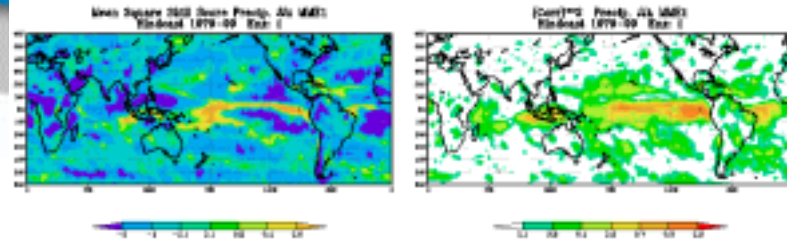
APCN MULTI-MODEL ENSEMBLE (Deterministic) PREDICTION SYSTEM



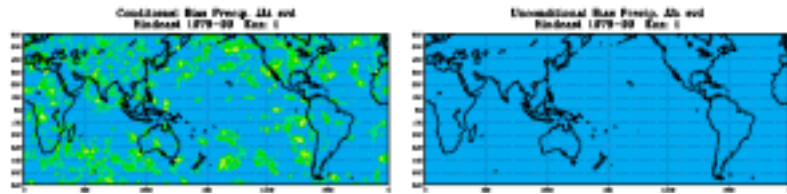
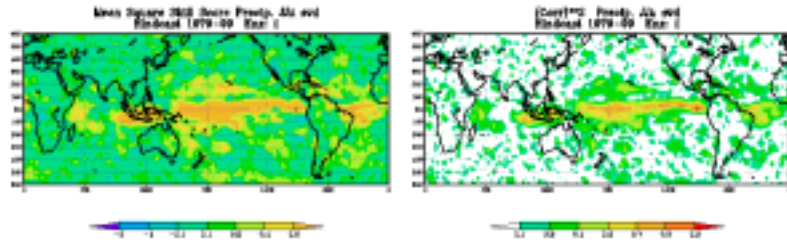
Multi-Model Mean	MME-1
Point-wise Regression using SVD Method Yun et al.(2002)	MME-2
Coupled Pattern Projection Method (CPPM)	MME-3
Multi-Model Synthetic Super Ensemble Yun et al. (2004)	MME-4

MSSS & its Decomposition: JJA PRECIP

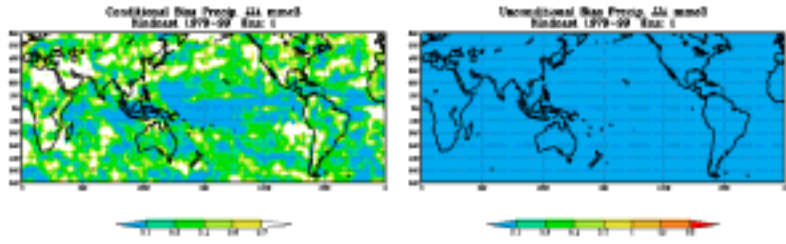
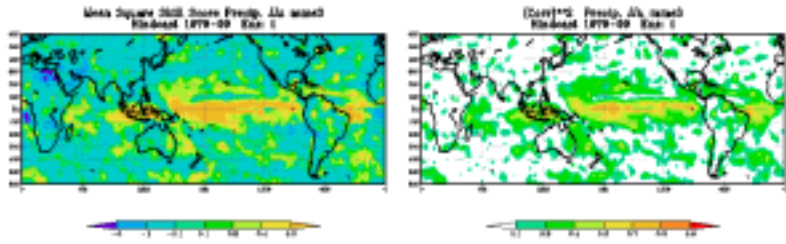
MME-1



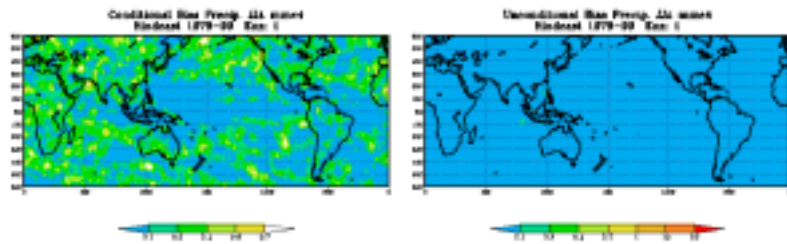
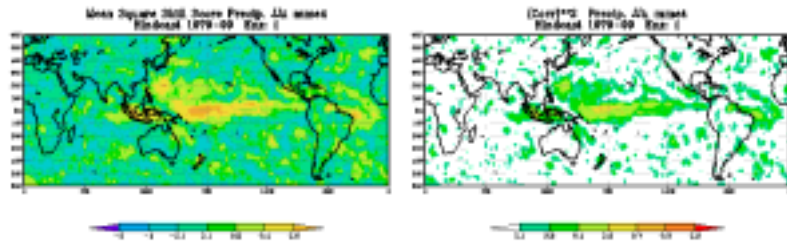
MME-2



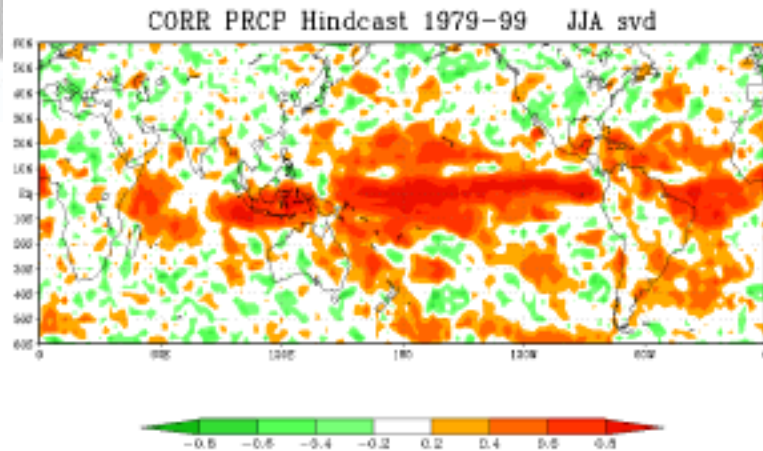
MME-3



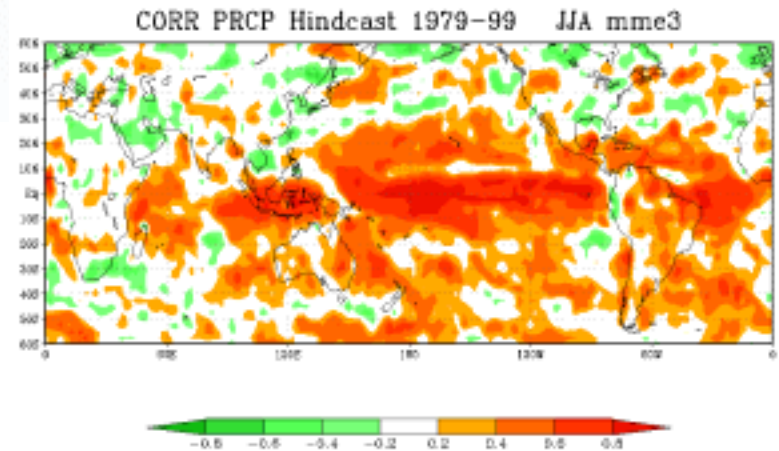
MME-4



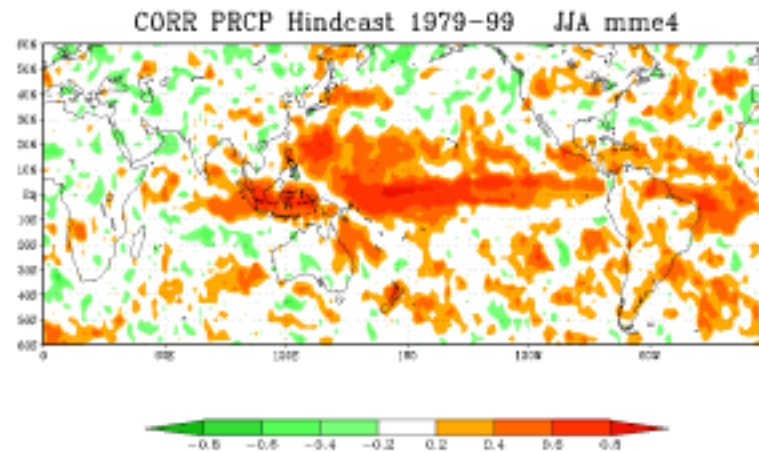
MME-2



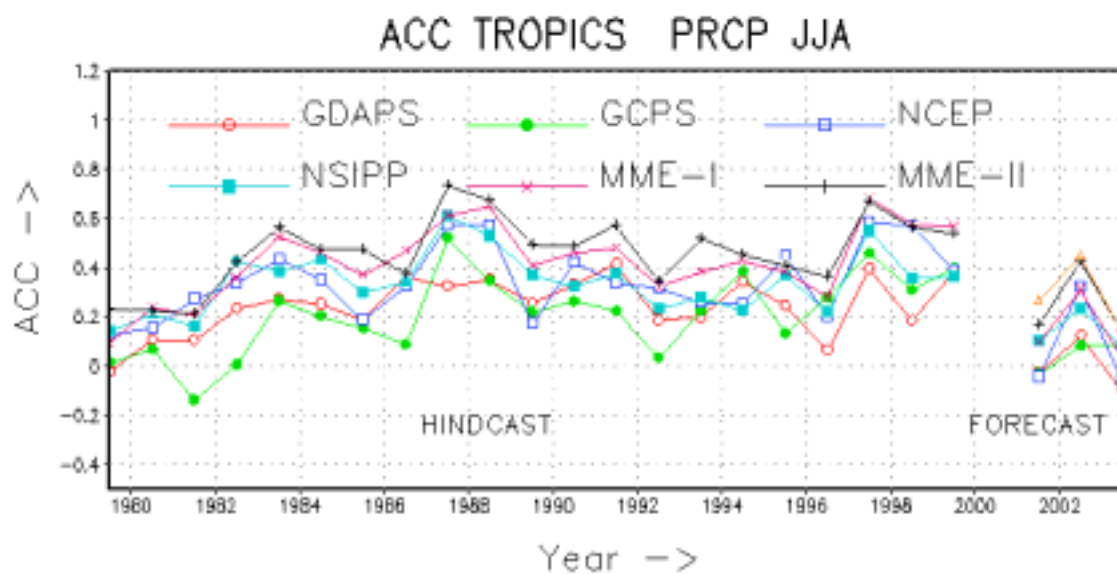
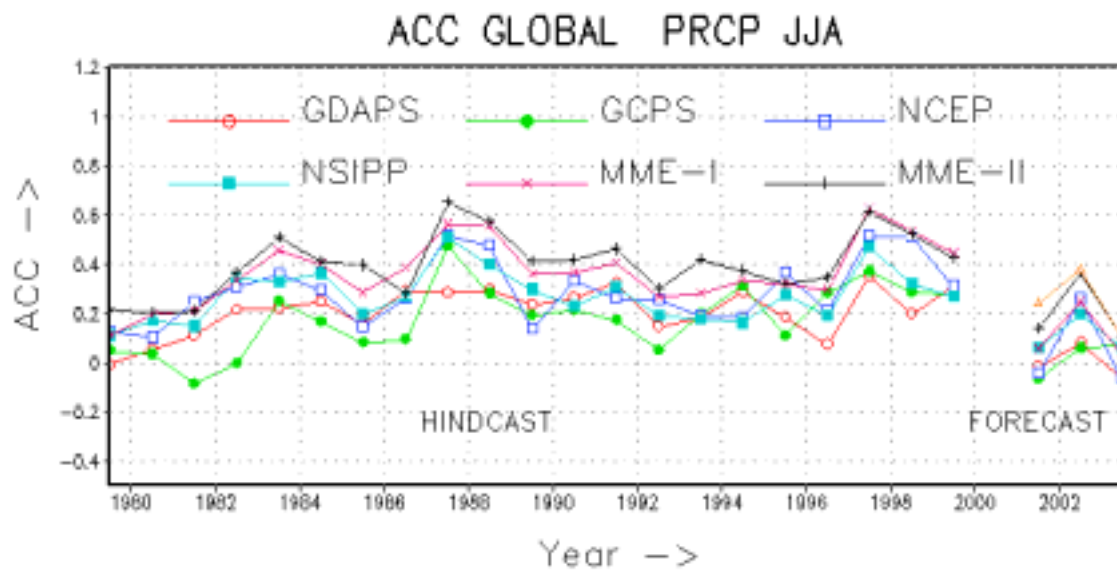
MME-3



MME-4



Performance of MME-4 strongly depends on number of EOF modes retained while constructing Synthetic Data

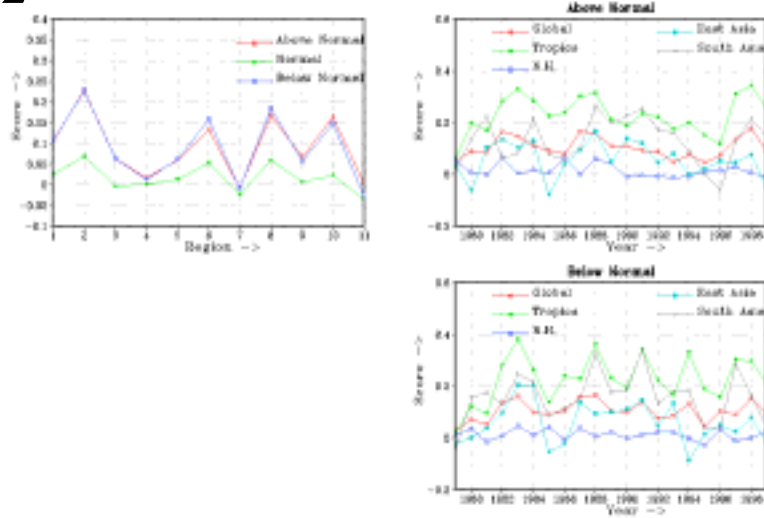


H.K Skill Score



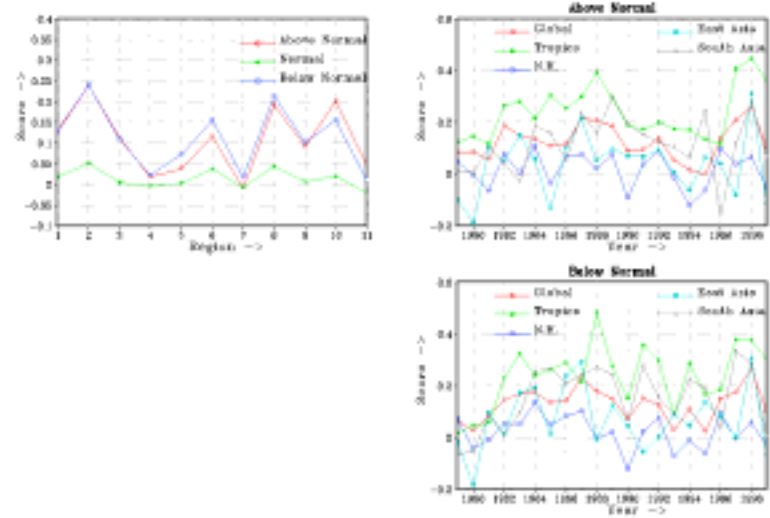
MME-2

H.K. Skill Score Precip. JJA Hindcast (1979-1999) svd



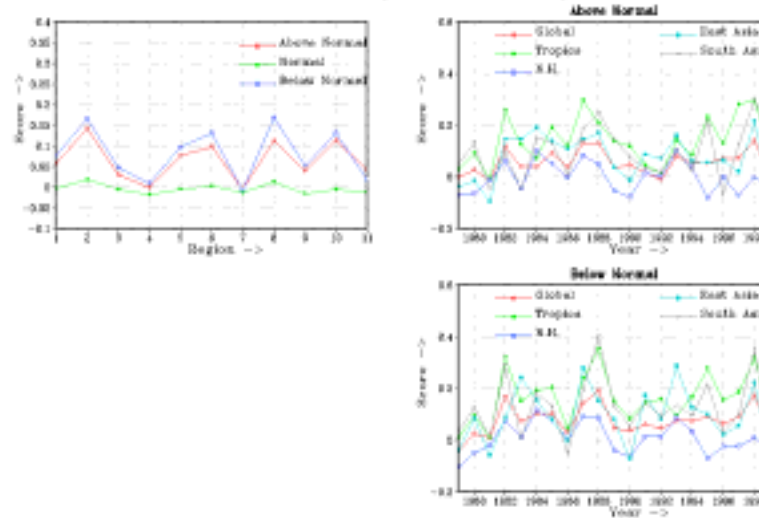
MME-3

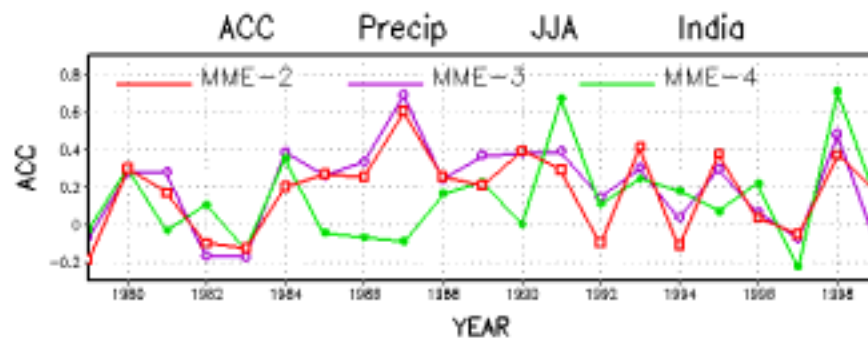
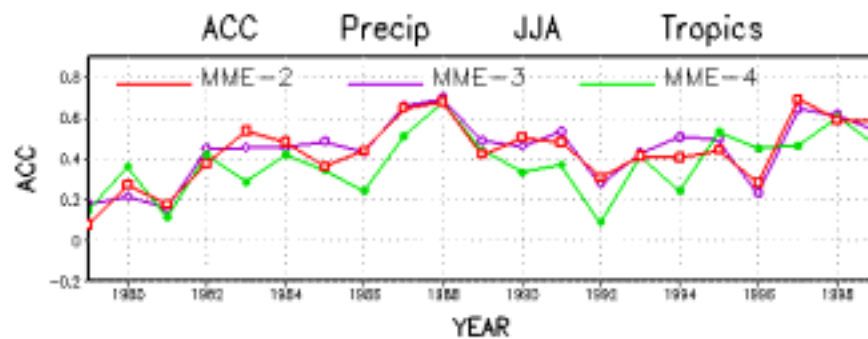
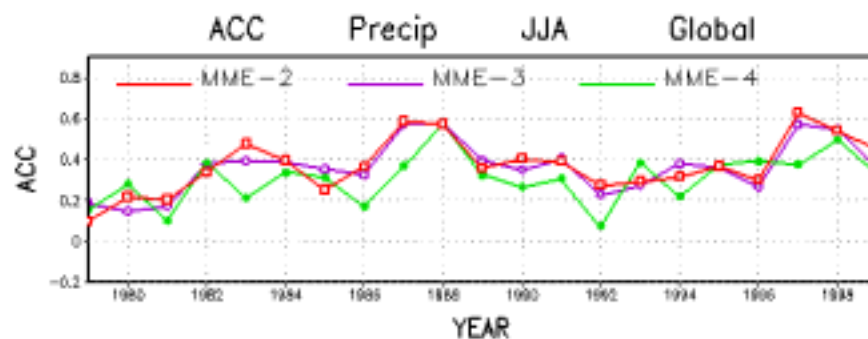
H.K. Skill Score Precip. JJA Hindcast (1979-1999) mme3



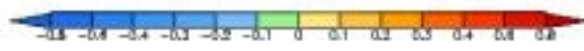
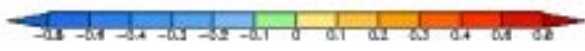
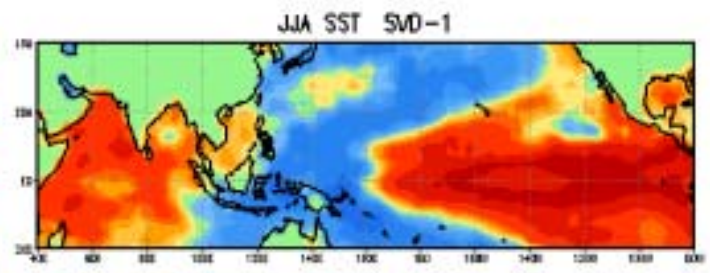
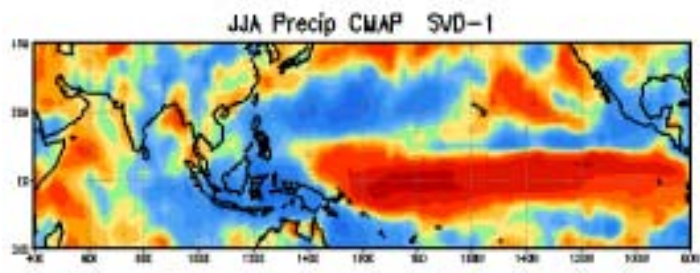
MME-4

H.K. Skill Score Precip. JJA Hindcast (1979-1999) mme4

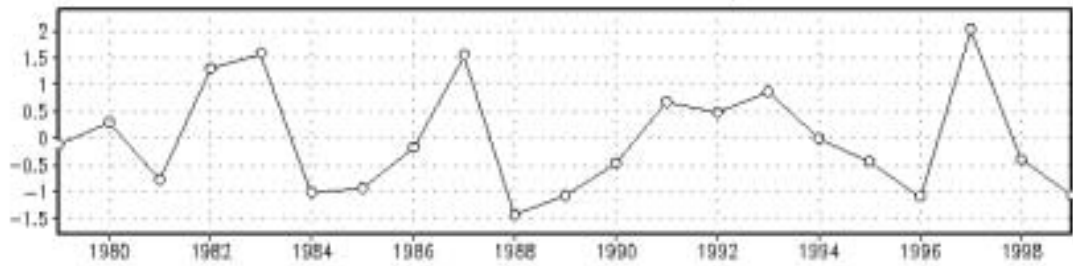




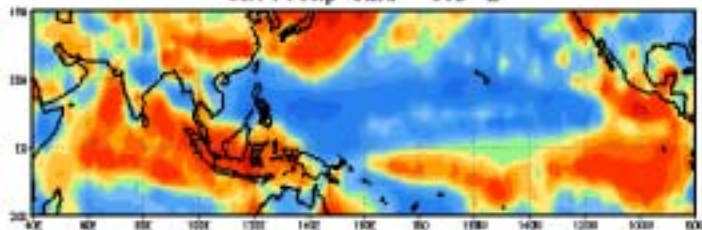
SVD Leading Modes Obs. Precip & SST JJA



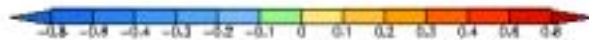
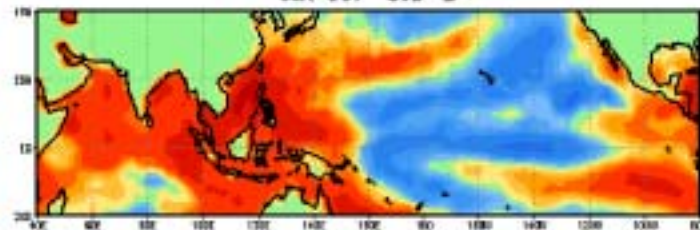
P.C. Time Series JJA Precip. SVD-1



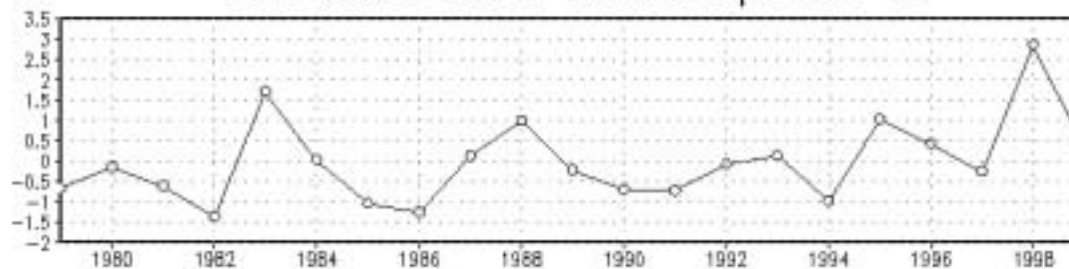
JJA Precip CMAP SVD-2



JJA SST SVD-2



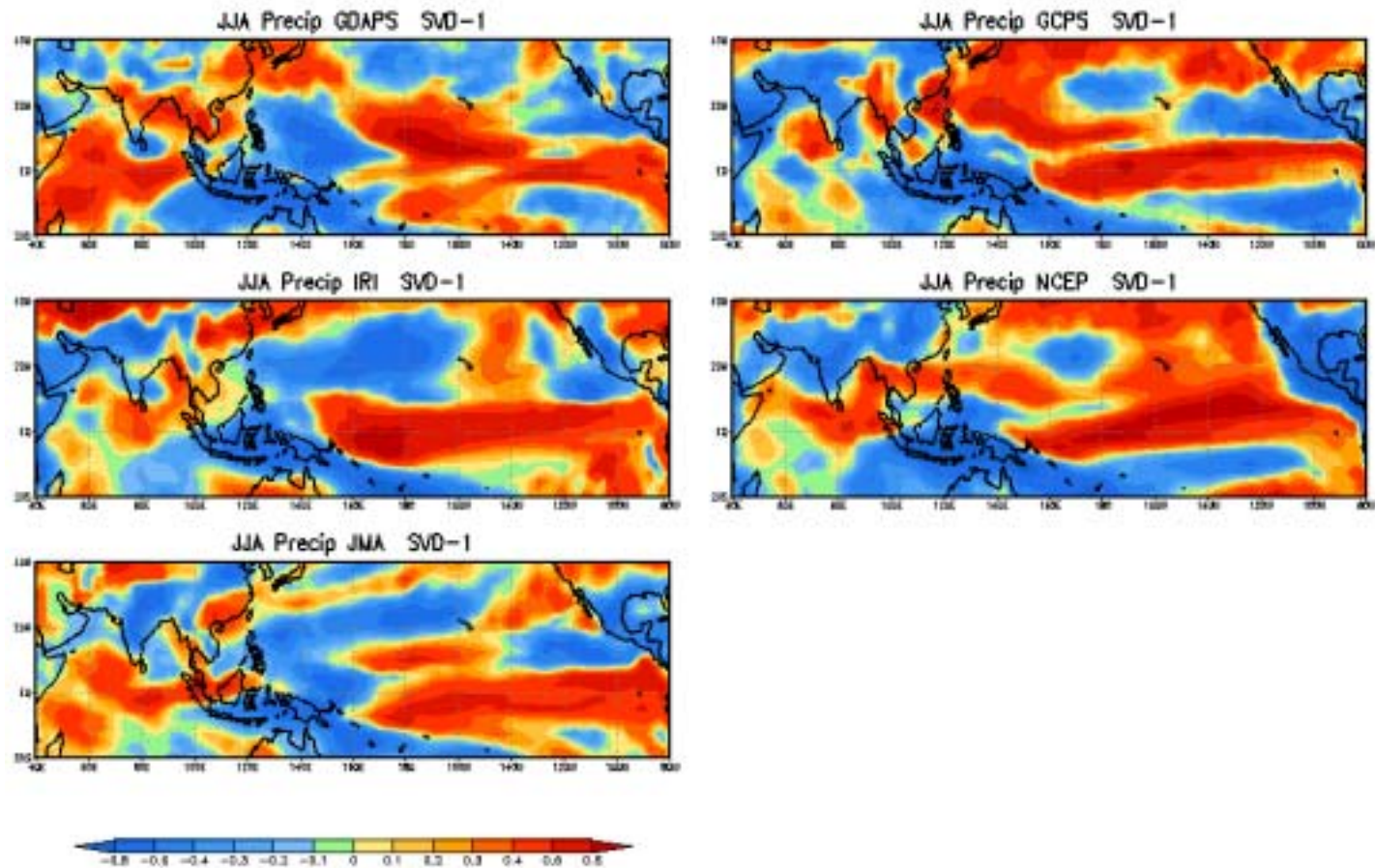
P.C. Time Series JJA Precip. SVD-2



SVD (Precip & SST JJA) Leading Modes: Model Precip

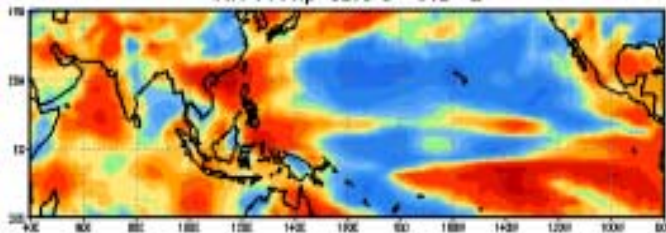
SVD-1

SVD-1 Precip

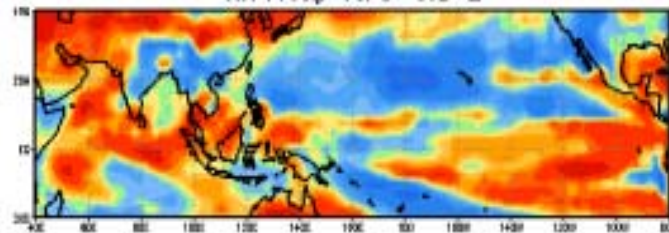


SVD-2 Precip

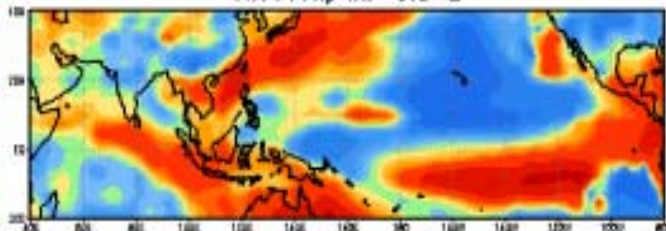
JJA Precip GDAPS SVD-2



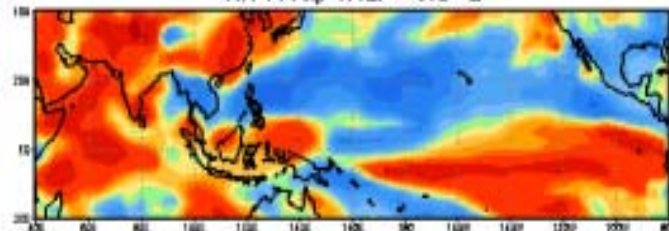
JJA Precip GCP5 SVD-2



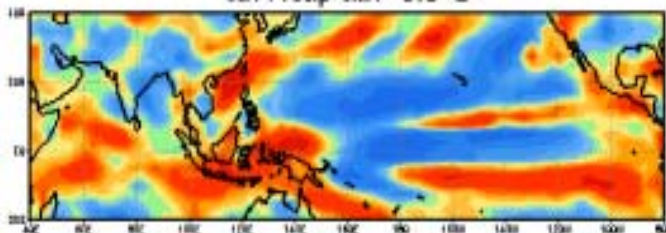
JJA Precip IRI SVD-2



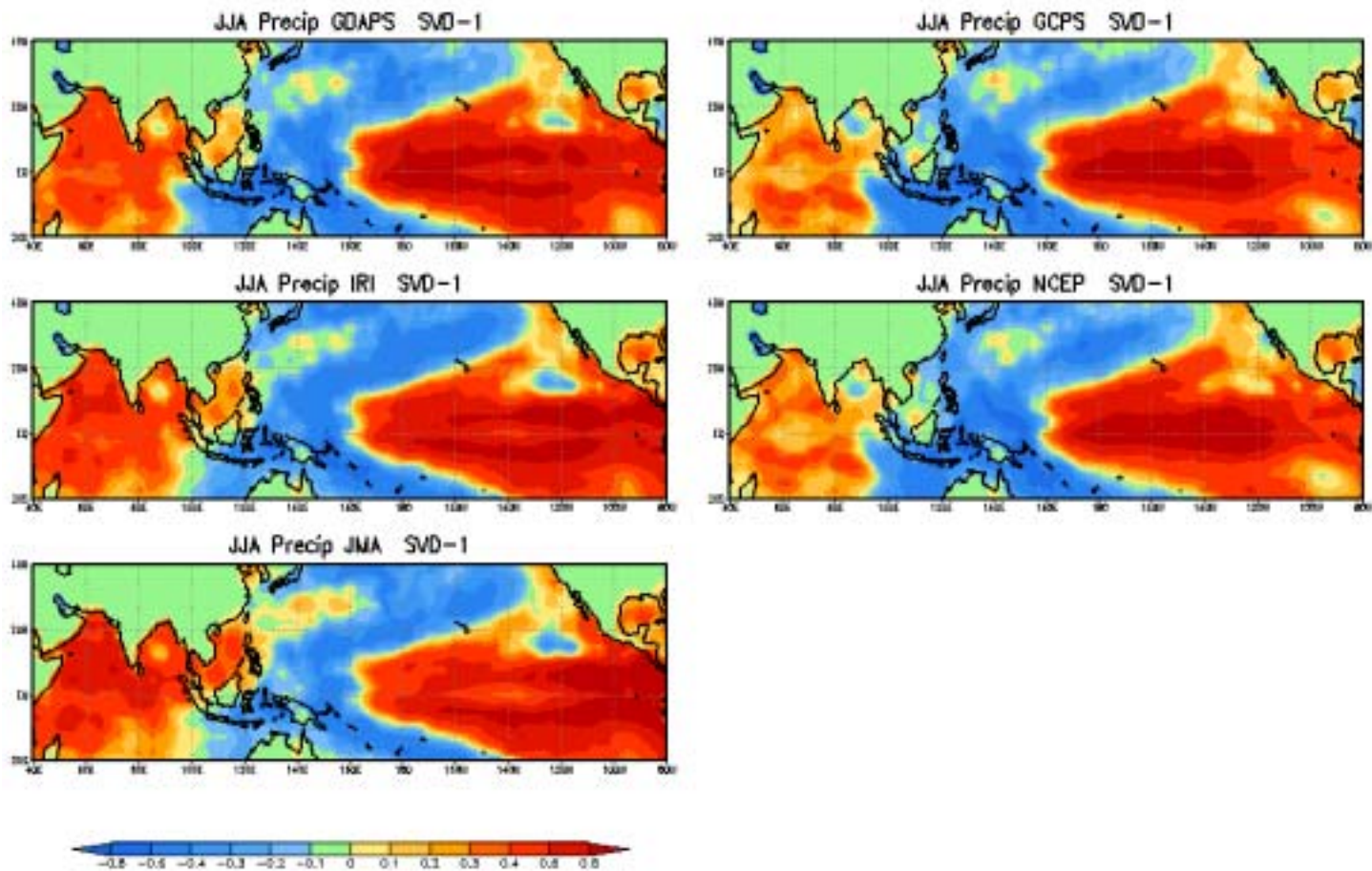
JJA Precip NCEP SVD-2



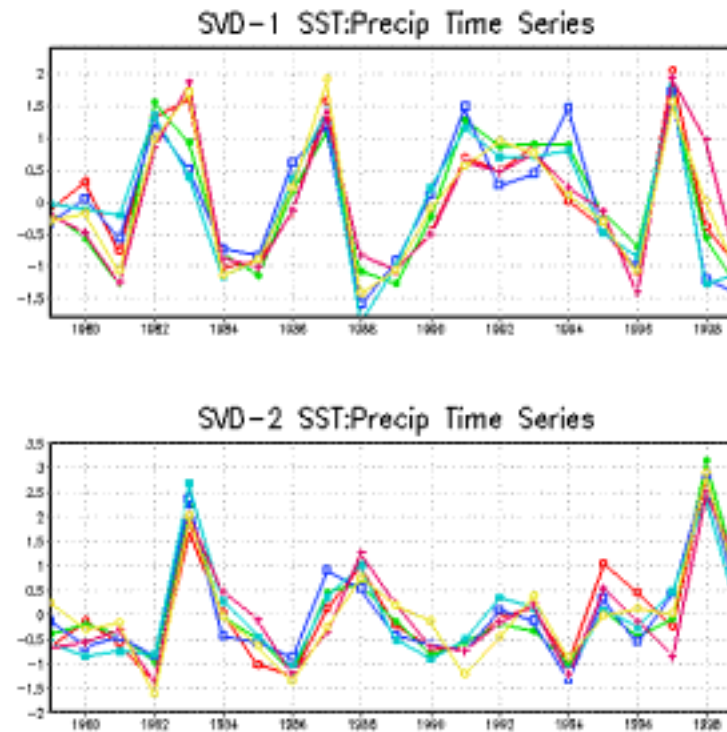
JJA Precip JMA SVD-2



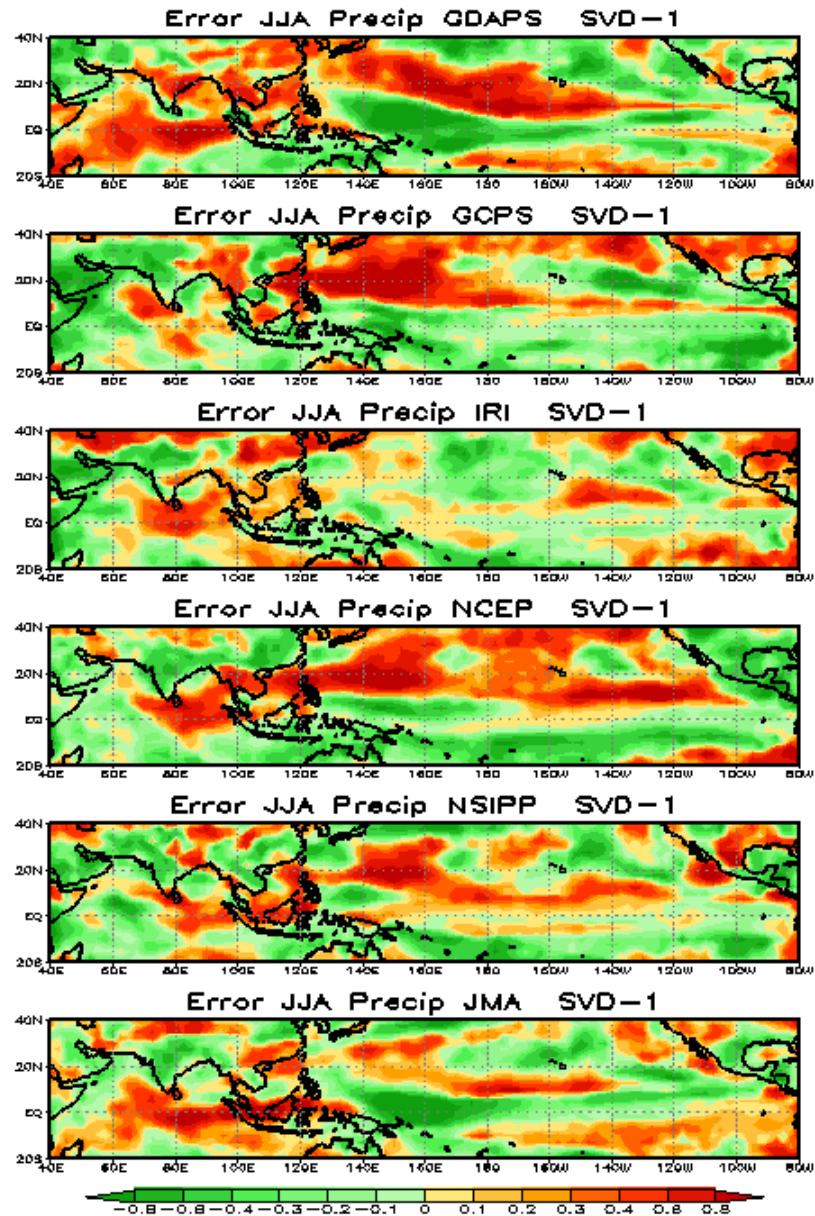
SVD-1 SST



Temporal Pattern of Leading Modes OBS & Model Precip JJA

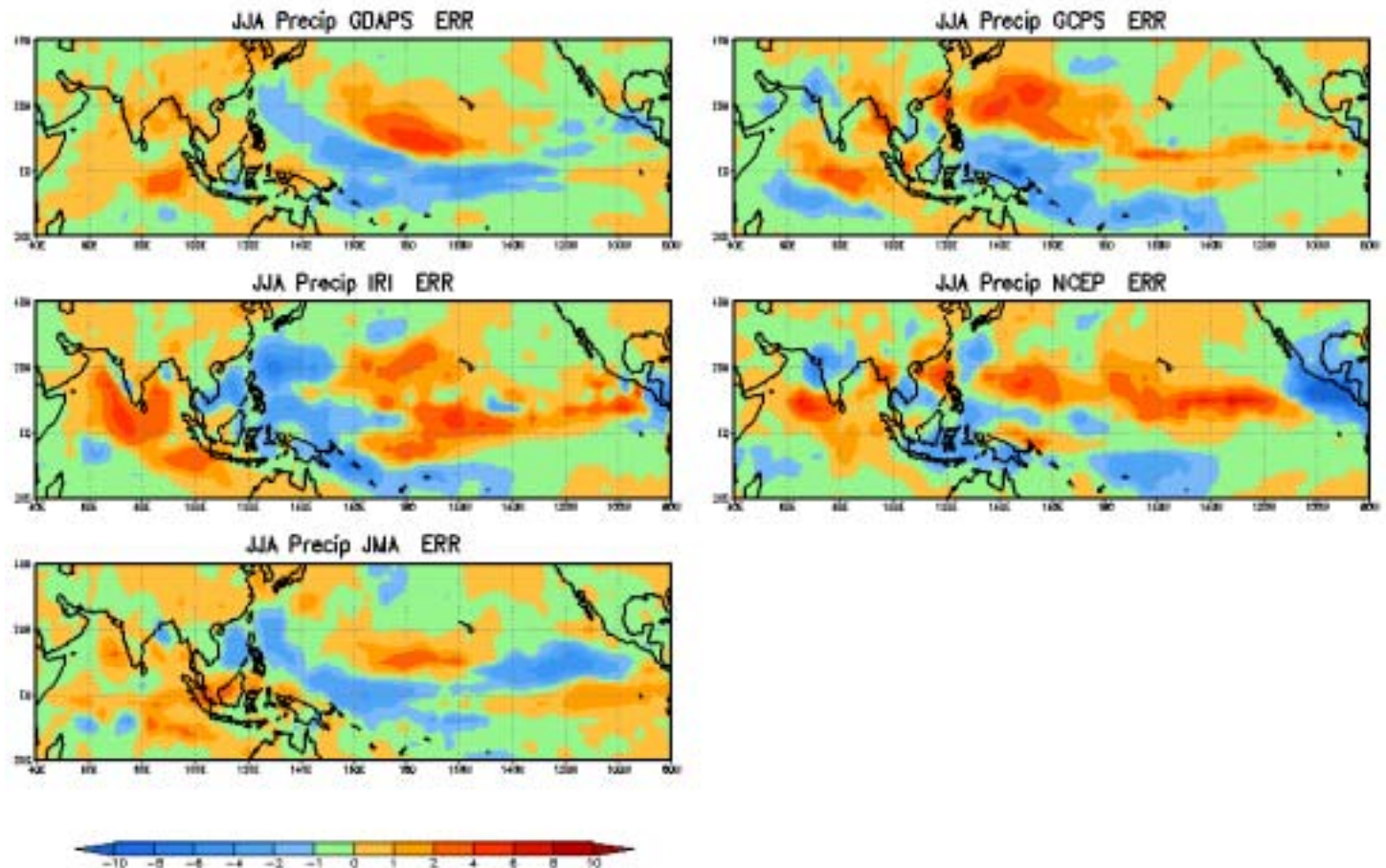


PC time-series of leading modes (for Observations and Models) vary in time similarly. This pattern provides hope for Multi-Model Ensemble Prediction



**Rainfall Error
Associated with
the First Mode**

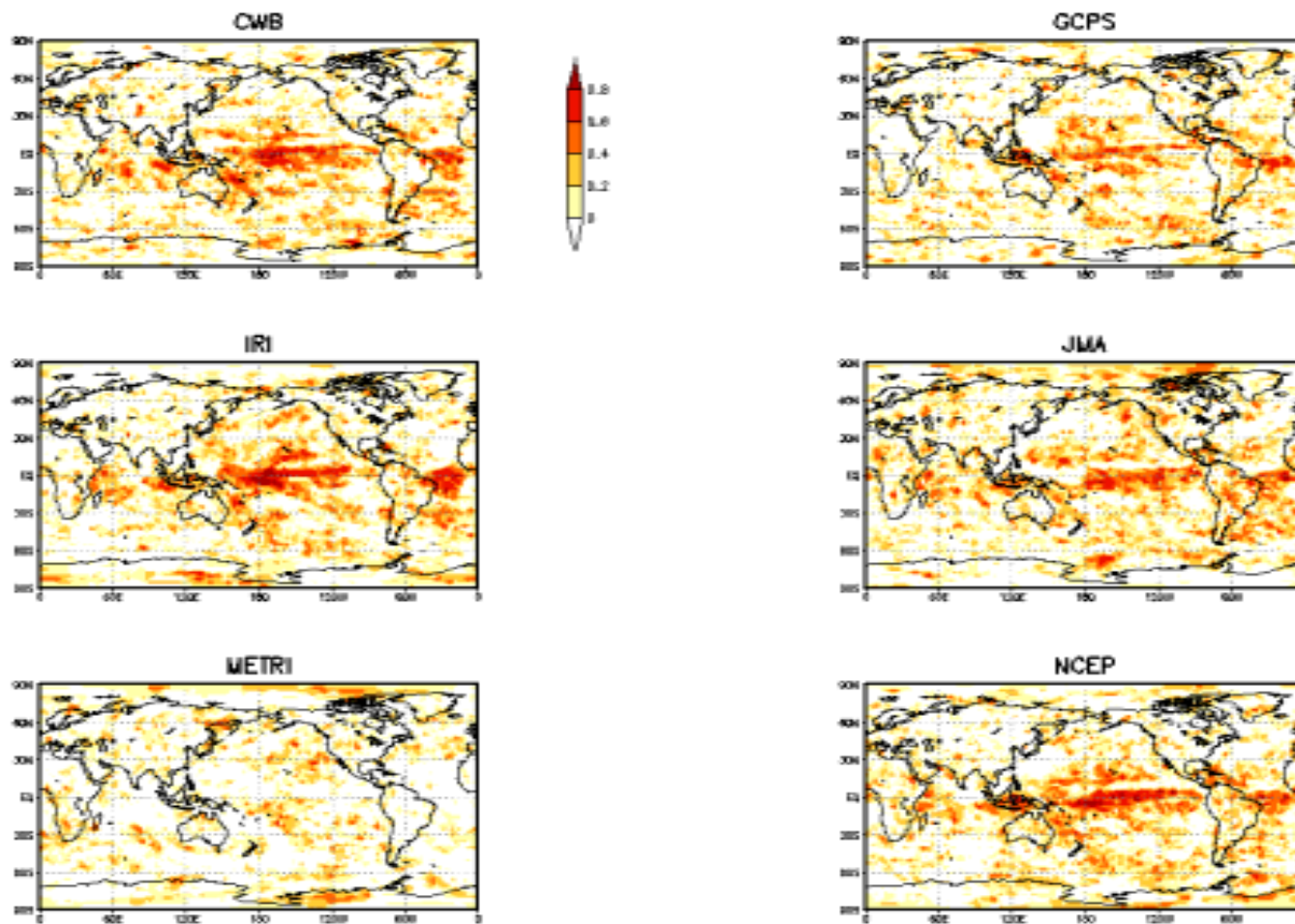
Estimated Errors in Model Predictions for 1997 due to Incorrect Response of Model to SST



ECONOMIC IMPACT ASSESSMENT OF DETERMINISTIC PREDICTION

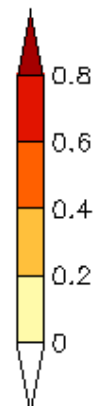
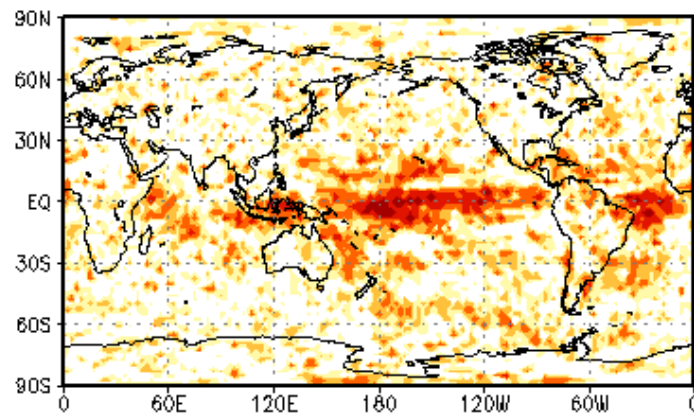
$$V = \frac{\min\left(\frac{C}{L}, \bar{o}\right) - (h + f)\frac{C}{L} - m}{\min\left(\frac{C}{L}, \bar{o}\right) - \frac{C}{L}\bar{o}}$$

Economic Value of a Prediction depends on Hits, False Alarms, Misses, Climatological Frequency of the event (depends on number of Categories), In addition to the Cost-Loss Ratio

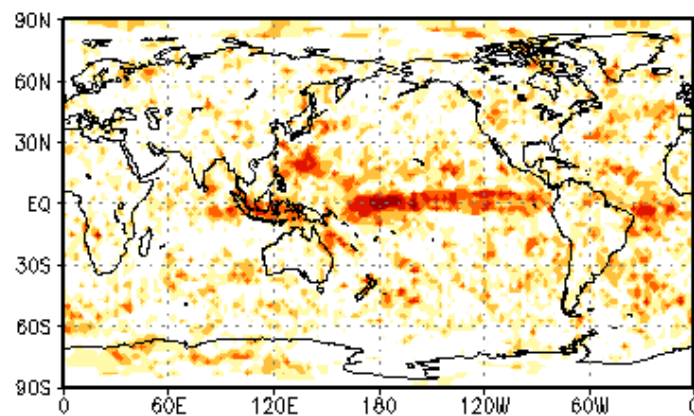


ECONOMIC VALUE Precip. A.N. JJA C/L=0.3

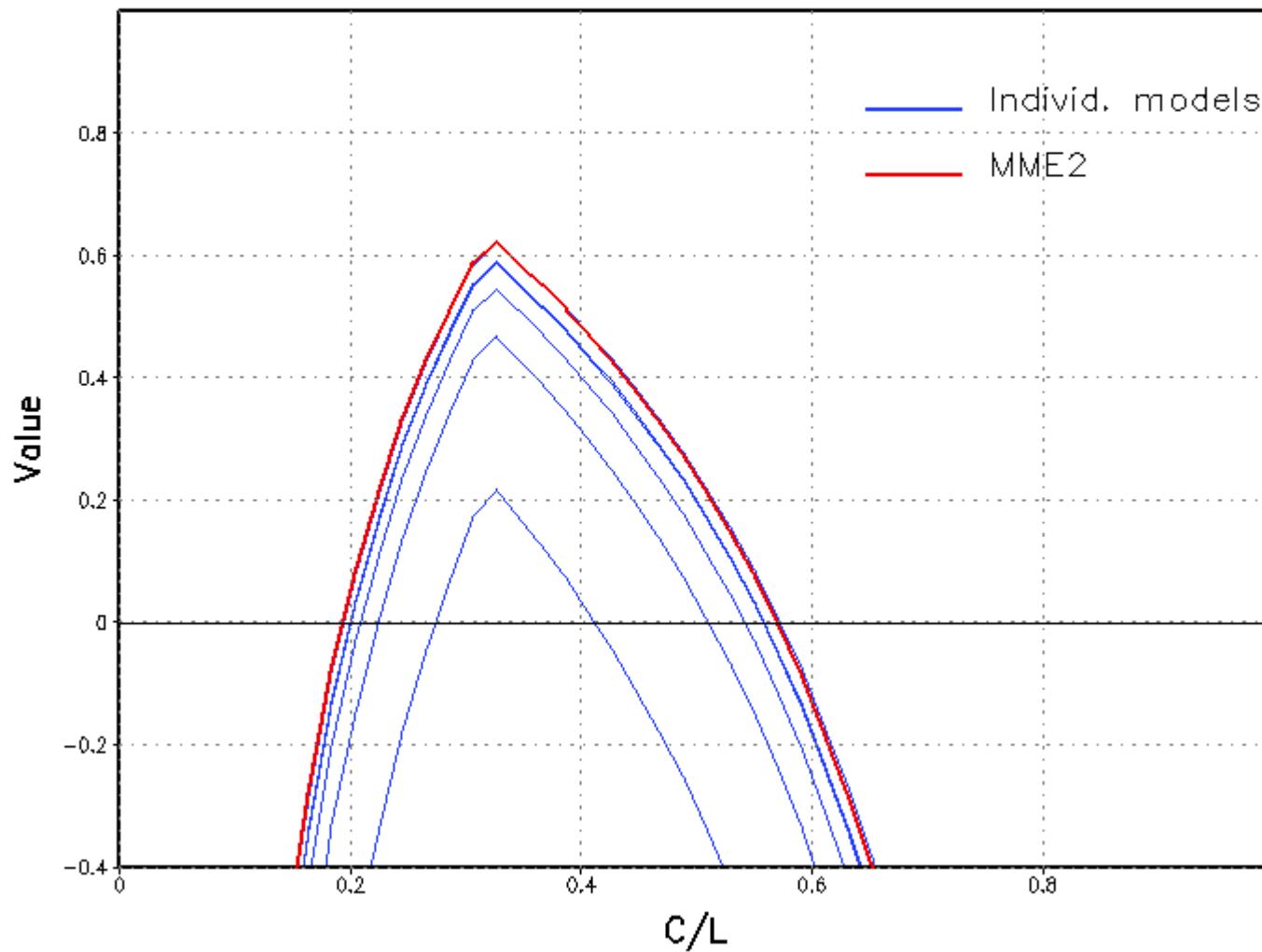
SVD



MME4



ECONOMIC VALUE Precip. JJA Tropics



SUMMARY

An Assessment has been carried out for each APCN Member Model

Significant Improvements in Skill come by using the APCN MME Procedures compared to those of individual Models

However, over the Asian Monsoon region, the skill remains too low.

This could be due to weakness in the hindcast data as well as weakness in the MME Procedures.

Economic Values of such predictions have been evaluated.

Improvements are required in MME Procedures to improve the quality of seasonal predictions