

Seasonal Forecast Verification



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- Definition of verification system for seasonal forecast
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Introduction

In this training, we consider the problem of quantifying the skill of a forecast.

Analysis of verification statistics and their components can help in the assessment of specific strengths and weaknesses of forecasting system.

Definition of Verification System



Definition of verification system

□ Root Mean Square Error (RMSE)

RMSE indicates measure of accuracy of the forecast (f) compared with observation (o). Then RMSE is defined as,

$$RMSE = \sqrt{\frac{1}{W} \sum_{i=1}^N w_i (f_i - o_i)^2}$$

where w is latitude weight, W is summation of w, and subscript i is grid point. RMSE indicates total amount of difference between forecast and observation map. The score is always greater than or equal to 0.0.

Definition of verification system

▣ Anomaly Correlation Coefficient (ACC)

ACC is pattern correlation between predicted and analyzed anomalies defined as,

$$ACC = \frac{\sum_{i=1}^N w_i (f_i - \bar{f})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^N w_i (f_i - \bar{f})^2 \sum_{i=1}^N w_i (o_i - \bar{o})^2}}$$

where over bar is time average. ACC indicates spatial similarity between forecast and observation map. The score always ranges from -1.0 to 1.0. If the forecast is perfect, the score of ACC equals to 1.0.

Definition of verification system

□ Mean Square Skill Score (MSSS)

(1)

A detailed description of mean squared skill score (MSSS) is provided by WMO (2002), so only a brief description is presented here. Let o_{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). Then, their averages for the POV, \bar{o}_j and \bar{f}_j and their sample variances s_{oj}^2 and s_{fj}^2 are given by

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

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

Definition of verification system

□ Mean Square Skill Score (MSSS) (2)

The mean squared error of the forecasts is

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

For the case of cross-validated POV climatology forecasts where forecast/observation pairs are reasonably temporally independent of each other (so that only one year at a time is withheld), the mean squared error of 'climatology' forecasts (Murphy 1988) is

$$MSE_{cj} = \left(\frac{n}{n-1} \right)^2 s_{xj}^2$$

Definition of verification system

□ Mean Square Skill Score (MSSS)

(3)

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'

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

Definition of verification system

□ Mean Square Skill Score (MSSS)

(4)

An overall MSSS is computed as,

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

where w_j is unity for verifications at stations and is equal to $\cos(\theta_j)$, where θ_j is the latitude at grid point j on latitude-longitude grids.

For either $MSSS_j$ or $MSSS$ a corresponding Root Mean Squared Skill Score (RMSSS) can be obtained easily from

$$RMSSS = 1 - (1 - MSSS)^{1/2}$$

Definition of verification system

□ Mean Square Skill Score (MSSS)

(5)

MSSS_j for forecasts fully cross-validated (with one year at a time withheld) can be expanded (Murphy 1988) as

$$MSSS_j = \left\{ 2 \frac{S_{ff}}{S_{xj}} r_{fxj} - \left(\frac{S_{ff}}{S_{xj}} \right)^2 - \left(\frac{[\bar{f}_j - \bar{x}_j]}{S_{xj}} \right)^2 + \frac{2n-1}{(n-1)^2} \right\} / \left\{ 1 + \frac{2n-1}{(n-1)^2} \right\}$$

where r_{fxj} is the product moment correlation of the forecasts and observations at point or station j

$$r_{fxj} = \frac{\frac{1}{n} \sum_{i=1}^n (f_{ij} - \bar{f}_j)(x_{ij} - \bar{x}_j)}{S_{ff} S_{xj}}$$

Definition of verification system

□ Mean Square Skill Score (MSSS) (6)

$$MSSS_j = \left\{ \underbrace{2 \frac{S_{ff}}{S_{xj}}}_{\text{A}} \underbrace{r_{fxj}}_{\text{B}} - \underbrace{\left(\frac{S_{ff}}{S_{xj}} \right)^2}_{\text{C}} - \left(\frac{[\bar{f}_j - \bar{x}_j]}{S_{xj}} \right)^2 + \frac{2n-1}{(n-1)^2} \right\} / \left\{ 1 + \frac{2n-1}{(n-1)^2} \right\}$$

A: phase errors

B: amplitude errors

C: bias errors

$$r_{fxj} = \frac{\frac{1}{n} \sum_{i=1}^n (f_{ij} - \bar{f}_j)(x_{ij} - \bar{x}_j)}{S_{ff} S_{xj}}$$

Definition of verification system

□ Taylor Diagram

(1)

Karl Taylor (2000) has devised a very useful diagrammatic form (termed "Taylor diagram") for conveying information about the pattern similarity between a model and observations.

Definition of verification system

□ Taylor Diagram (2)

The correlation coefficient R between f and o is calculated with the following formula,

$$R = \frac{\frac{1}{N} \sum_{i=1}^N (f_i - \bar{f})(o_i - \bar{o})}{\sigma_f \sigma_o}$$

where σ_f and σ_o are standard deviation of f and o , and over bar is the mean value.

$$\sigma_f = \frac{1}{N} \sum_{i=1}^N (f_i - \bar{f})^2$$

$$\sigma_o = \frac{1}{N} \sum_{i=1}^N (o_i - \bar{o})^2$$

Definition of verification system

□ Taylor Diagram

(3)

The pattern *RMS* difference between f and o is also calculated with the following formula,

$$E' = \sqrt{\frac{1}{N} \sum_{i=1}^N [(f_i - \bar{f}) - (o_i - \bar{o})]^2}$$

Definition of verification system

□ Taylor Diagram

(4)

The pattern *RMS* difference between f and o is also calculated with the following formula,

$$E' = \sqrt{\frac{1}{N} \sum_{i=1}^N [(f_i - \bar{f}) - (o_i - \bar{o})]^2},$$

$$E'^2 = \frac{1}{N} \sum_{i=1}^N [(f_i - \bar{f}) - (o_i - \bar{o})]^2,$$

$$E'^2 = \frac{1}{N} \sum_{i=1}^N \underbrace{(f_i - \bar{f})^2}_{\sigma_f^2} + \underbrace{(o_i - \bar{o})^2}_{\sigma_o^2} - 2 \underbrace{(f_i - \bar{f})(o_i - \bar{o})}_{\sigma_f \sigma_o R}$$

Definition of verification system

□ Taylor Diagram

(5)

Therefore,

$$E'^2 = \sigma_f^2 + \sigma_o^2 - 2\sigma_f\sigma_o R,$$

and the Law of Cosines,

$$c^2 = a^2 + b^2 - 2ab \cos \phi.$$

Definition of verification system

□ Taylor Diagram

(6)

The geometric relationship between R , E' , σ_f and σ_r is shown figure.

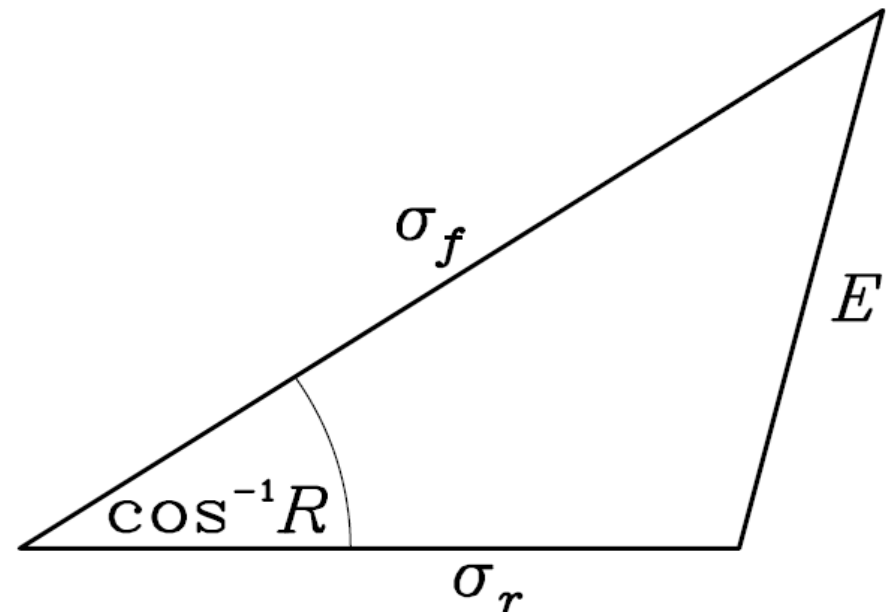


Figure 1: Geometric relationship between the correlation coefficient, R , the pattern RMS error, E' , and the standard deviations, σ_f and σ_r , of the test and reference fields, respectively.

Definition of verification system

□ Taylor Diagram

(7)

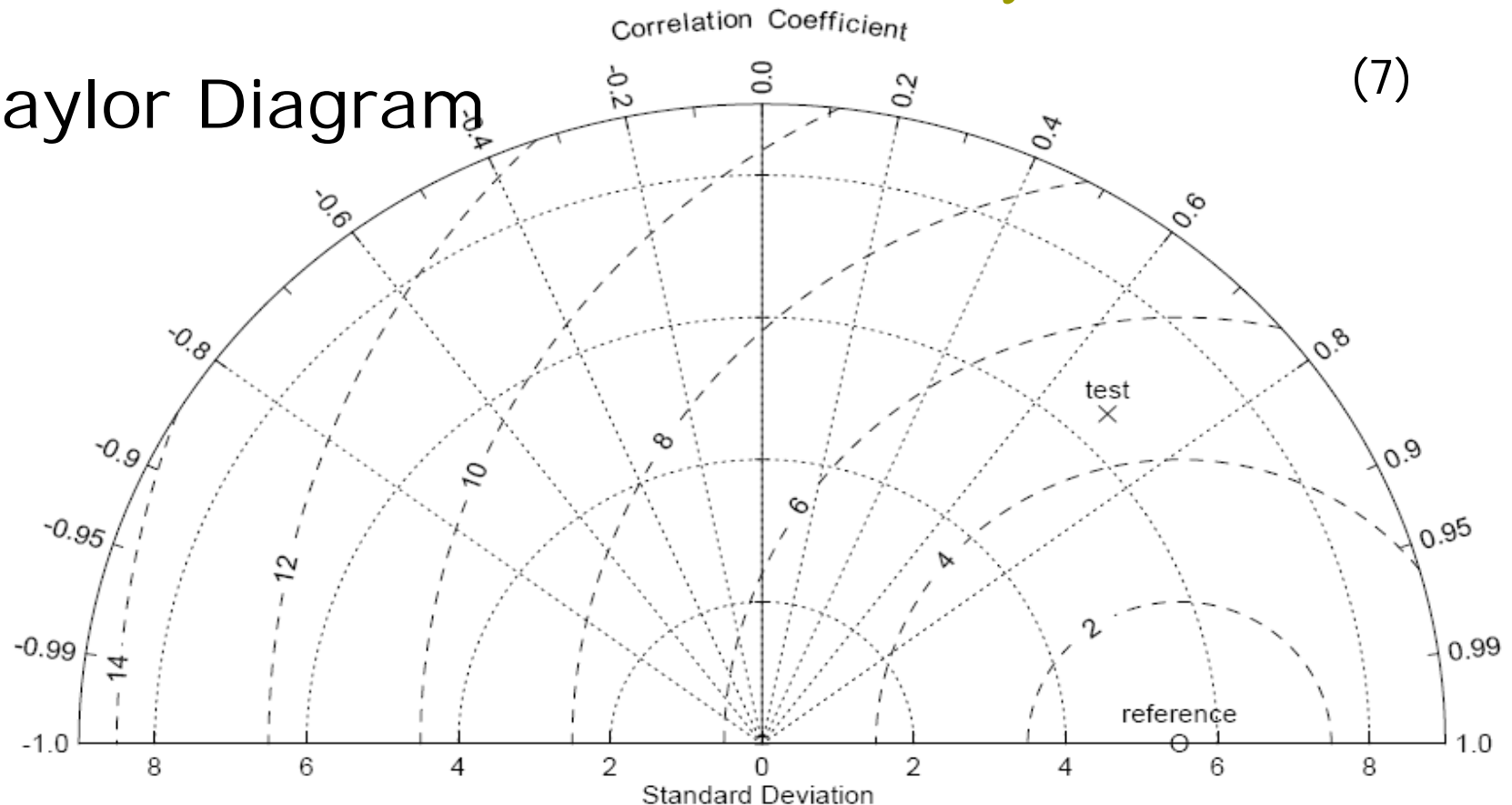


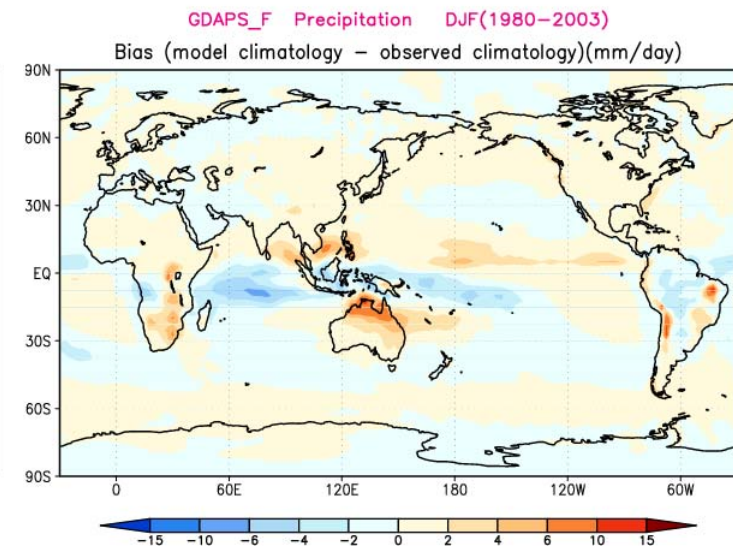
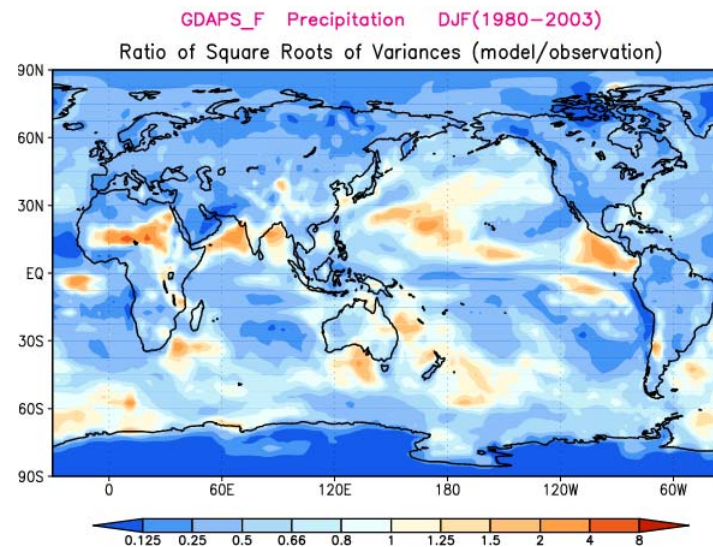
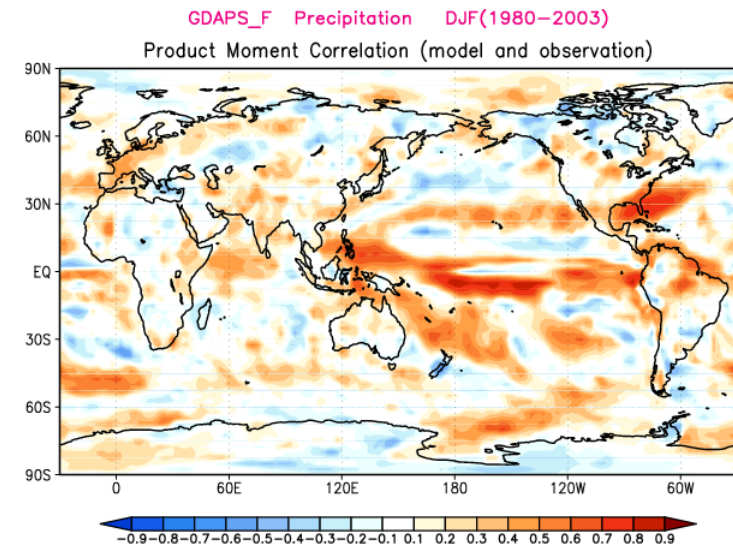
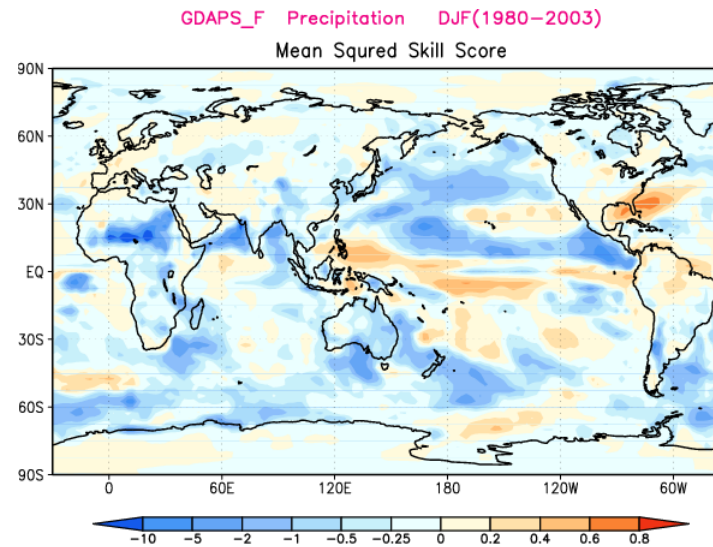
Figure 2: Diagram for displaying pattern statistics. The radial distance from the origin is proportional to the standard deviation of a pattern. The RMS difference between the test and reference field is proportional to their distance apart (in the same units as the standard deviation). The correlation between the two fields is given by the azimuthal position of the test field.

Verification of Hindcast



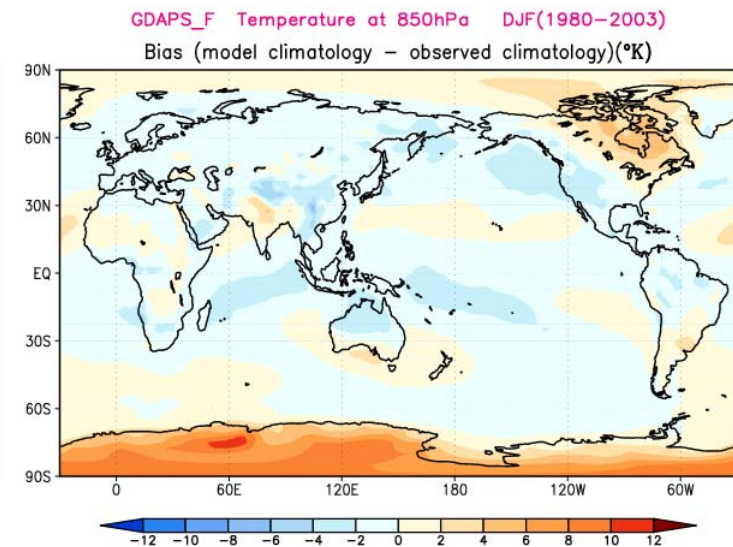
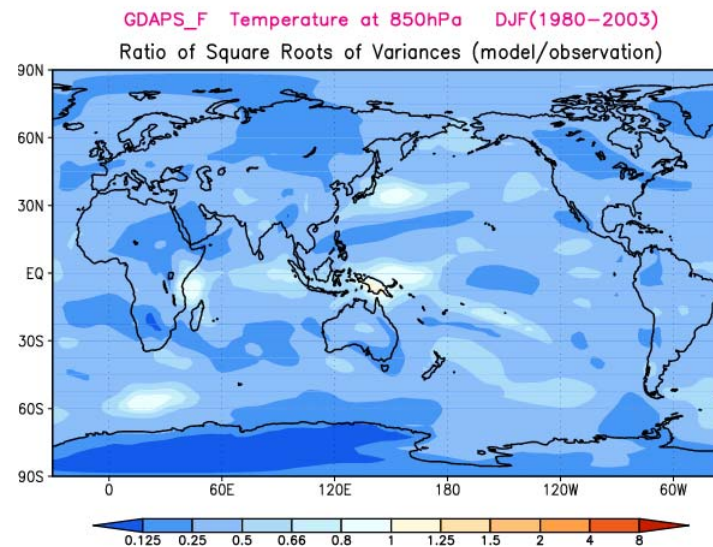
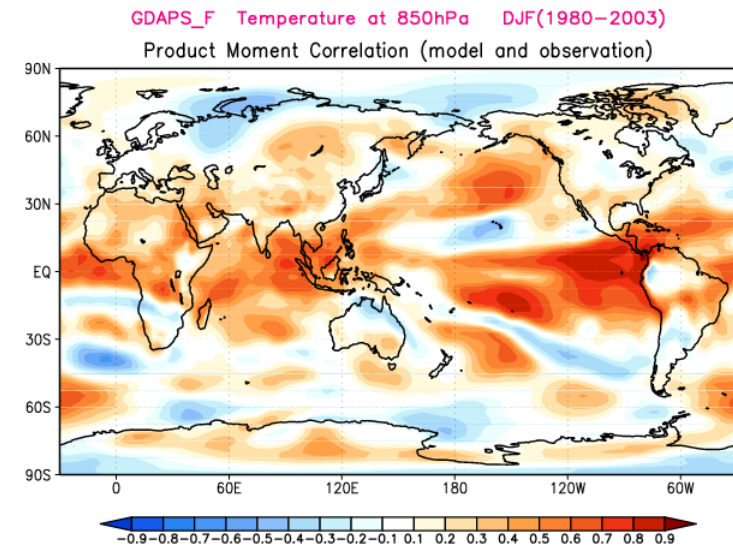
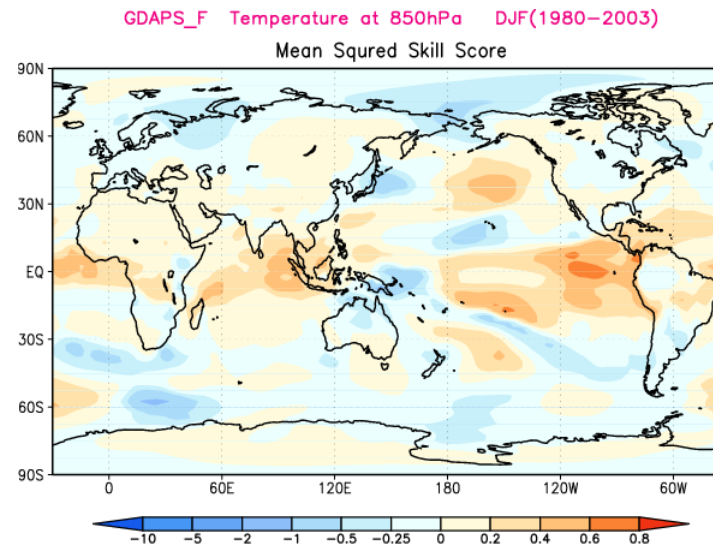
Verification of hindcast

□ MSSS



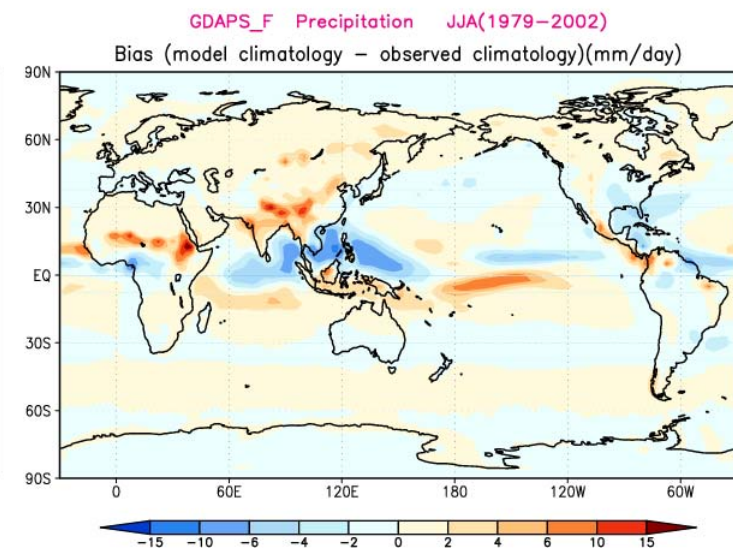
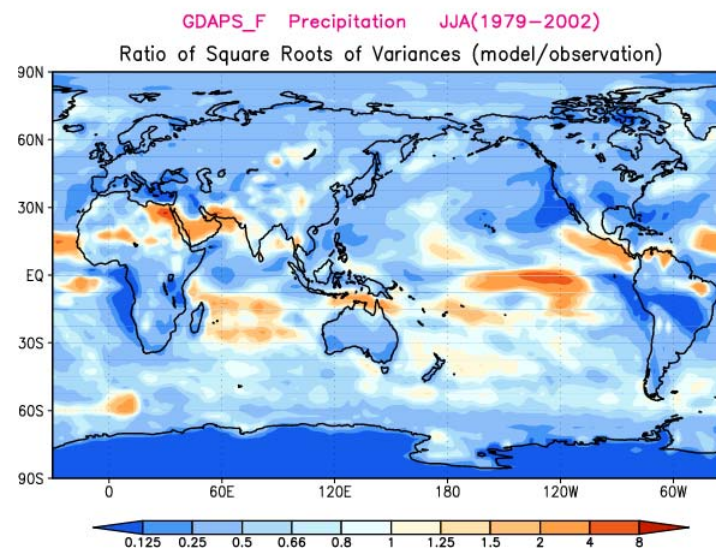
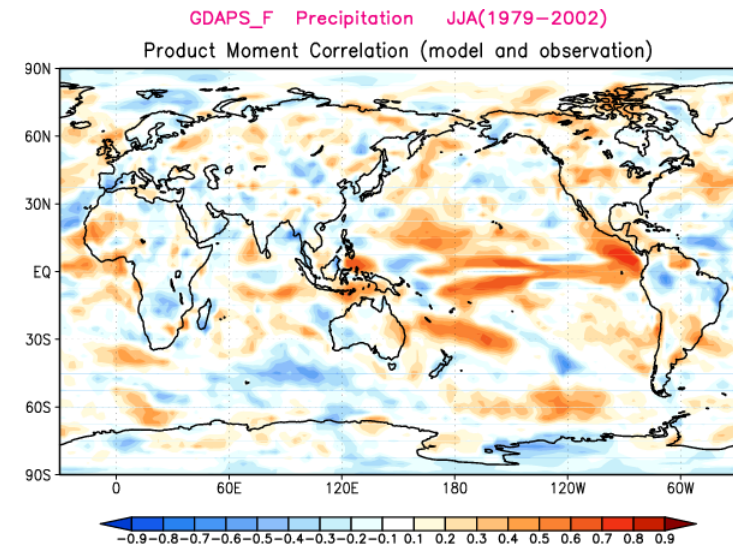
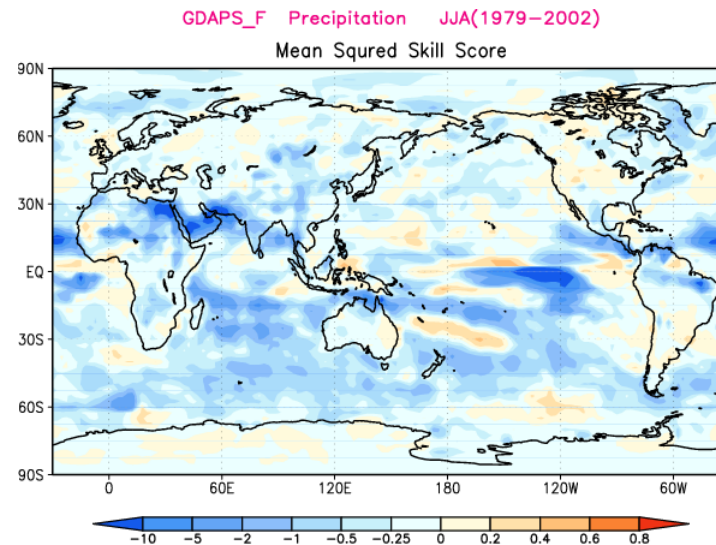
Verification of hindcast

□ MSSS



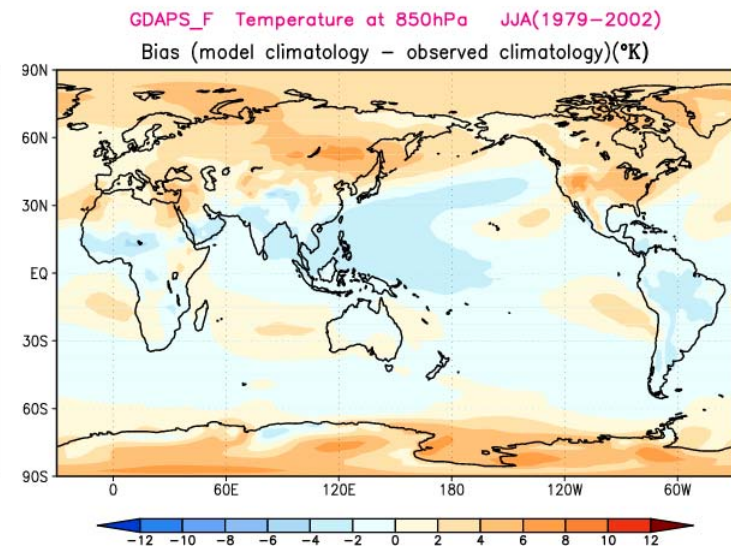
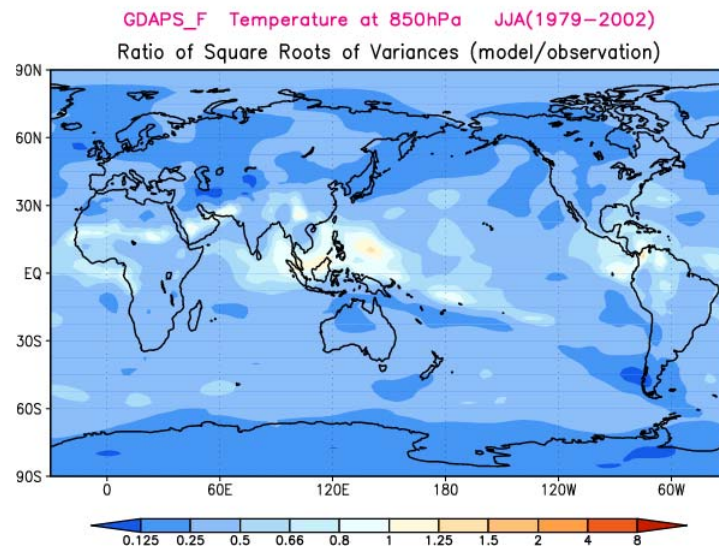
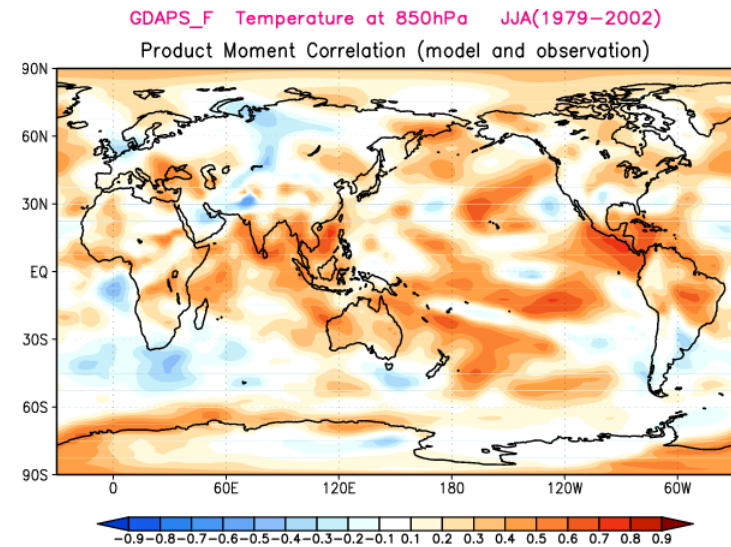
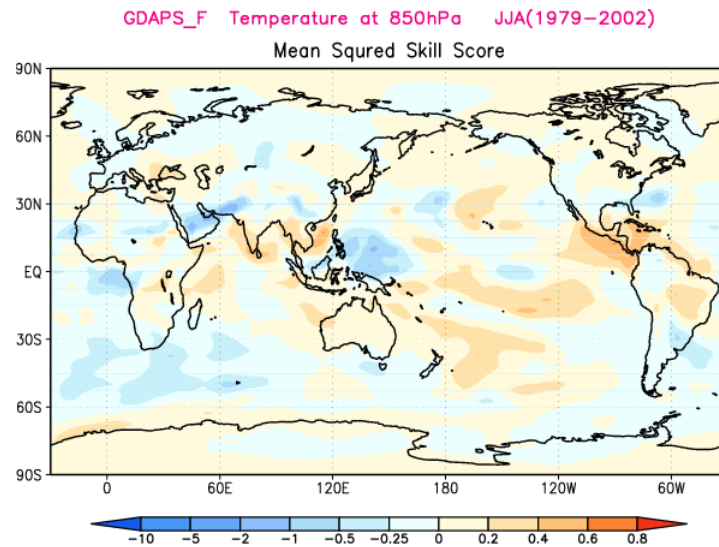
Verification of hindcast

□ MSSS



Verification of hindcast

□ MSSS

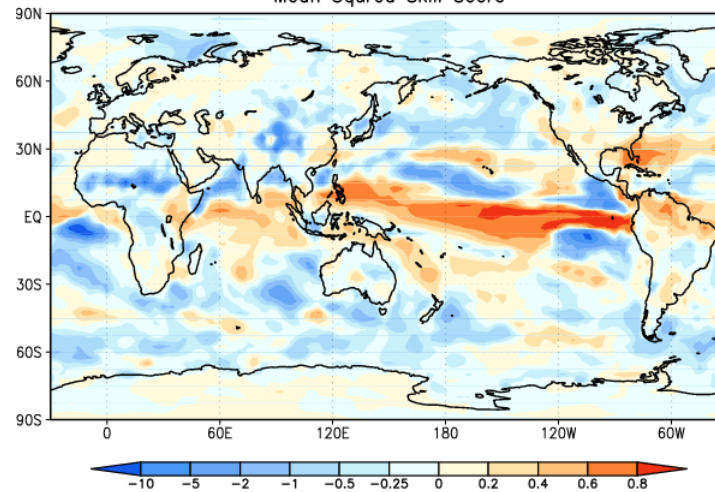


Verification of hindcast

□ MSSS

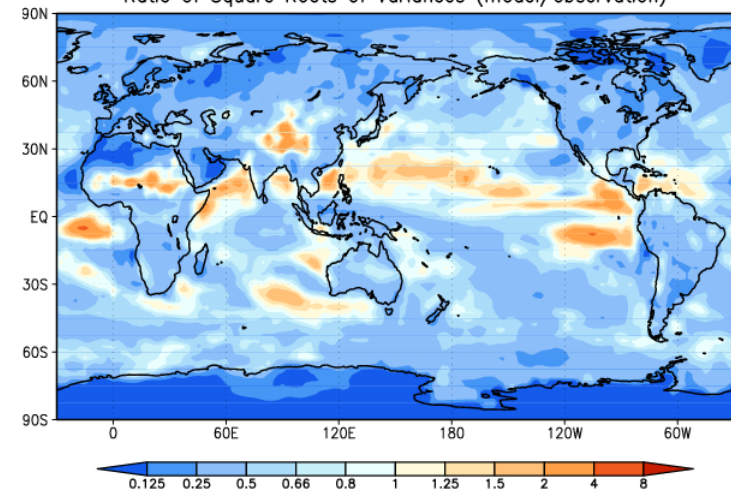
SCM Precipitation DJF(1981–1998)

Mean Squared Skill Score



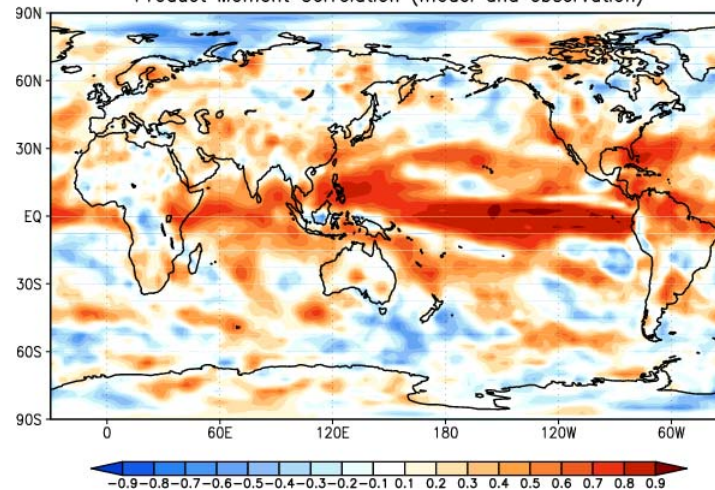
SCM Precipitation DJF(1981–1998)

Ratio of Square Roots of Variances (model/observation)



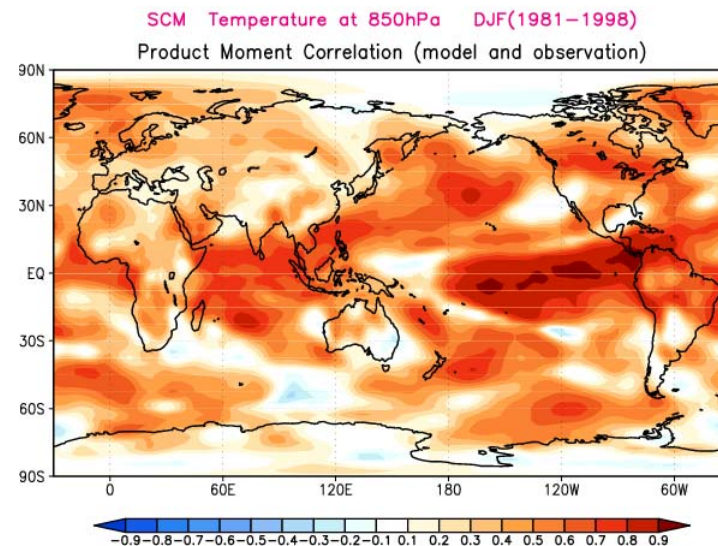
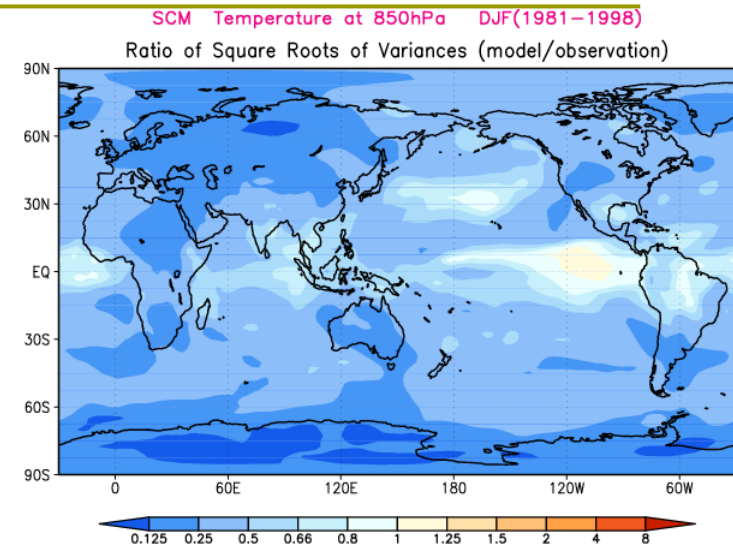
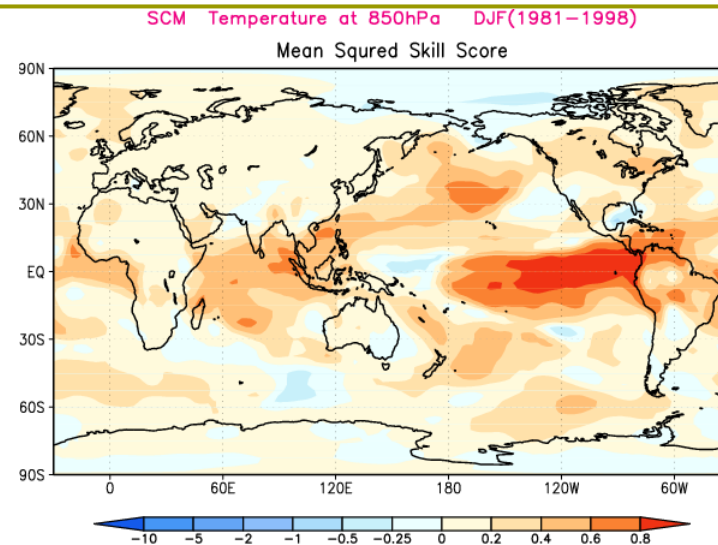
SCM Precipitation DJF(1981–1998)

Product Moment Correlation (model and observation)



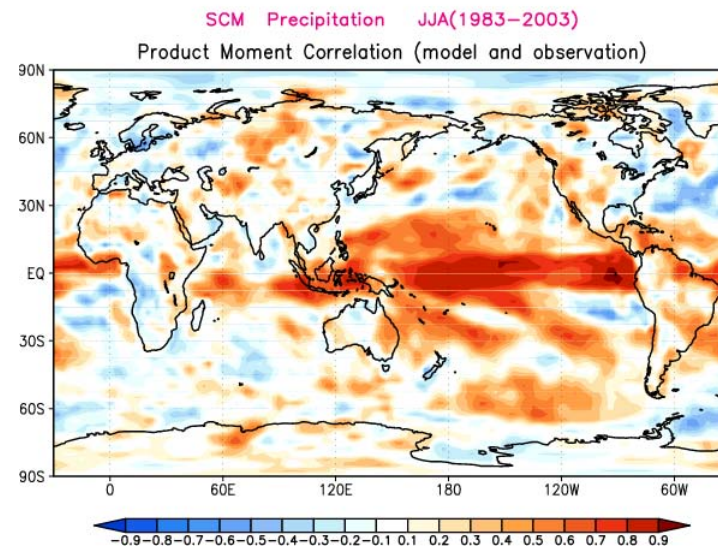
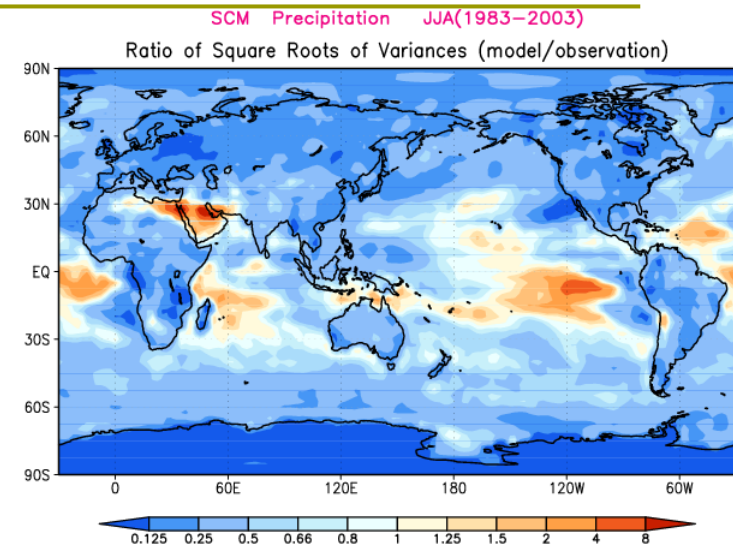
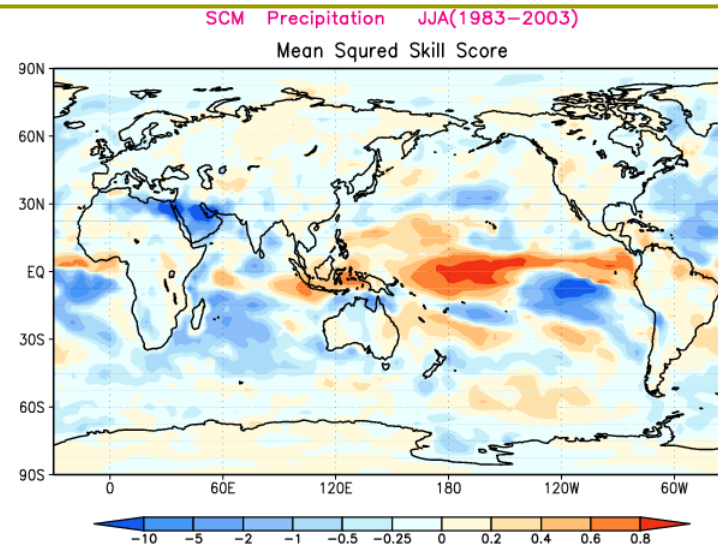
Verification of hindcast

□ MSSS



Verification of hindcast

□ MSSS

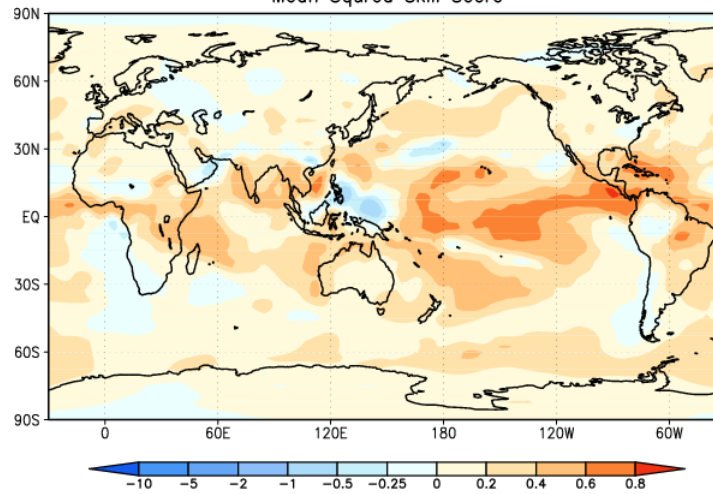


Verification of hindcast

□ MSSS

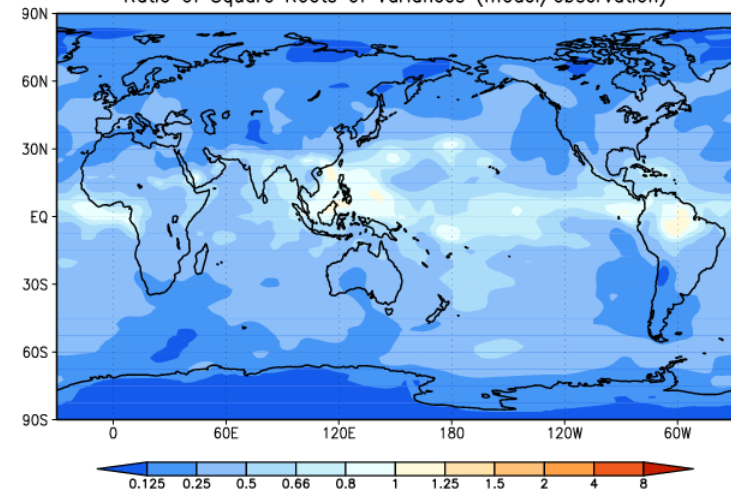
SCM Temperature at 850hPa JJA(1983–2003)

Mean Squared Skill Score



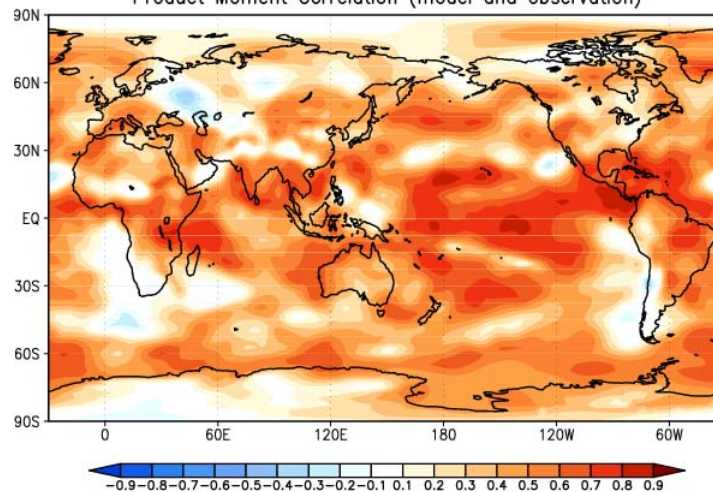
SCM Temperature at 850hPa JJA(1983–2003)

Ratio of Square Roots of Variances (model/observation)



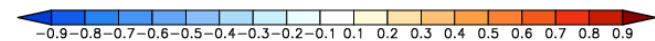
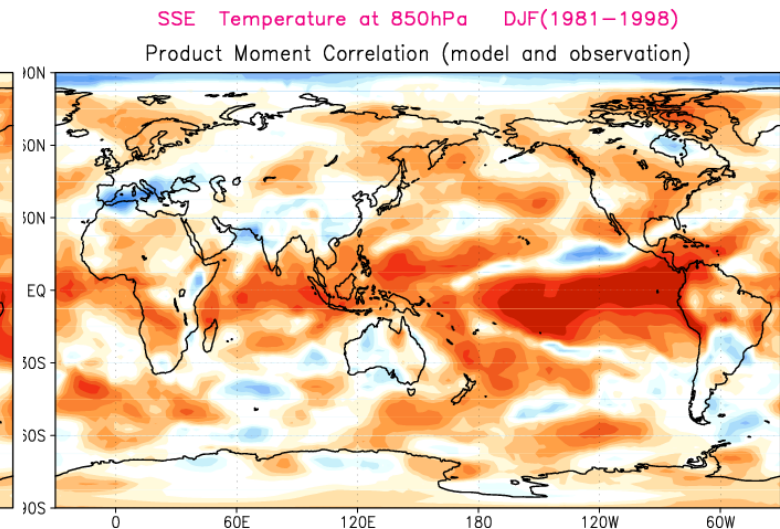
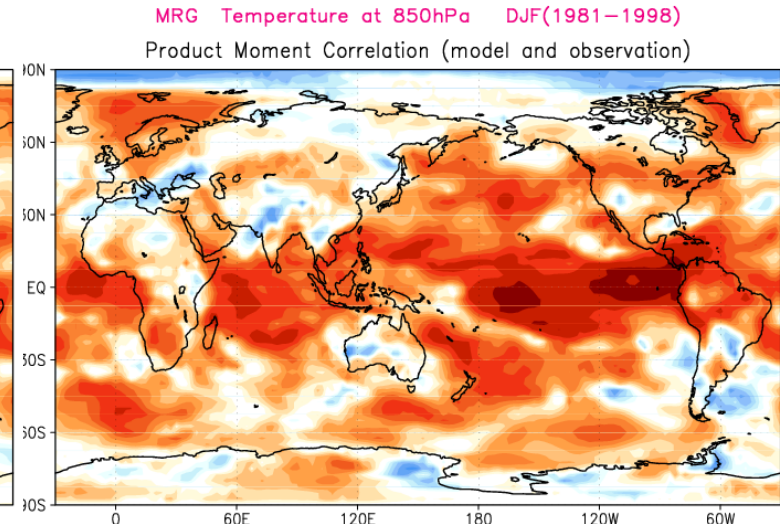
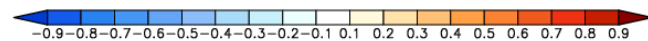
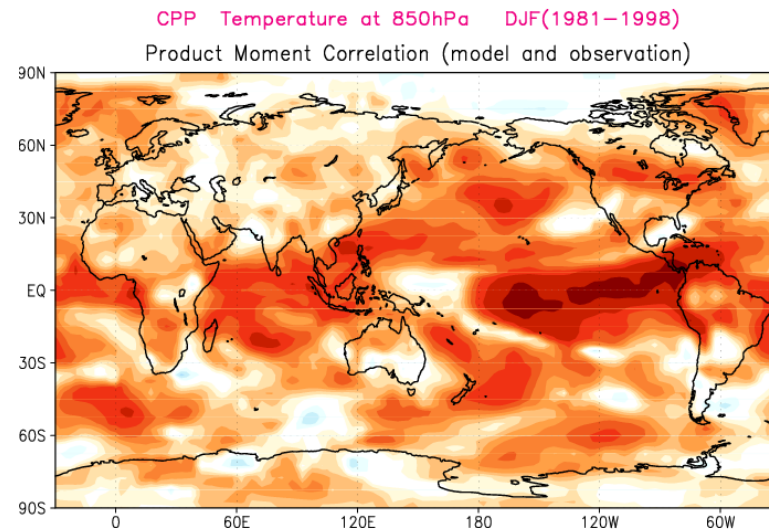
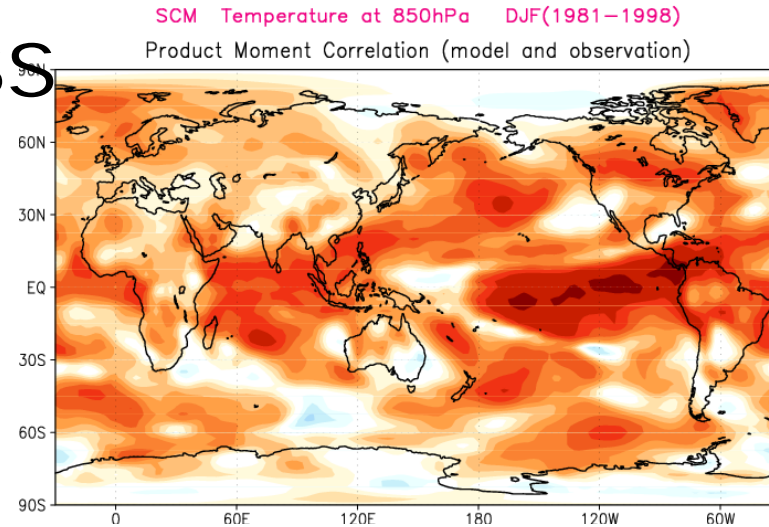
SCM Temperature at 850hPa JJA(1983–2003)

Product Moment Correlation (model and observation)



Verification of hindcast

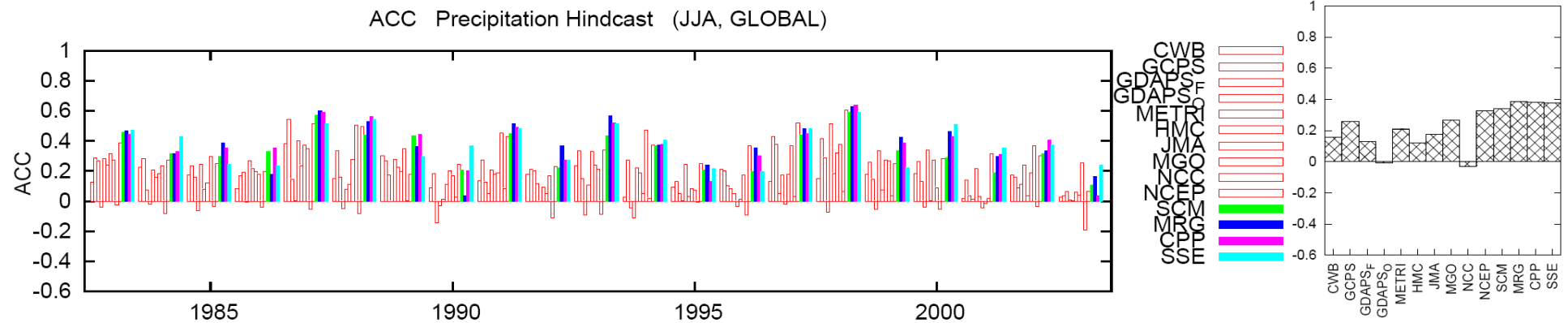
□ MSSS



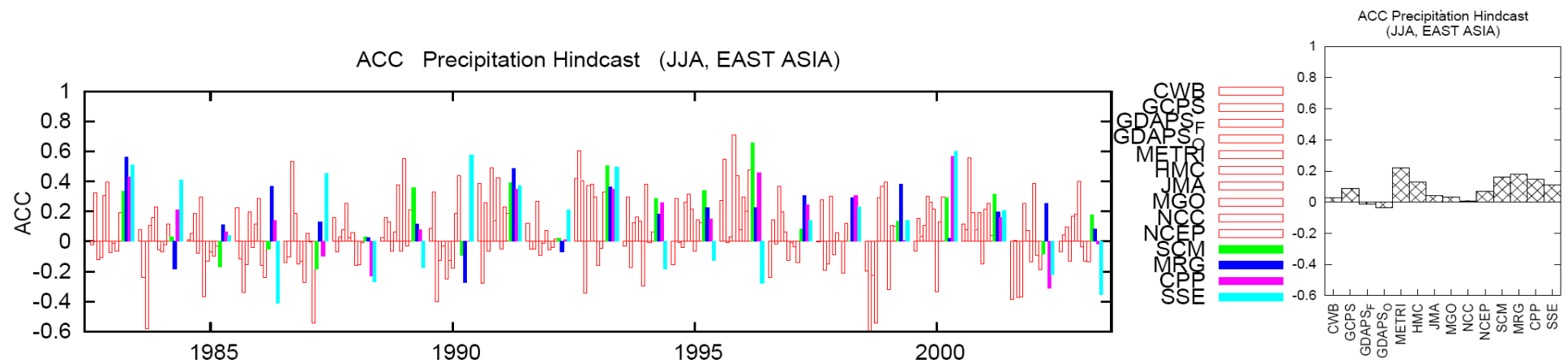
Verification of hindcast

ACC

ACC Prec. Global JJA



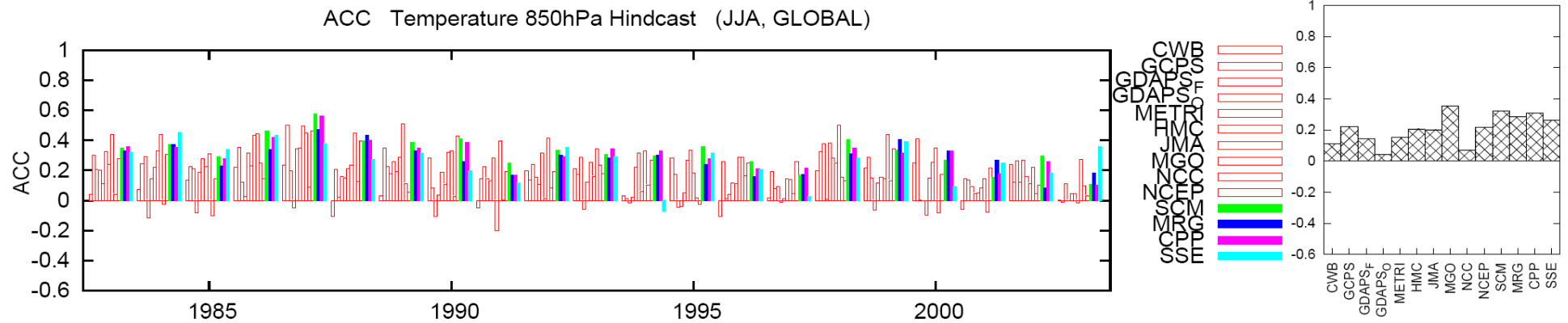
ACC Prec. East Asia JJA



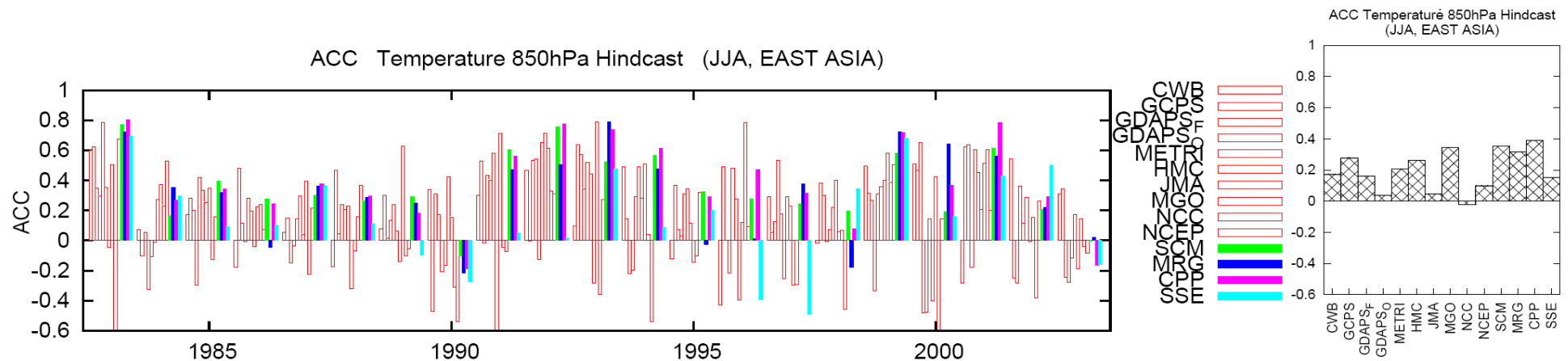
Verification of hindcast

ACC

ACC T850 Global JJA



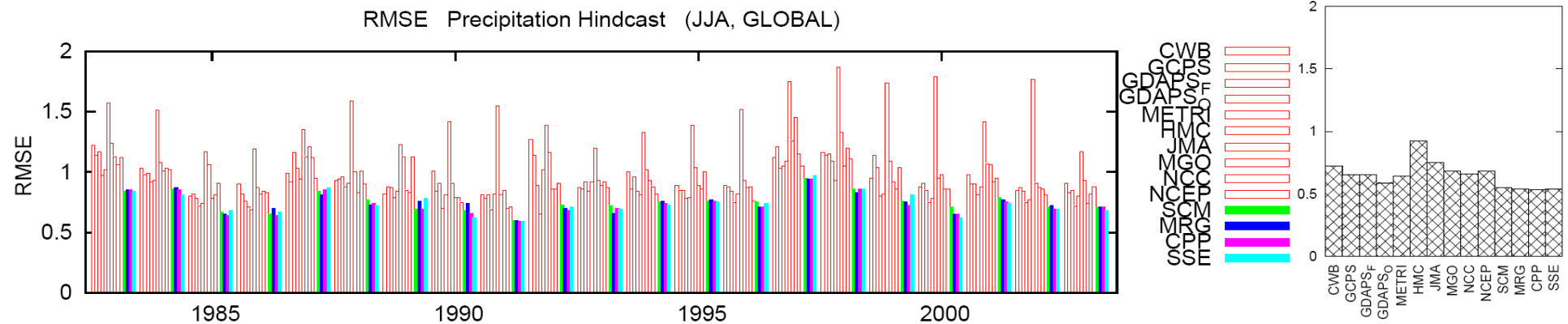
ACC T850 East Asia JJA



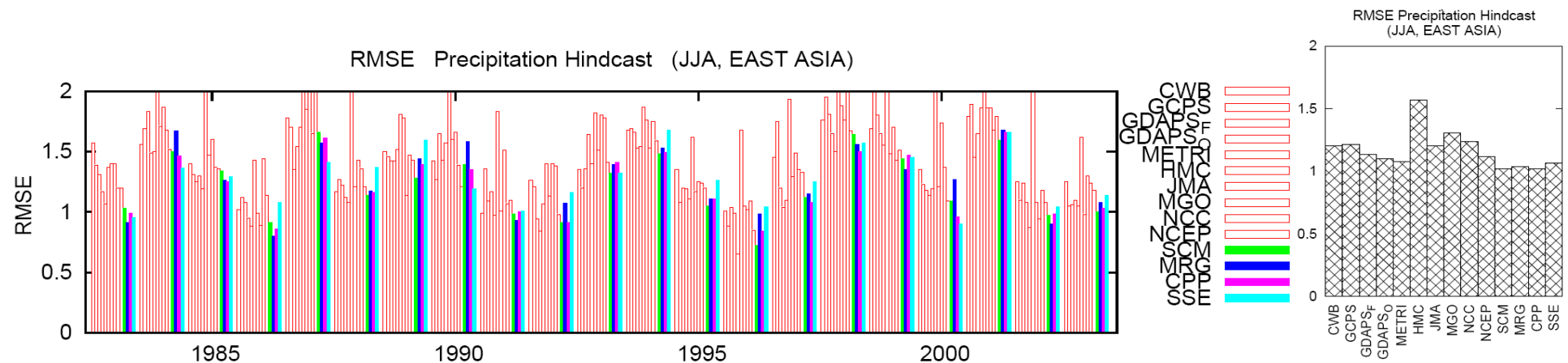
Verification of hindcast

RMSE

RMSE Prec. Global JJA



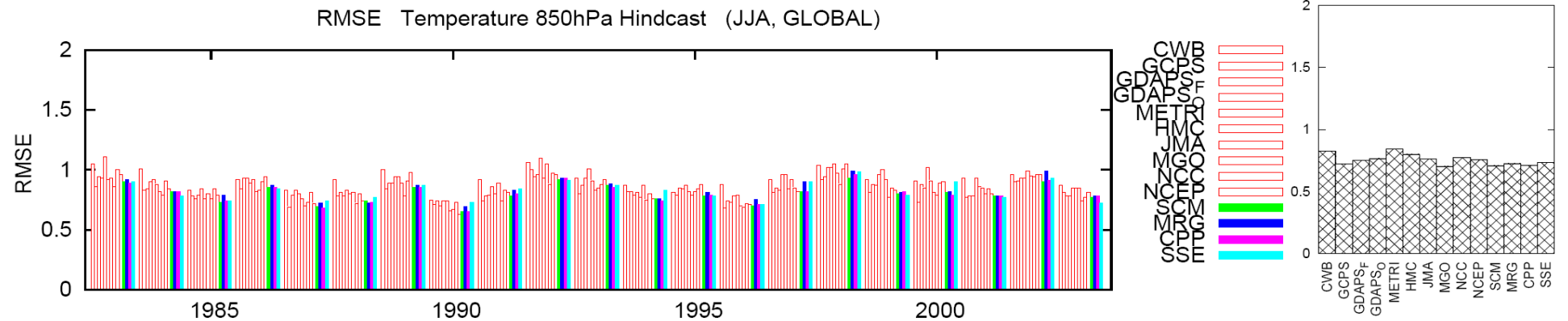
RMSE Prec. East Asia JJA



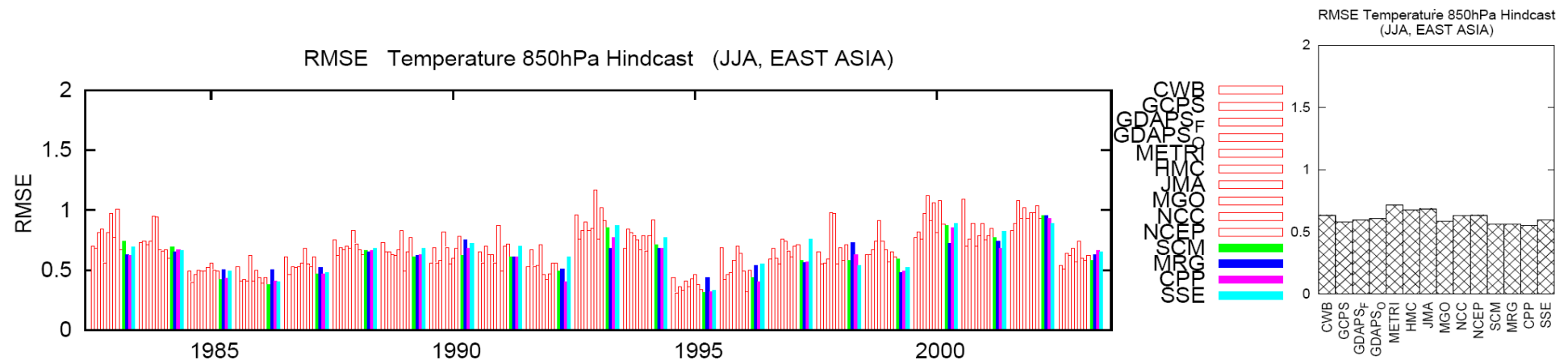
Verification of hindcast

RMSE

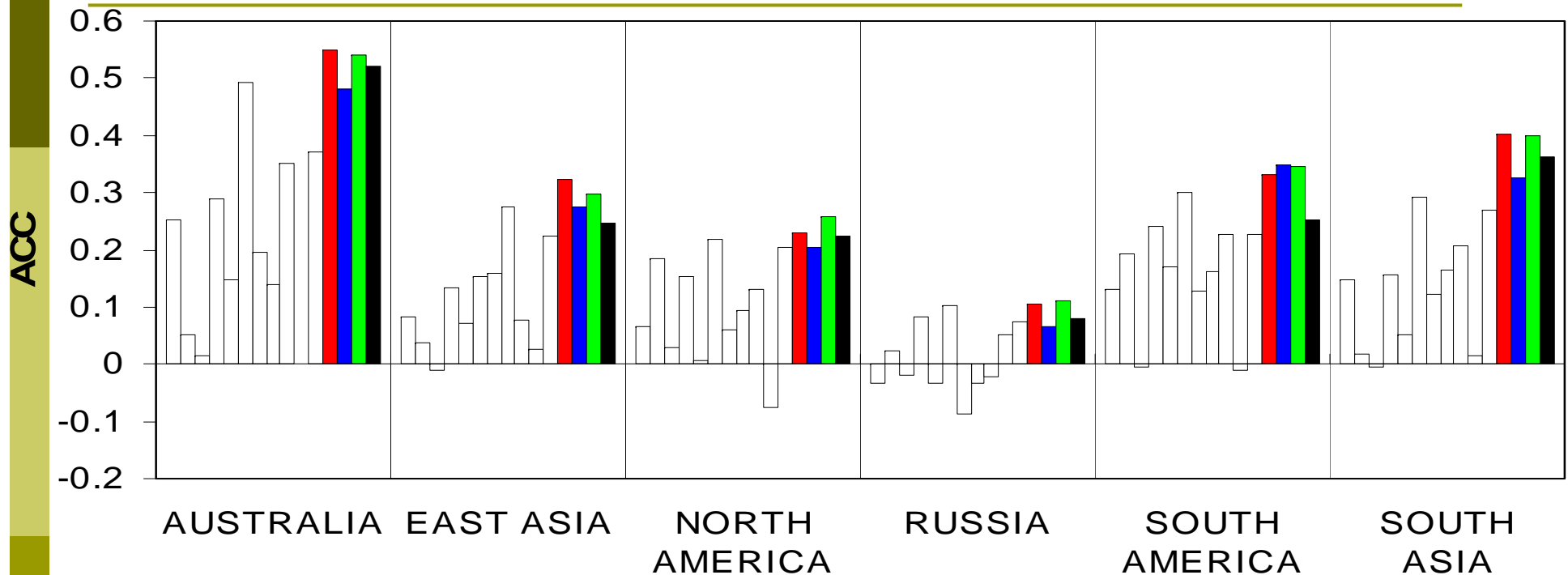
RMSE T850 Global JJA



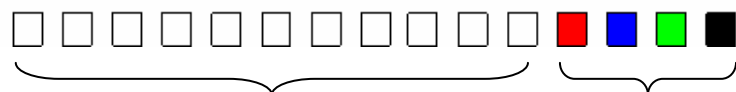
RMSE T850 East Asia JJA



Verification of hindcast

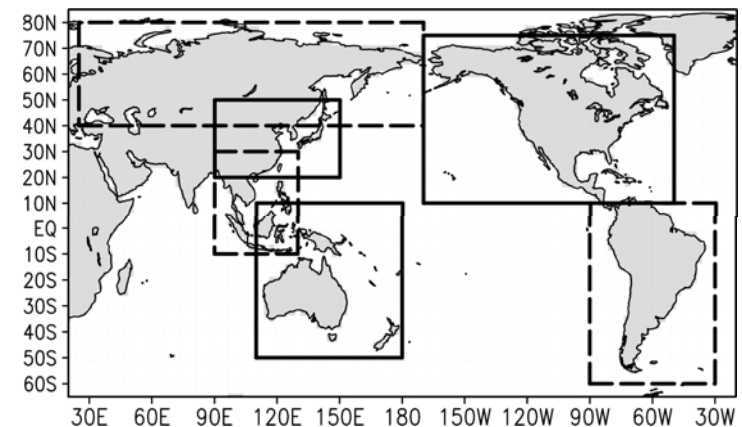


Anomaly Correlation Coefficient for hindcast
in each region (precipitation, JJA, 1983-2003)

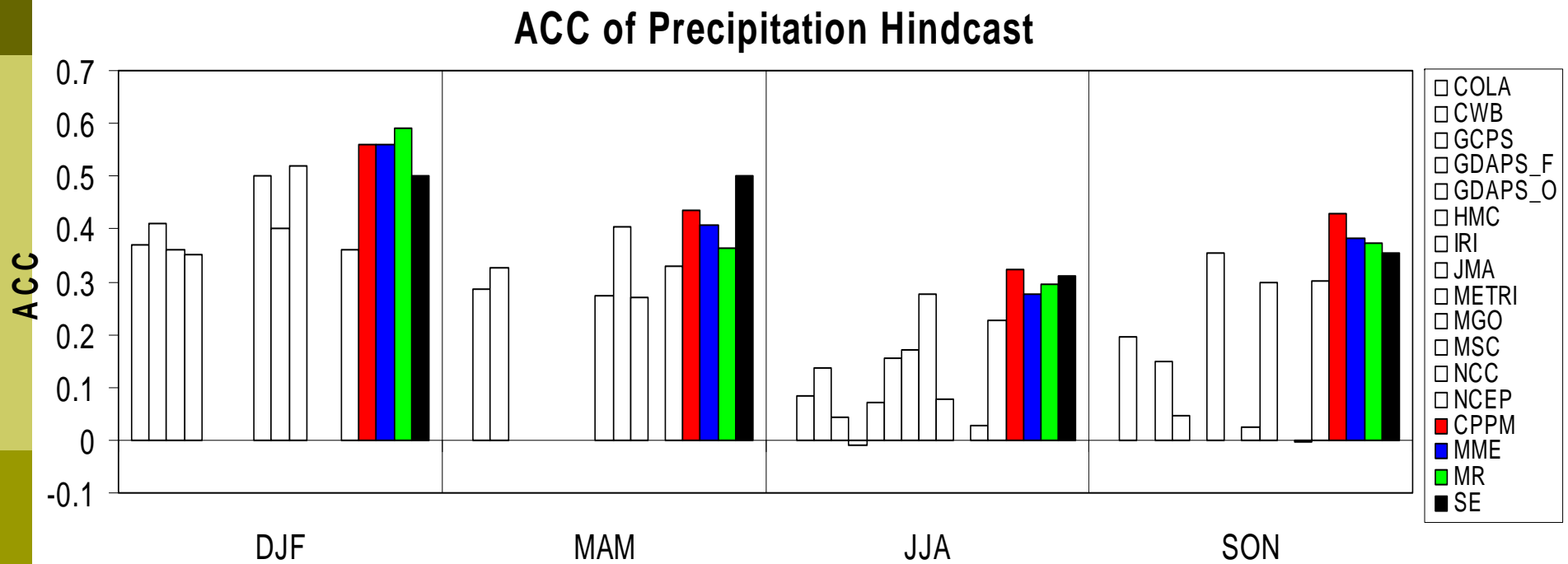


individual model

multi-model
ensemble schemes



Verification of hindcast



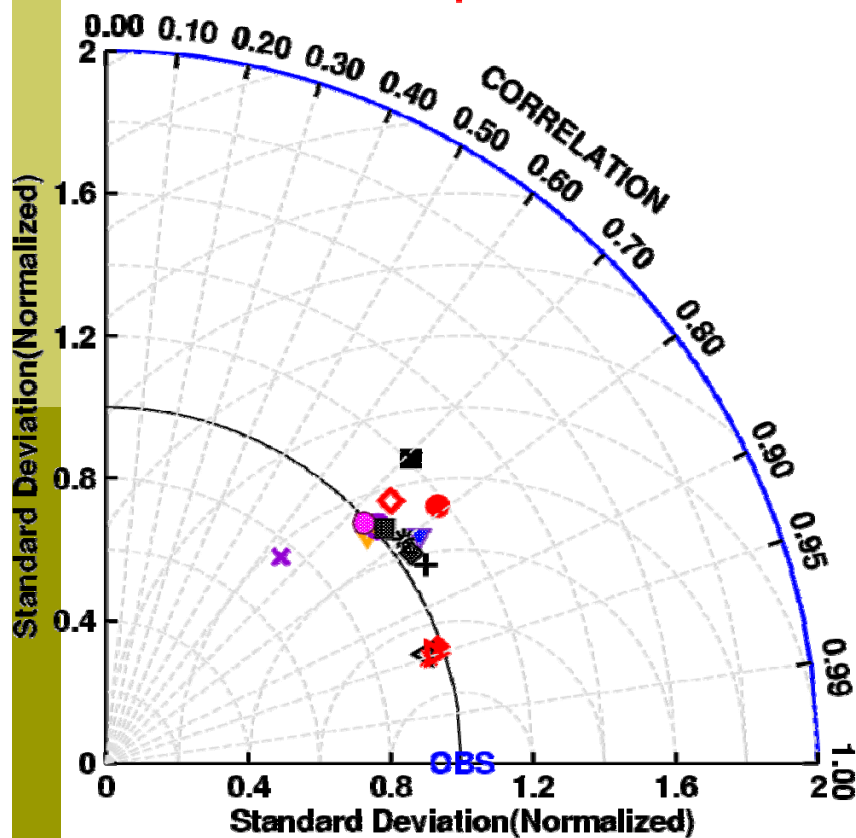
**Seasonality of ACC of precipitation hindcast in East Asia
(average from 1983 to 2003)**

Verification of hindcast

□ Taylor diagram

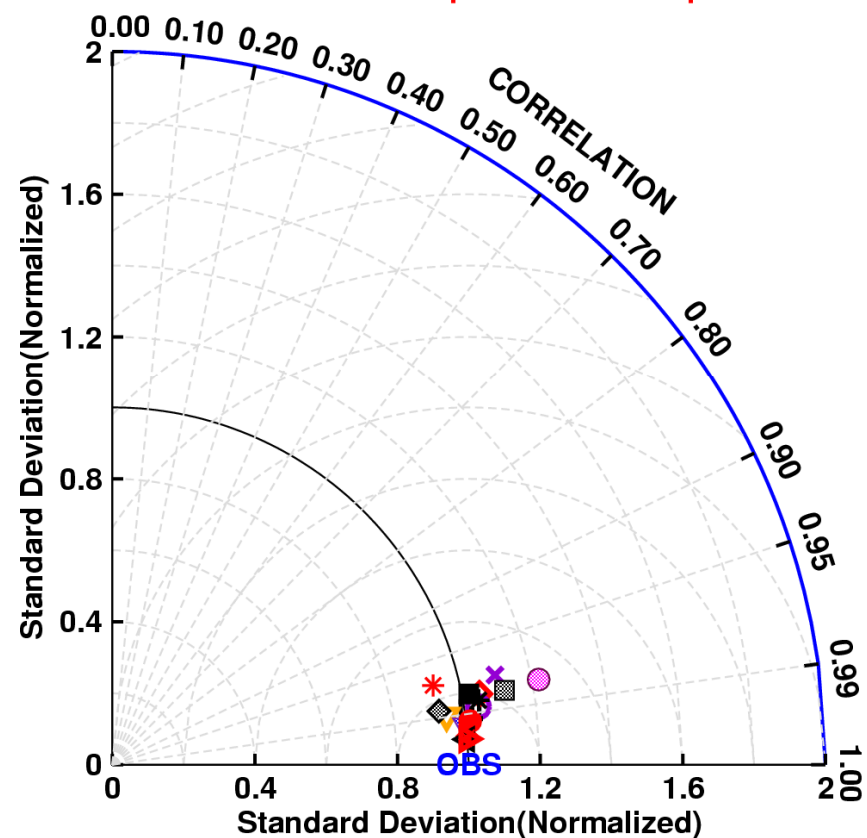
Total Space-Time Pattern Analysis: DJF

Precipitation



Total Space-Time Pattern Analysis: DJF

Temperature at 850hpa



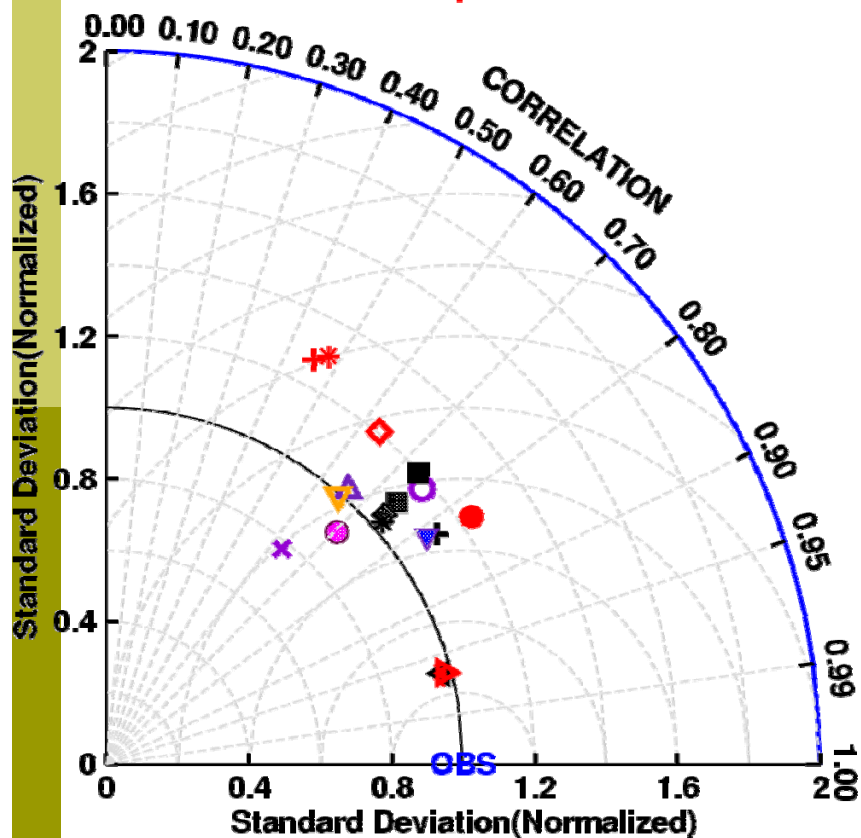
- COLA
- ◇ CWB
- ▽ GDAPS_O
- GCPS
- * HMC
- × IAP
- + IRI
- ▽ JMA
- METRI
- MGO
- ◆ MSC
- * NASA
- NCEP
- POAMA
- ◇ CPP
- ▽ SCM
- △ MRG
- × SSE

Verification of hindcast

□ Taylor diagram

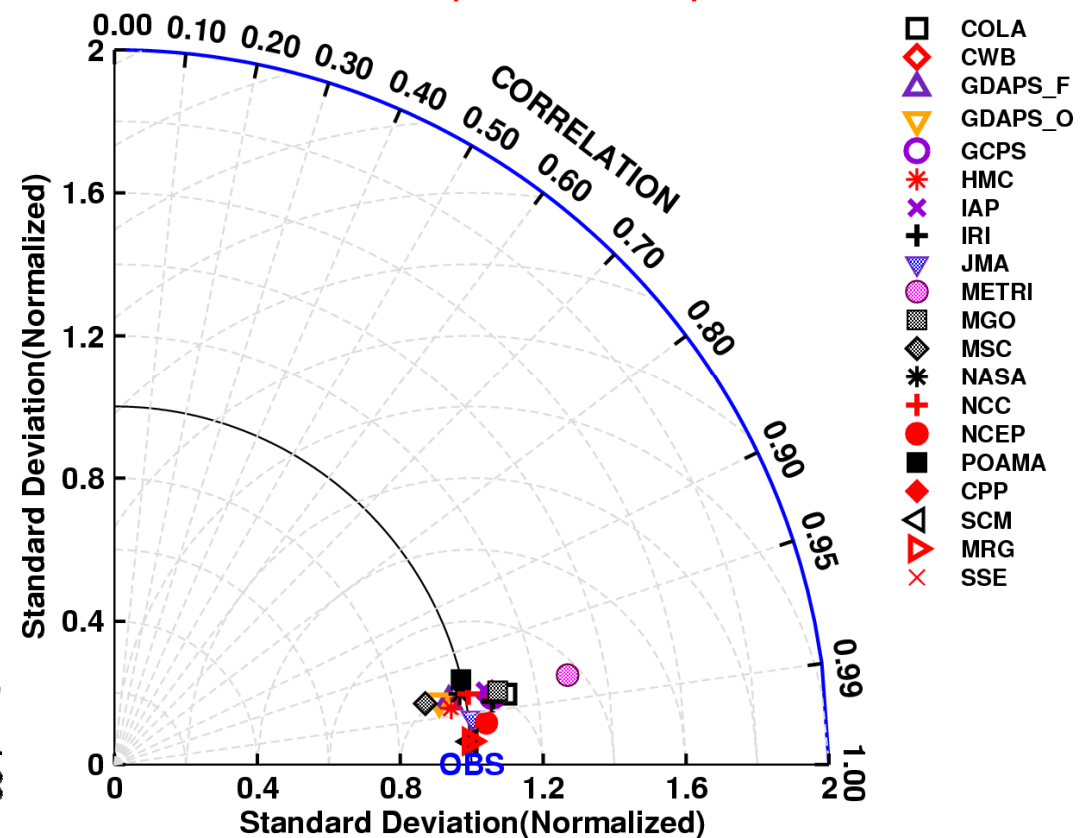
Total Space-Time Pattern Analysis: JJA

Precipitation



Total Space-Time Pattern Analysis: JJA

Temperature at 850hpa

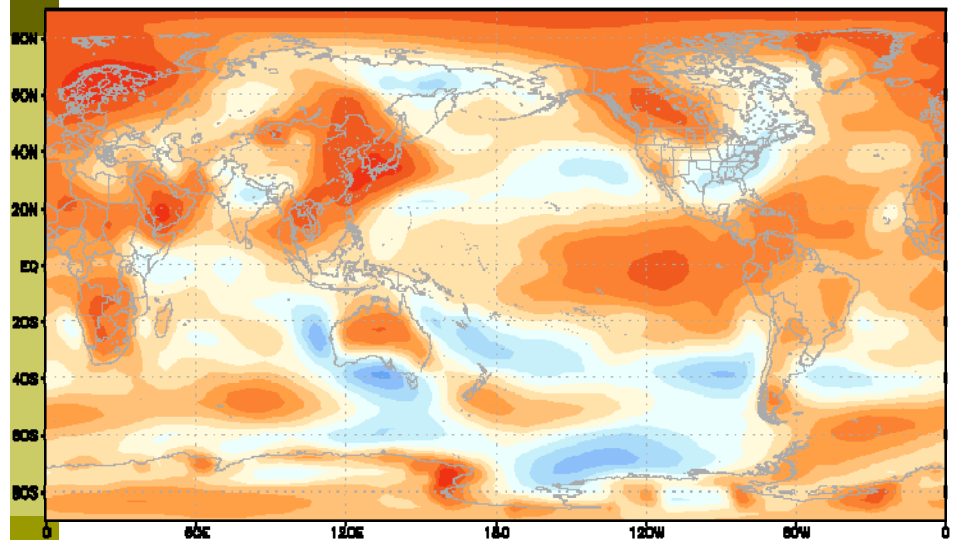


Assessment of Seasonal Forecast



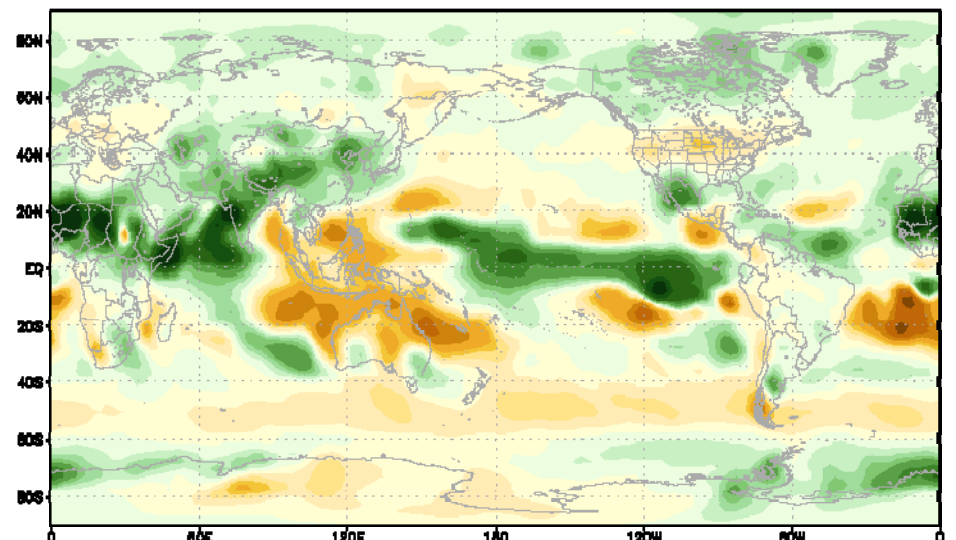
Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, DJF 2008_07



-1.6 -1.2 -0.8 -0.6 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.6 0.8 1.2 1.6 [°C]

Percent of Precipitation (1983–2003 base period)
APCC_MME, DJF 2008_07

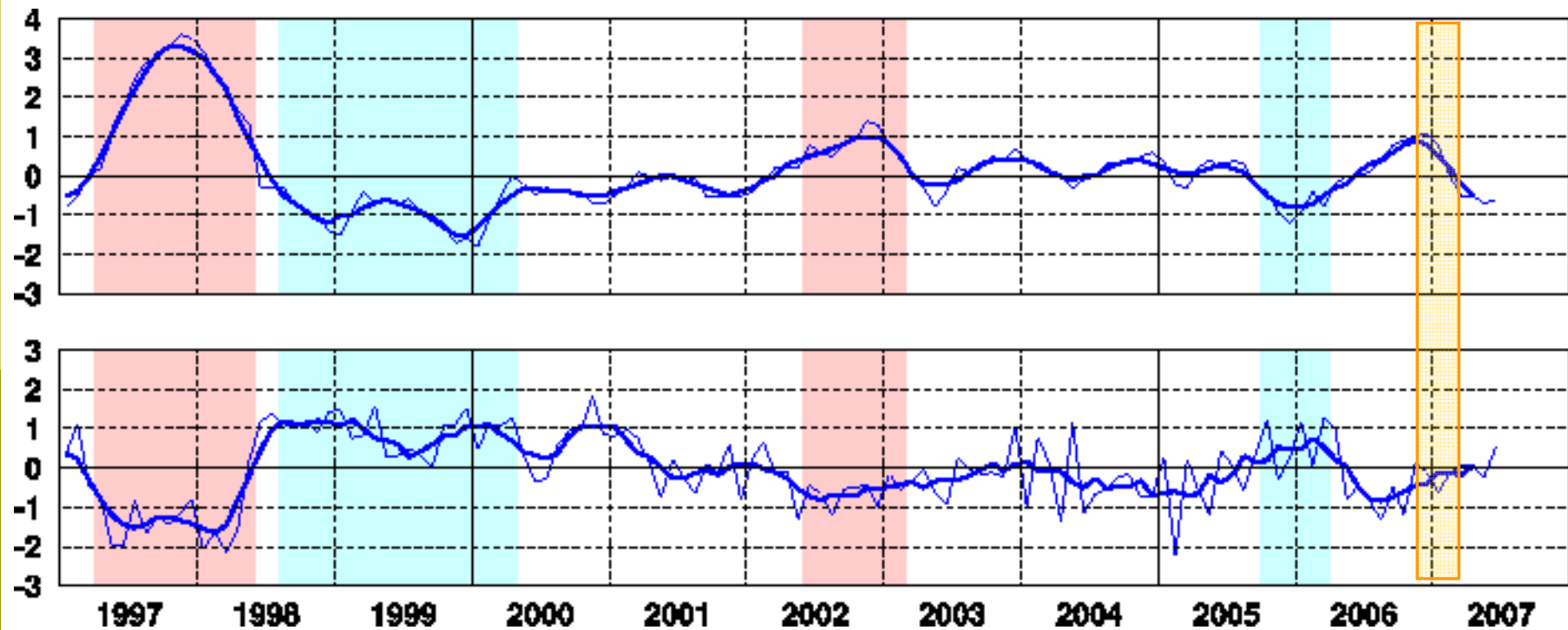


20 40 60 70 80 85 90 95 100 105 110 115 120 130 140 160 [%]

Assessment of Seasonal Forecast

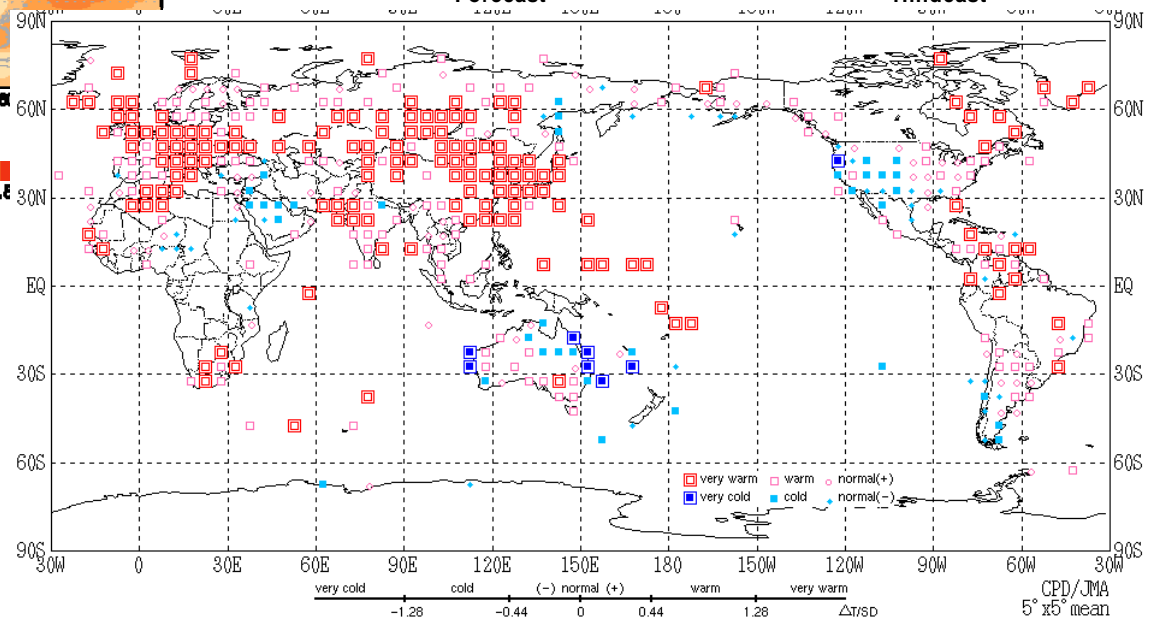
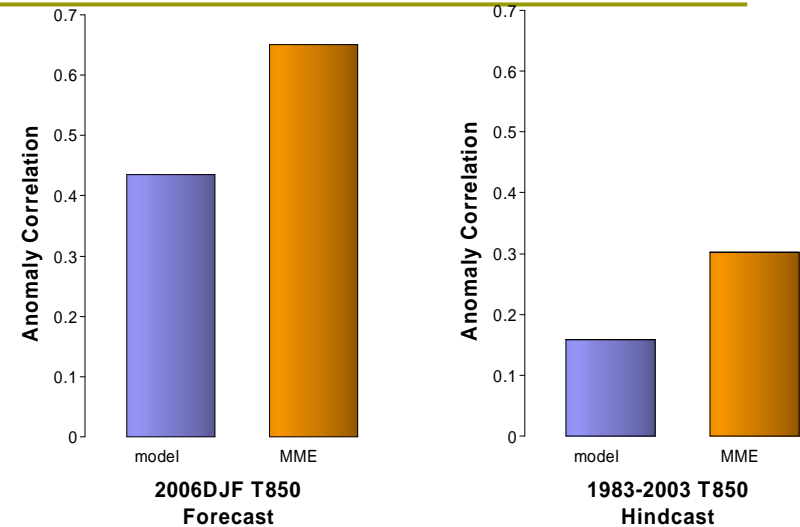
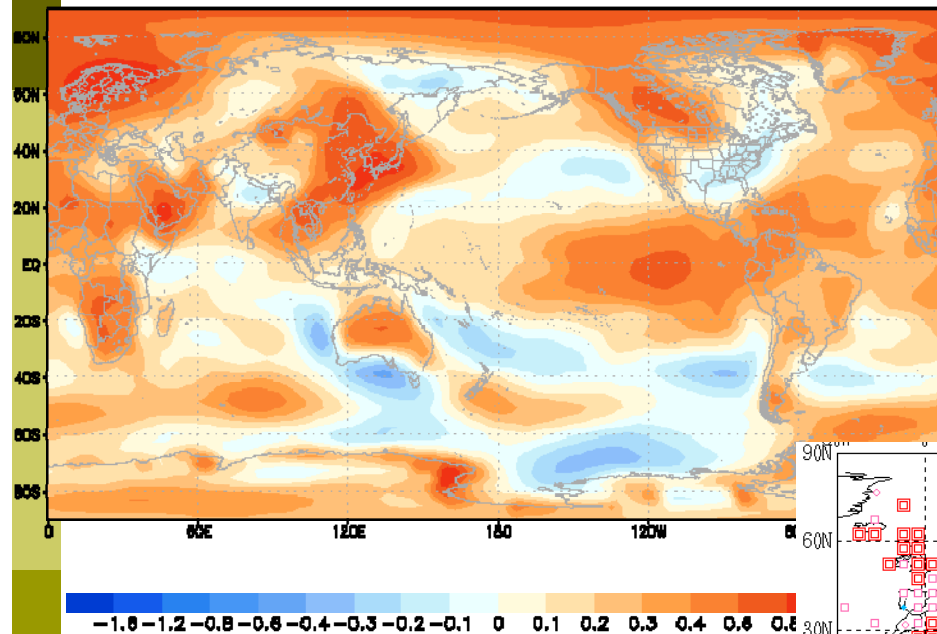
□ 2006/7 DJF

■ El Nino



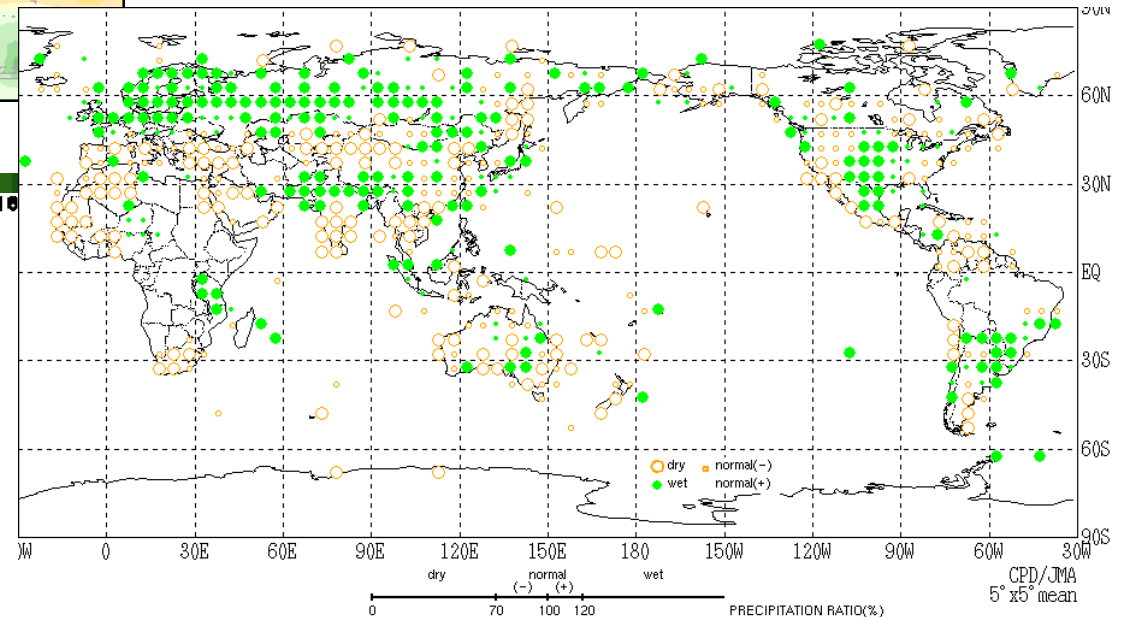
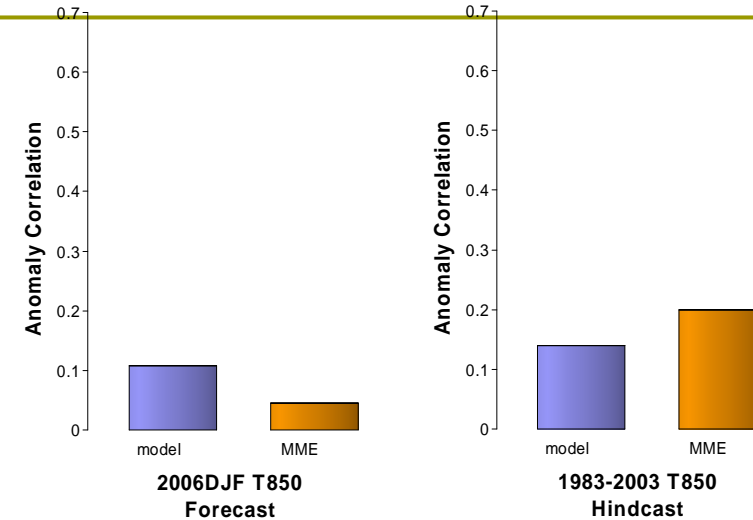
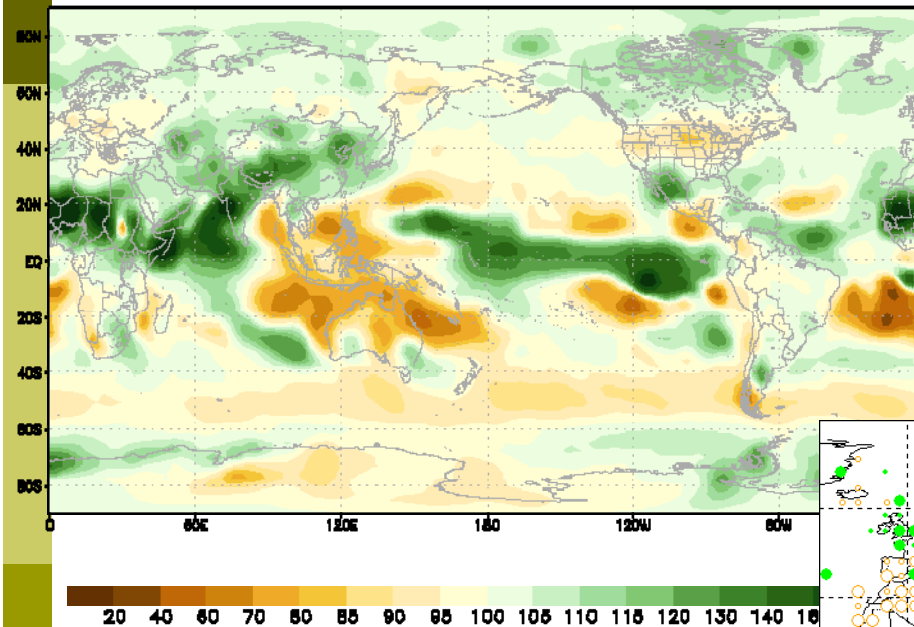
Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, DJF 2006_07



Assessment of Seasonal Forecast

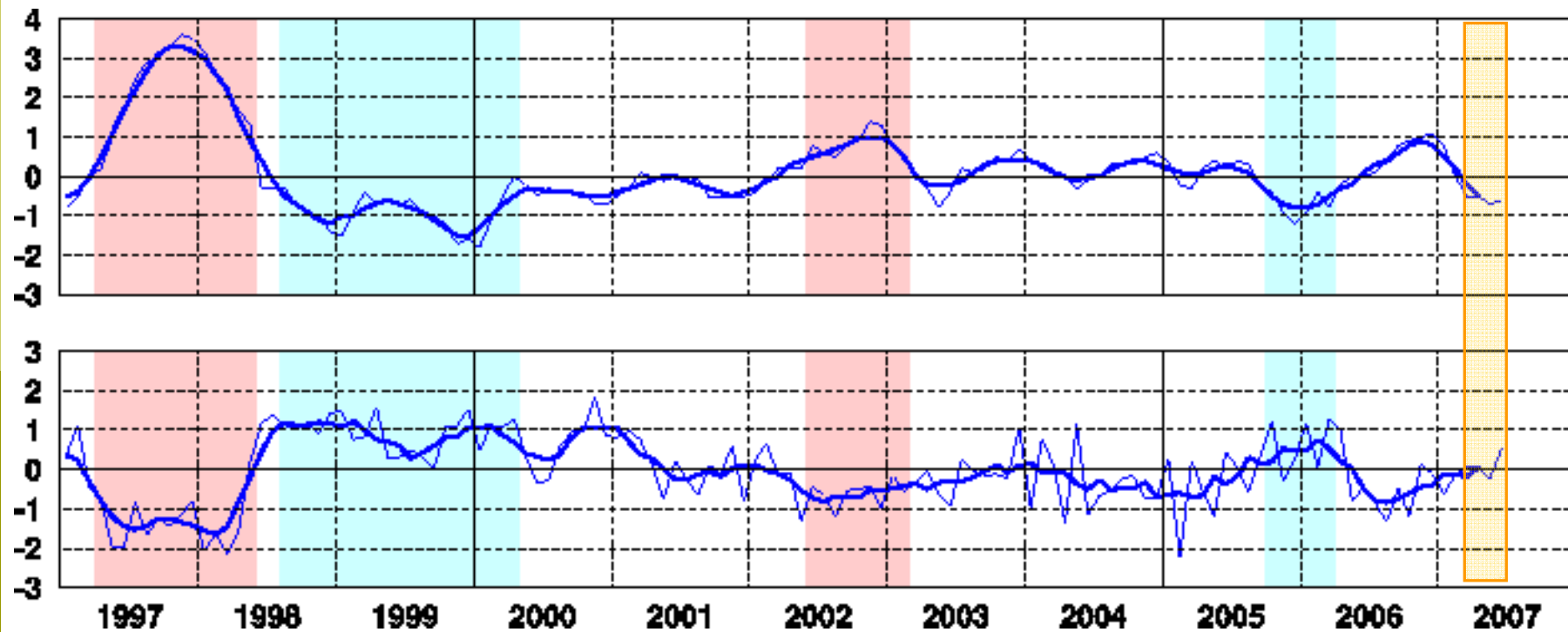
Percent of Precipitation (1983–2003 base period)
APCC_MME, DJF 2008_07



Assessment of Seasonal Forecast

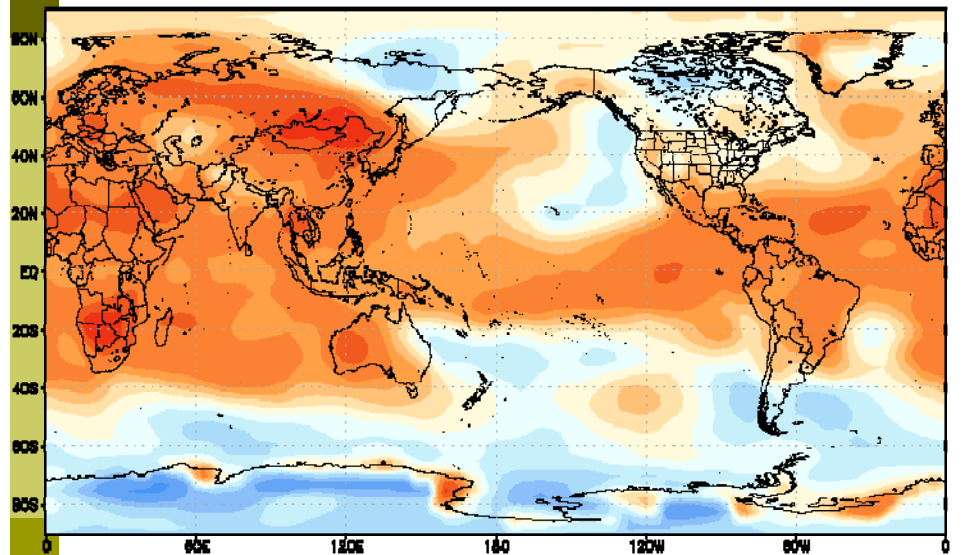
□ 2007 MAM

■ El Nino to La Nina



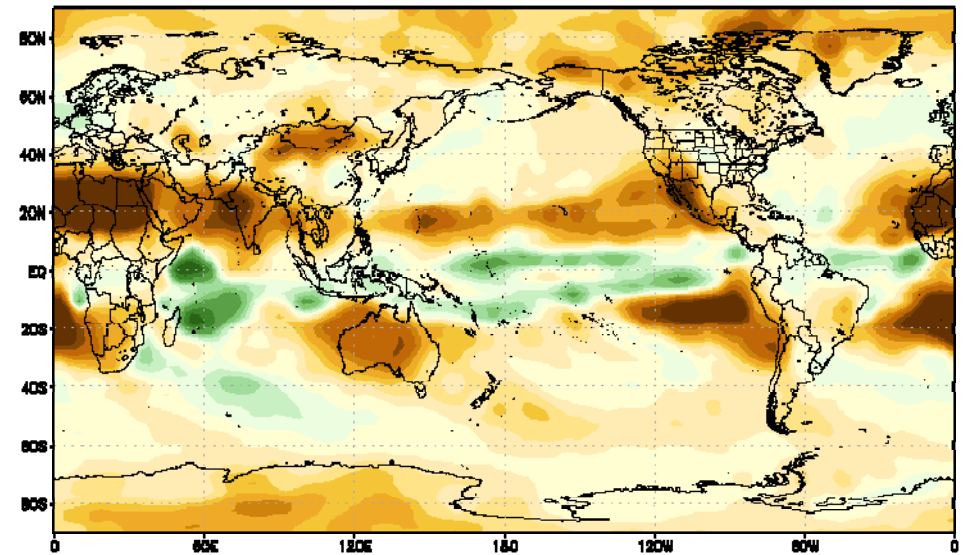
Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, MAM 2007



-1.6 -1.2 -0.8 -0.6 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.6 0.8 1.2 1.6 [C]

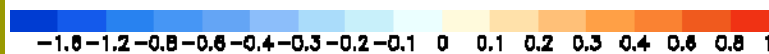
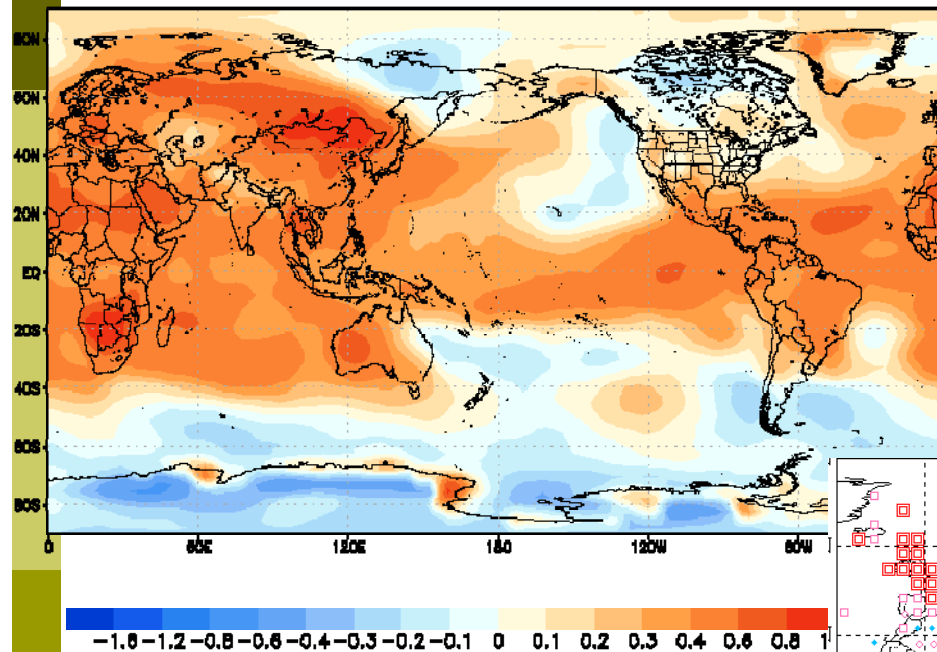
Percent of Precipitation (1983–2003 base period)
APCC_MME, MAM 2007



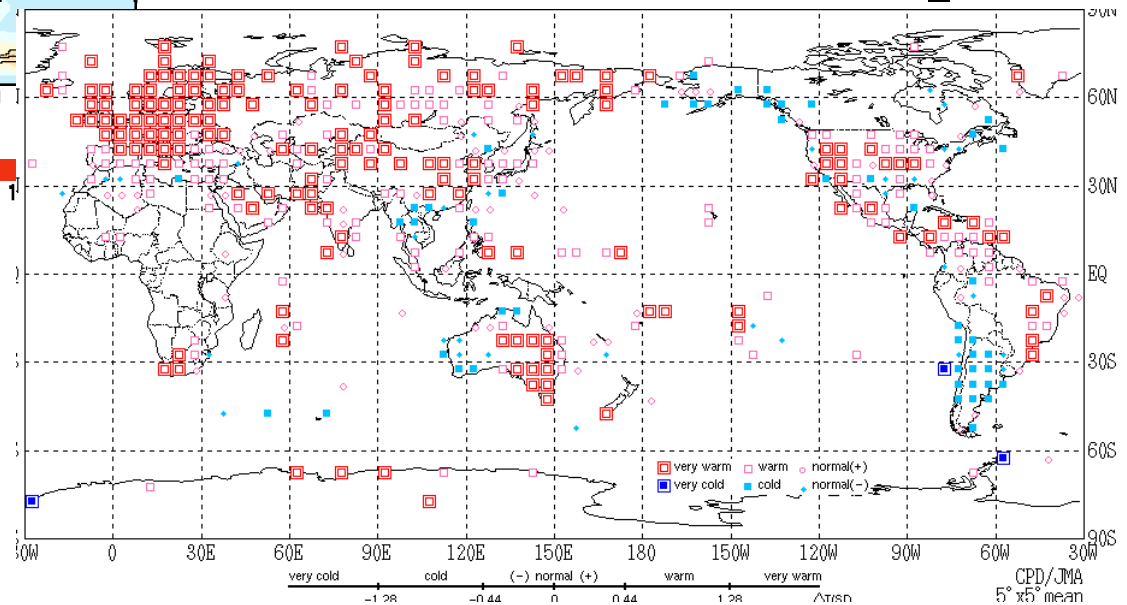
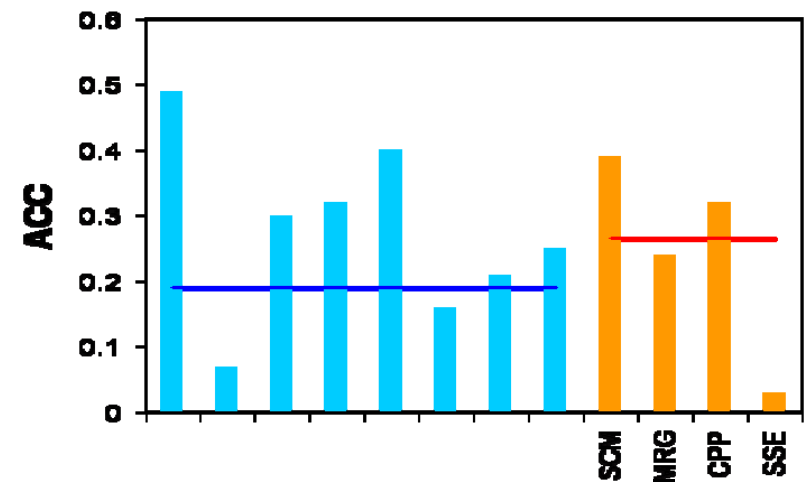
20 40 60 70 80 85 90 95 100 105 110 115 120 130 140 160 180 [%]

Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, MAM 2007

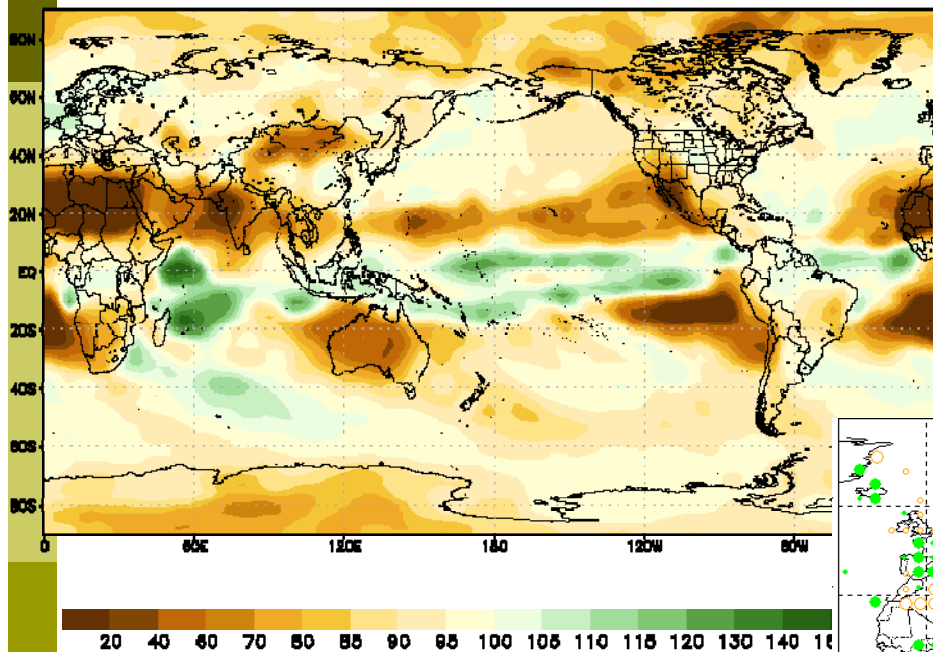


Forecast verification (t850, Global)

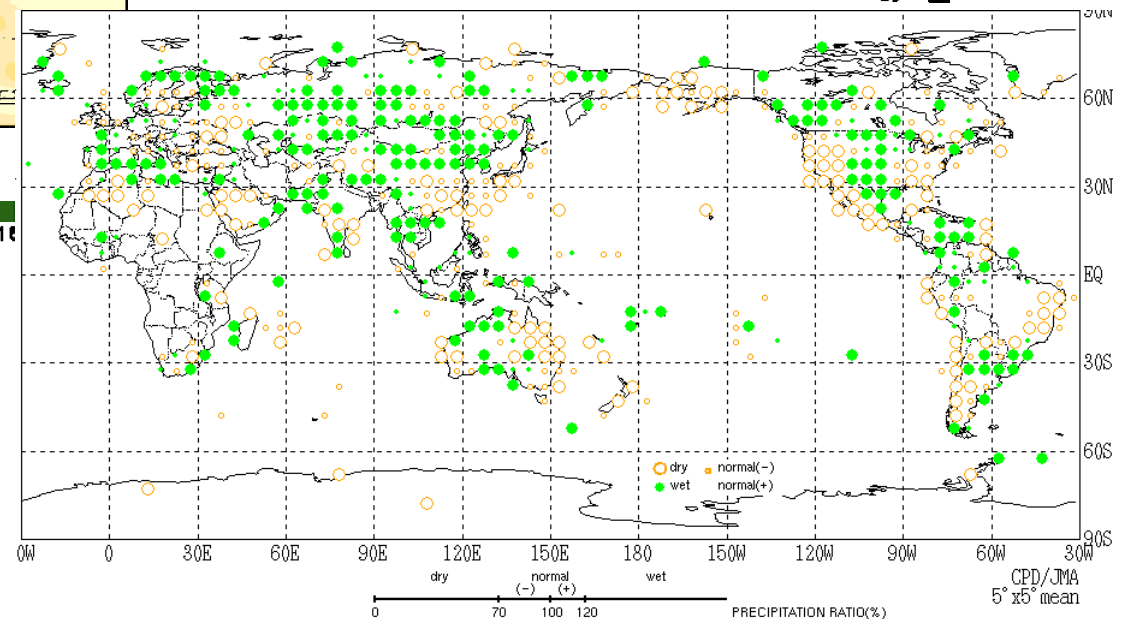
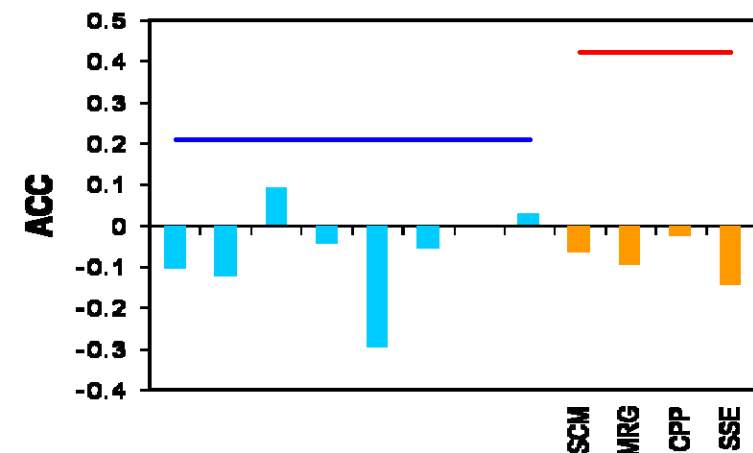


Assessment of Seasonal Forecast

Percent of Precipitation (1983–2003 base period)
APCC_MME, MAM 2007



Forecast verification (prec, Global)

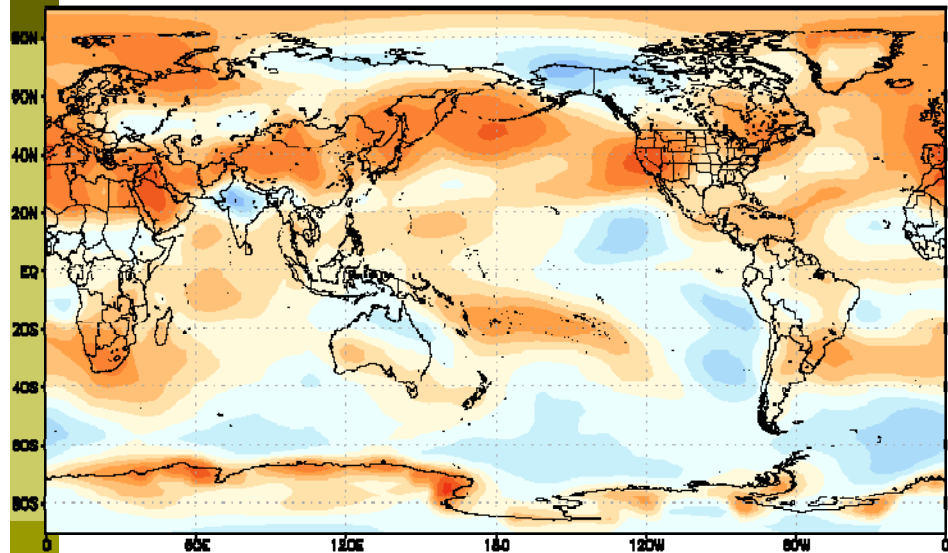


Exercise: Assessment of 2007JJA forecast



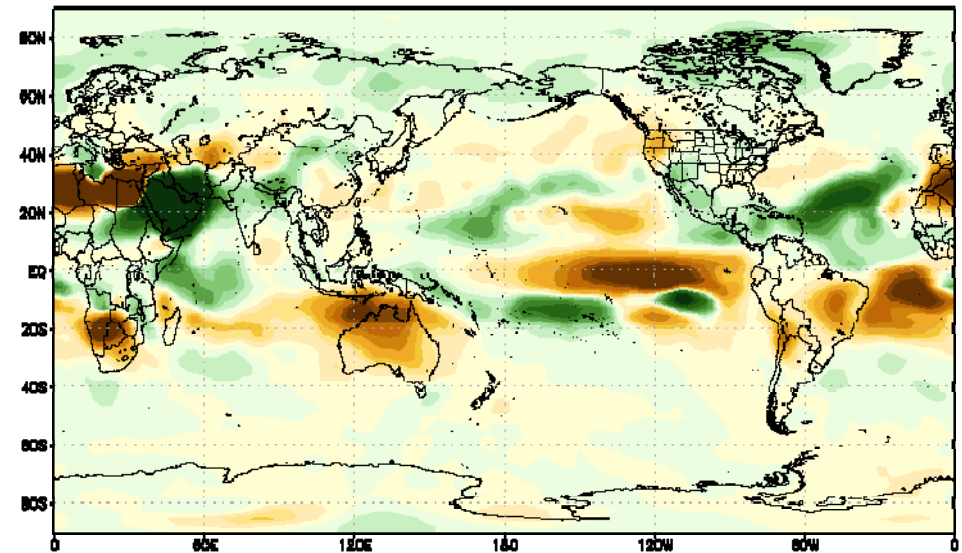
Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, JJA 2007



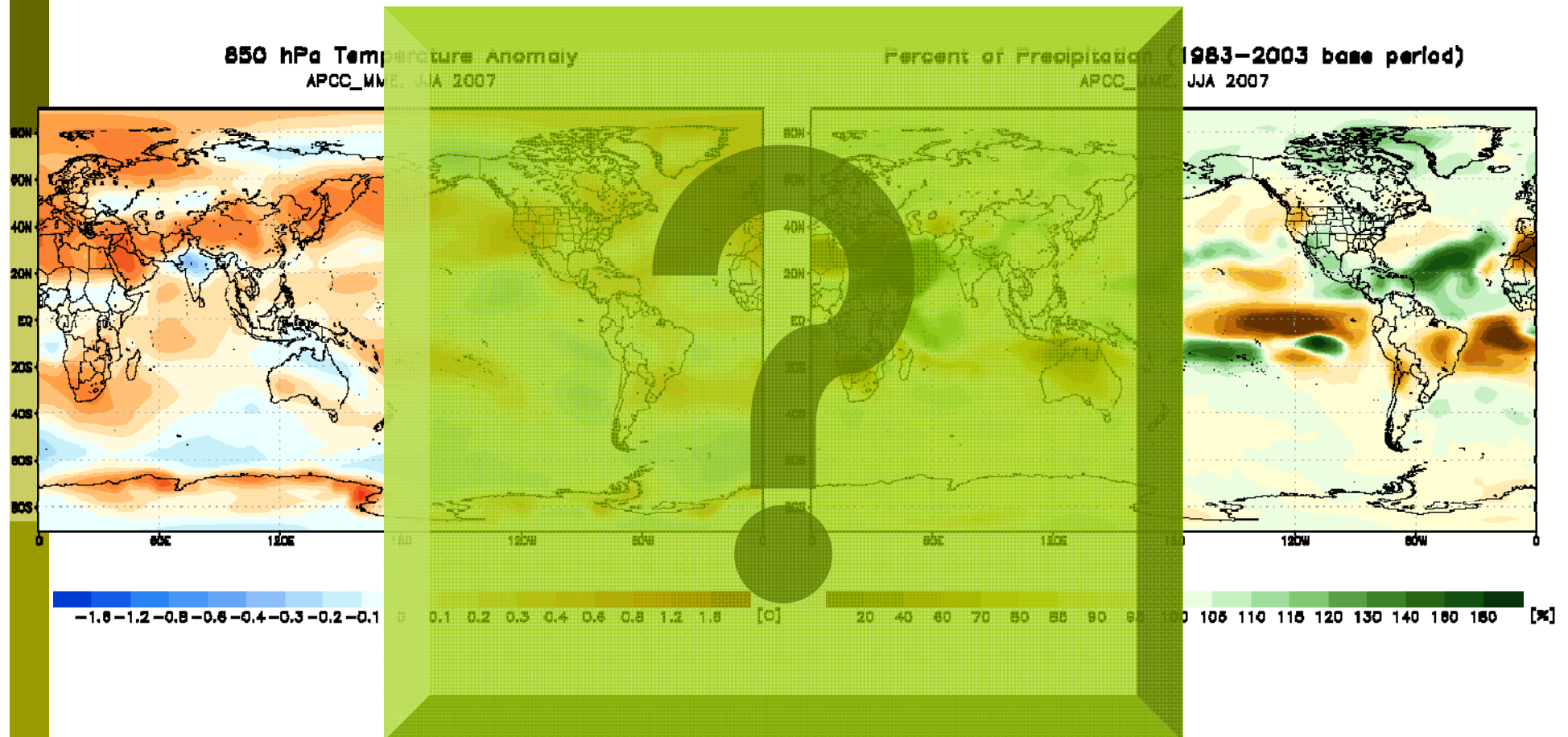
-1.6 -1.2 -0.8 -0.6 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.6 0.8 1.2 1.6 [C]

Percent of Precipitation (1983–2003 base period)
APCC_MME, JJA 2007



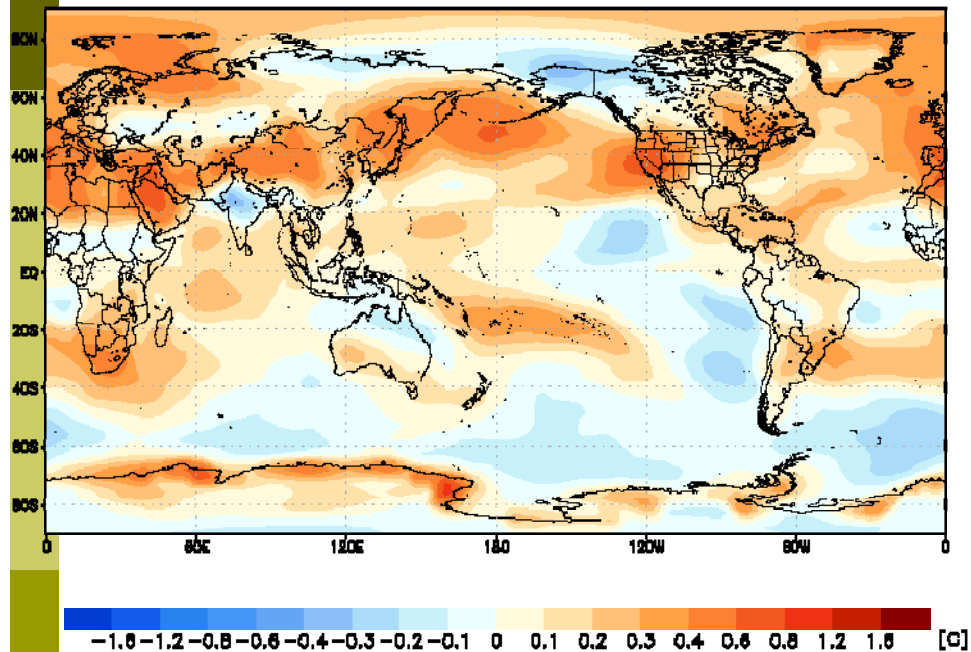
20 40 60 70 80 85 90 95 100 105 110 115 120 130 140 160 160 [%]

Assessment of Seasonal Forecast



Assessment of Seasonal Forecast

850 hPa Temperature Anomaly
APCC_MME, JJA 2007



Assessment of Seasonal Forecast

Percent of Precipitation (1983–2003 base period)
APCC_MME, JJA 2007

