



Probabilistic predictions of monsoon rainfall with the ECMWF Monthly and Seasonal Forecast Systems

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Why monsoon rainfall ?

... and why south Asian monsoon rainfall in particular ?

- The variability of Asian summer monsoon rainfall, particularly over India, is originated by the super-position of seasonally-coherent SST forced signals and intra-seasonal variabilities with quasi-periodic (MJO-like) and chaotic components.
- Increasingly frequent claims are made in scientific meetings/literature that monsoon rainfall can be better predicted by statistical methods than by dynamical, GCM-based ensemble forecasts.



From CURRENT SCIENCE, 25 July 2007:

P. K. Xavier (LMD, Paris) and B. N. Goswami (IITM, Pune) :

A promising alternative to prediction of seasonal mean all India rainfall

- ... The theoretically achievable skill for seasonal prediction of rainfall being barely useful, there is a need to explore alternative strategies ... we propose here that predicting the phases of the monsoon sub-seasonal oscillations 3-4 weeks in advance is such an alternative strategy. .. Using an empirical model, it is demonstrated that ... useful predictions of monsoon breaks 3 weeks in advance could be made.
- ... 21 year hindcasts from DEMETER project (ECHAM4-OPA8.1) ... for most years, there is hardly any correspondence with with observed EIMR (from CMAP).



From CURRENT SCIENCE, 25 July 2007:

P. K. Xavier (LMD, Paris) and B. N. Goswami (IITM, Pune) :

A promising alternative to prediction of seasonal mean all India rainfall

Analogue-based prediction of pentad OLR principal comp.

$$\text{OLR}(x, y, t + \tau) = \sum_{k=1}^K \text{EOF}_k(x, y) \times \text{PC}_k(t_0 + \tau).$$

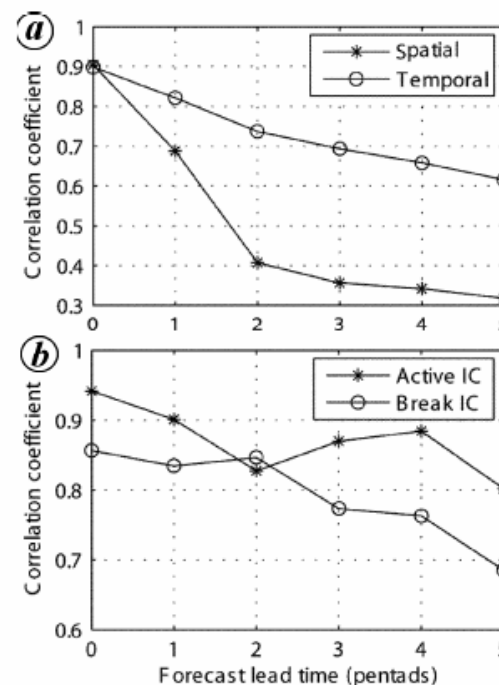
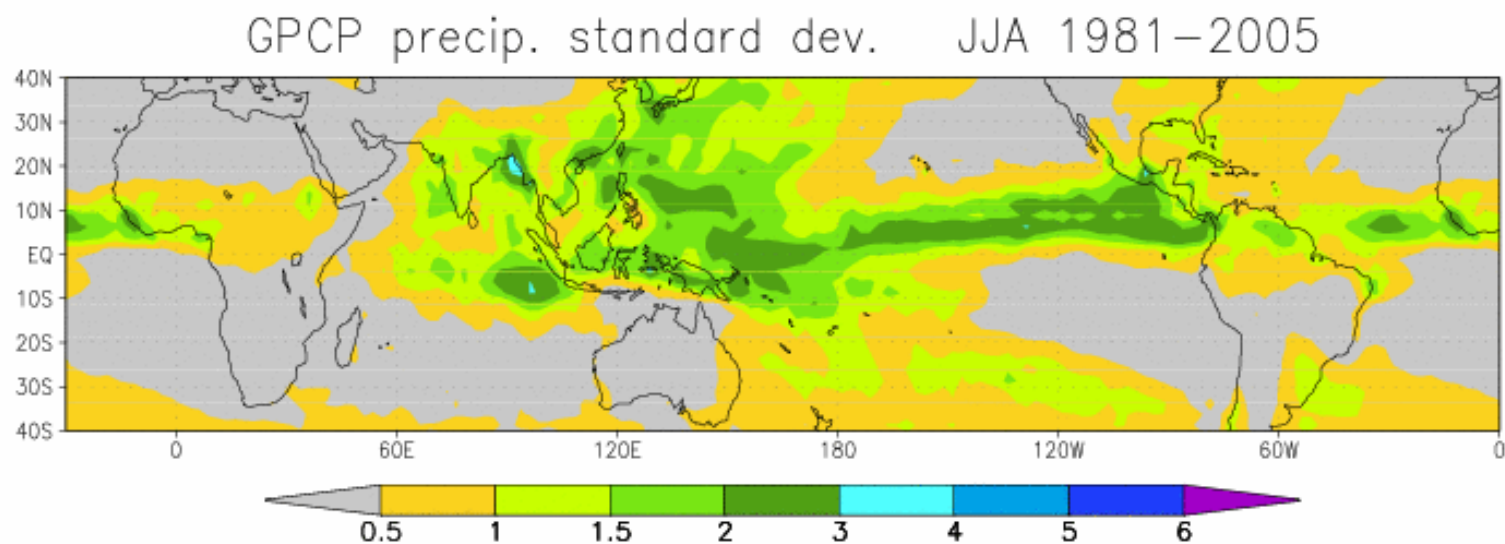
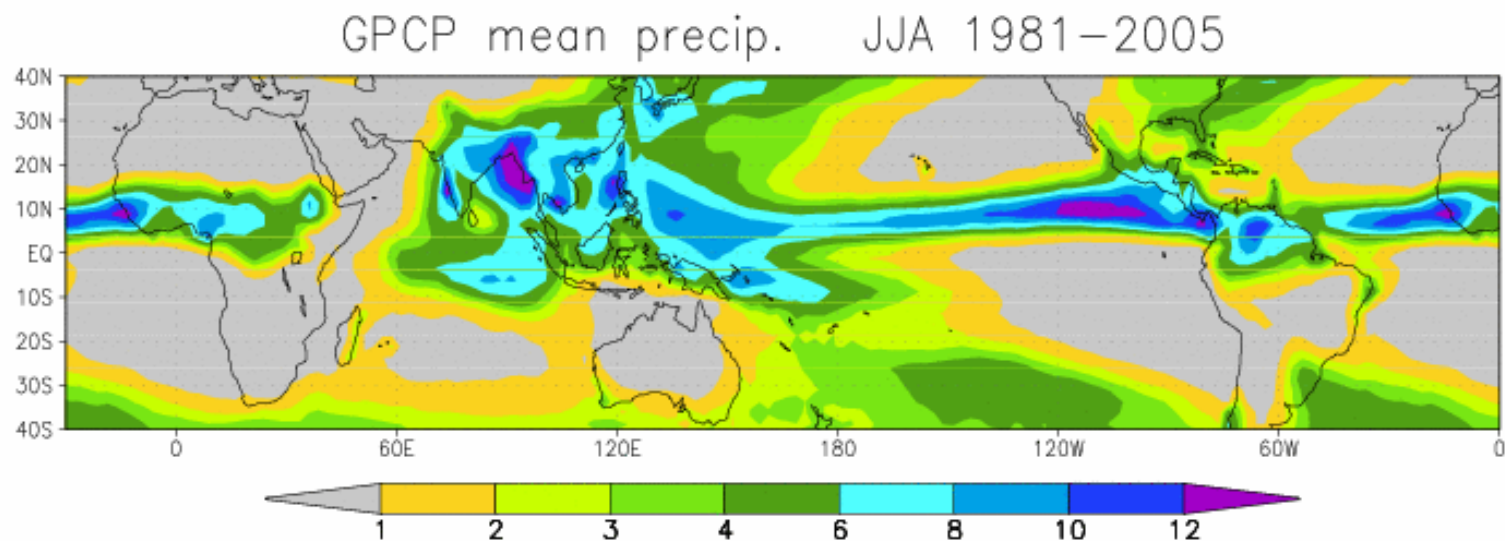


Figure 6. *a*, Spatial and temporal correlations between observations and predictions over Central India at different lead times. *b*, Temporal correlations between predictions and observations from active and break initial conditions at different lead times.

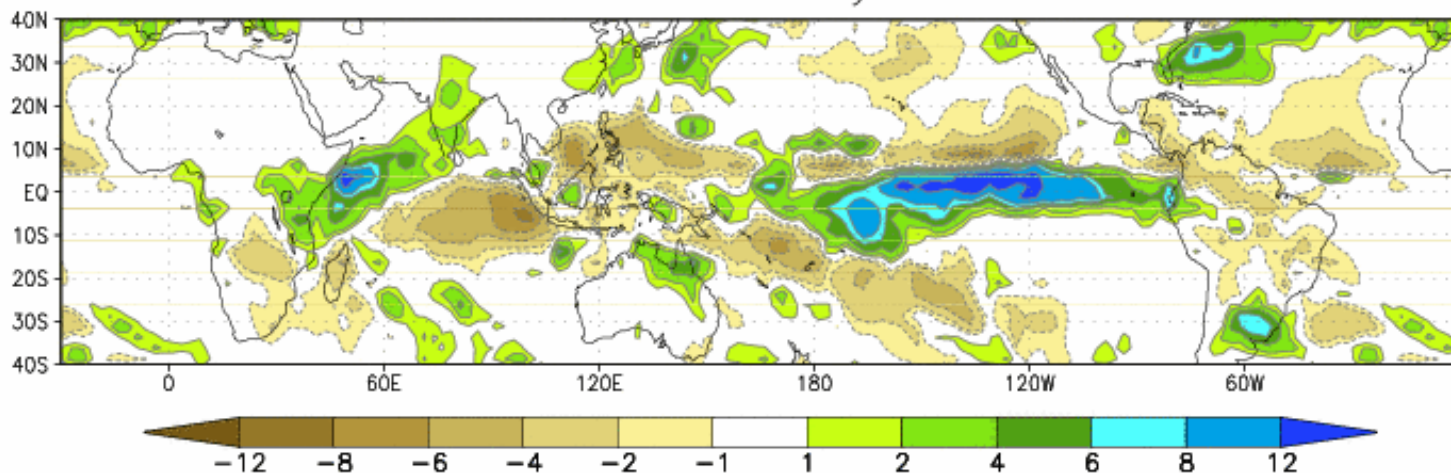
GPCP rainfall climatology: JJA 1981-2005



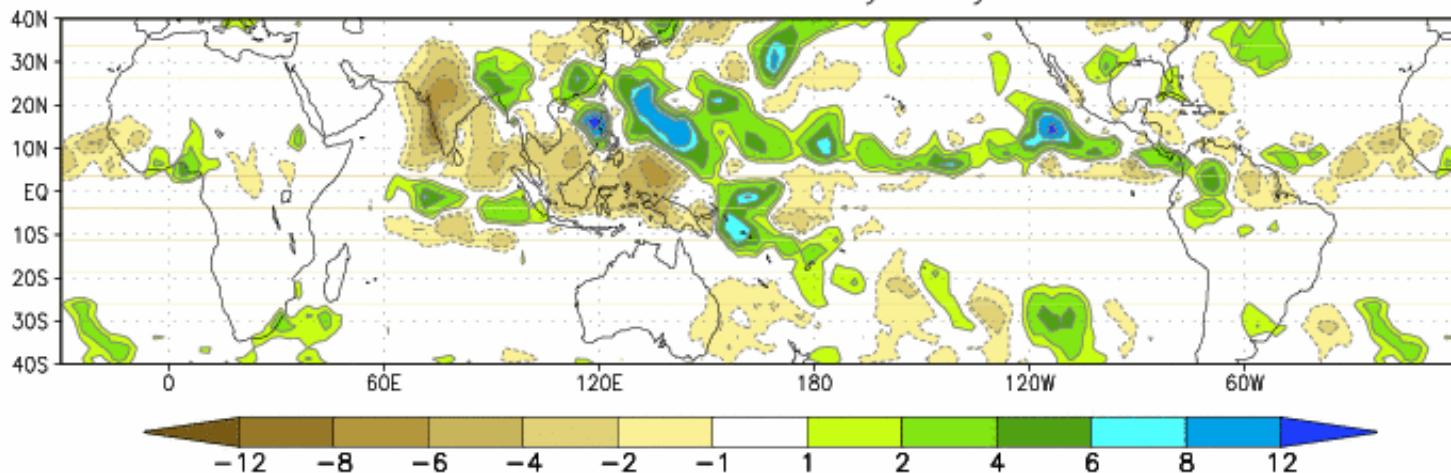


Rainfall anomalies in Dec. 1997 and July 2002

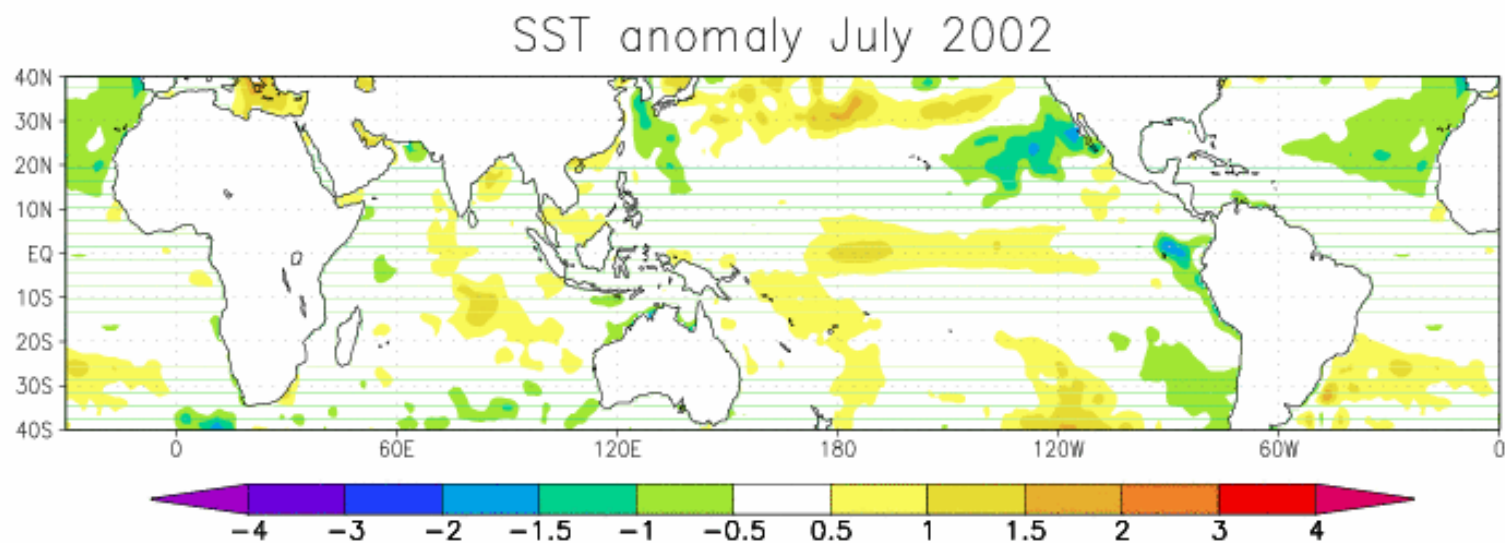
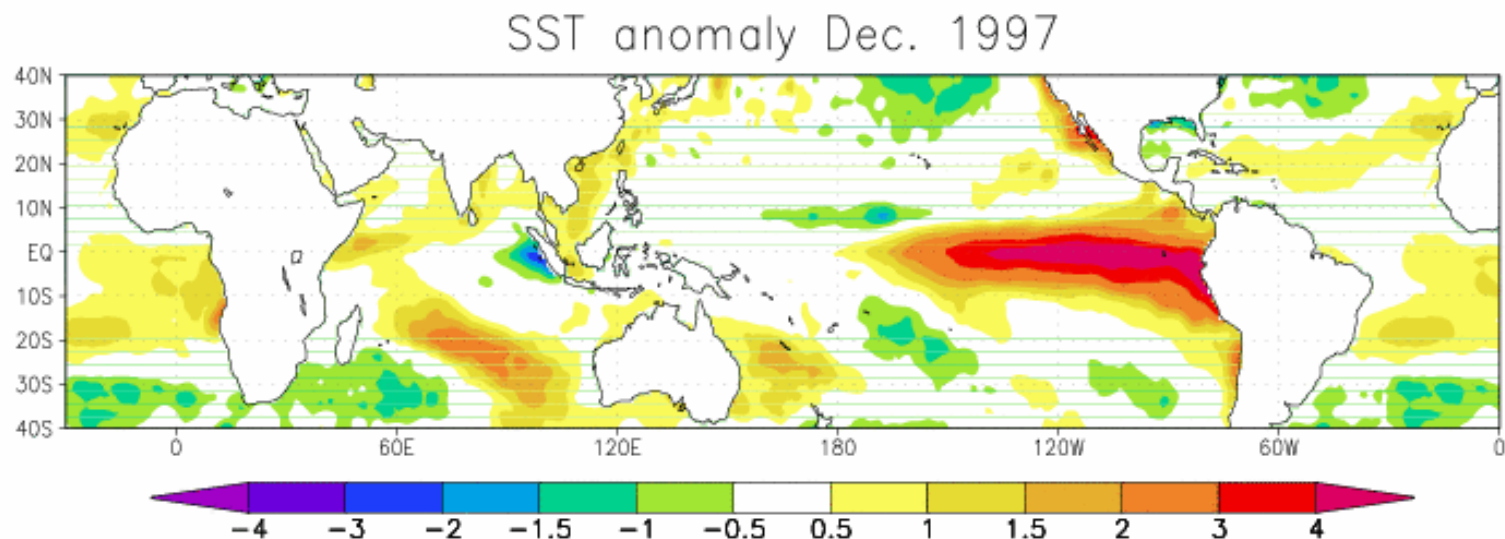
GPCP rainfall anomaly Dec. 1997

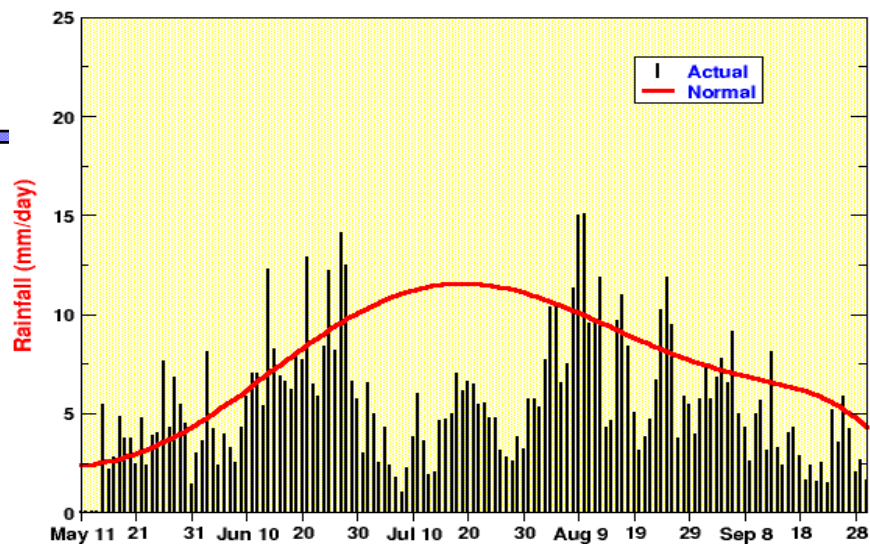
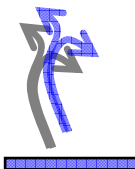


GPCP rainfall anomaly July 2002



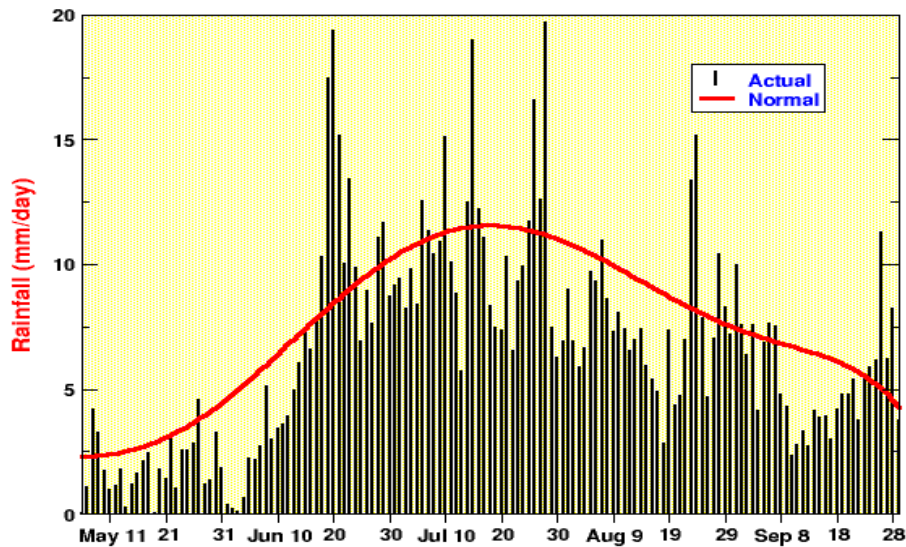
SST anomalies in Dec. 1997 and July 2002



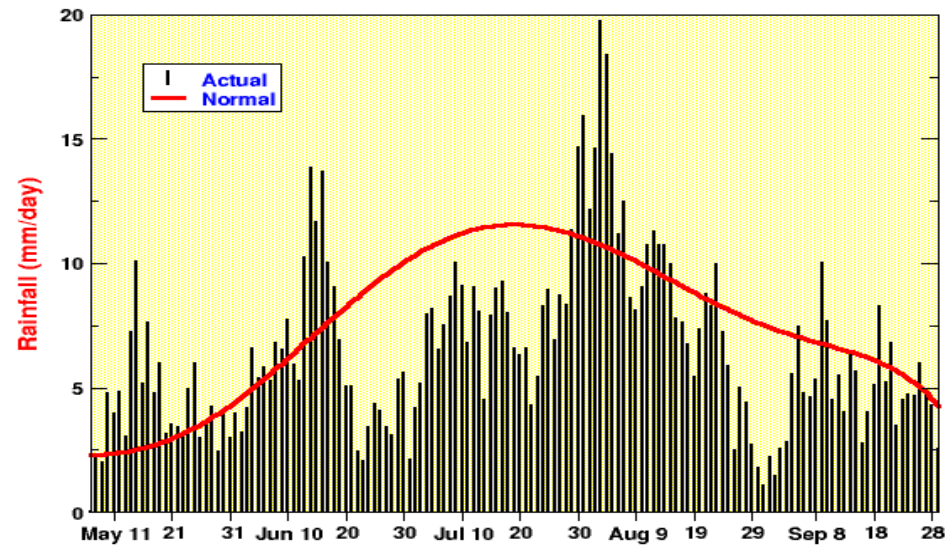


2002

All-India Rainfall time-series (May-September)

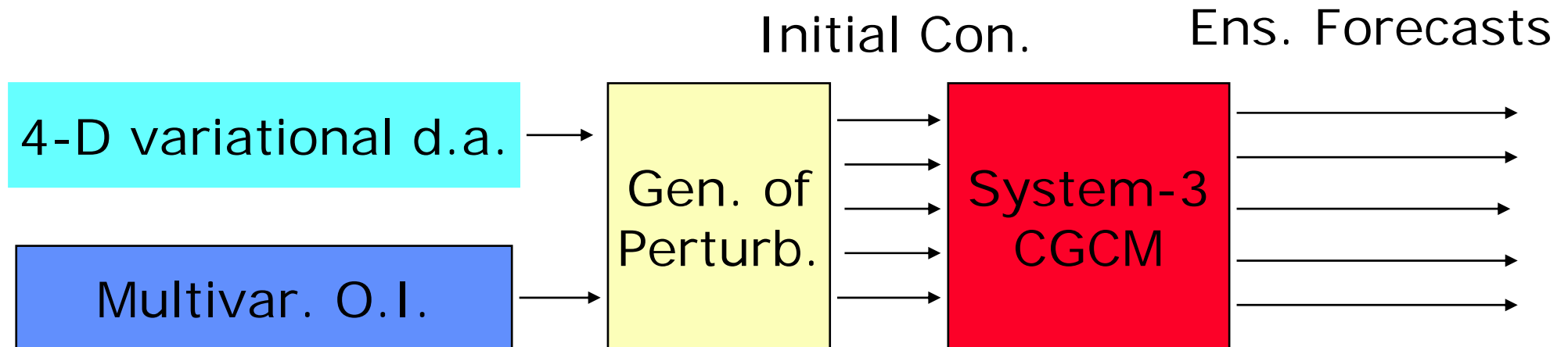
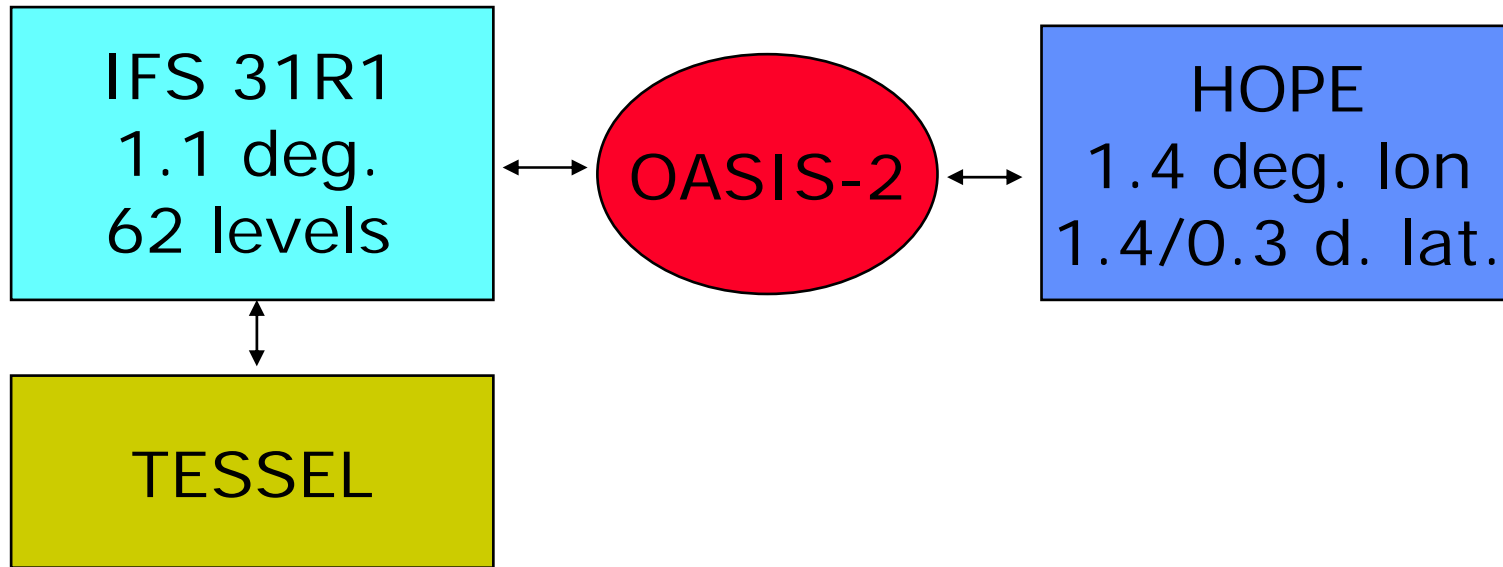


2003



2004

ECMWF Seasonal forecast system (Sys-3)





The seasonal forecast System-3 (implem. March 07)

- **COUPLED MODEL (IFS + OASIS2 + HOPE)**

- Recent cycle of atmospheric model (Cy31R1)
- Atmospheric resolution TL159 and 62 levels
- Time varying greenhouse gasses.
- Includes ocean currents in wave model

- **INITIALIZATION**

- Includes bias correction in ocean assimilation.
- Includes assimilation of salinity and altimeter data.
- ERA-40 data used to initialize ocean and atmosphere in hindcasts
- Ocean reanalysis back to 1959, using ENACT/ENSEMBLES ocean data

- **ENSEMBLE GENERATION**

- Extended range of back integrations: 11 members, 1981-2005.
- Revised wind and SST perturbations.
- Use EPS Singular Vector perturbations in atmospheric initial conditions.

- **Forecasts extended to 7 months (to 13 months 4x per year).**

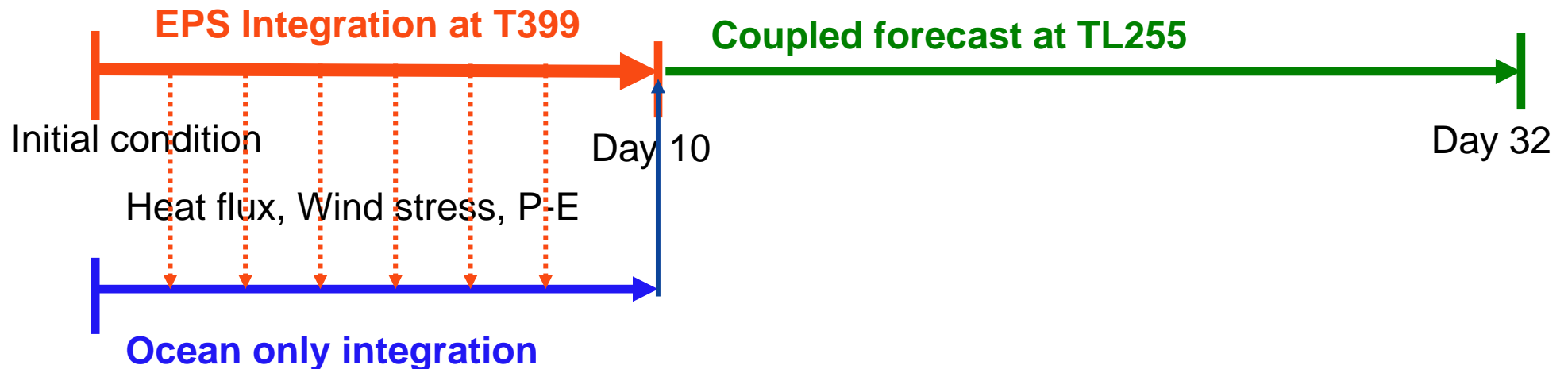


Planned unified VAREPS/monthly system

Present TL159 monthly system:



Future 32-day VAREPS/monthly system:





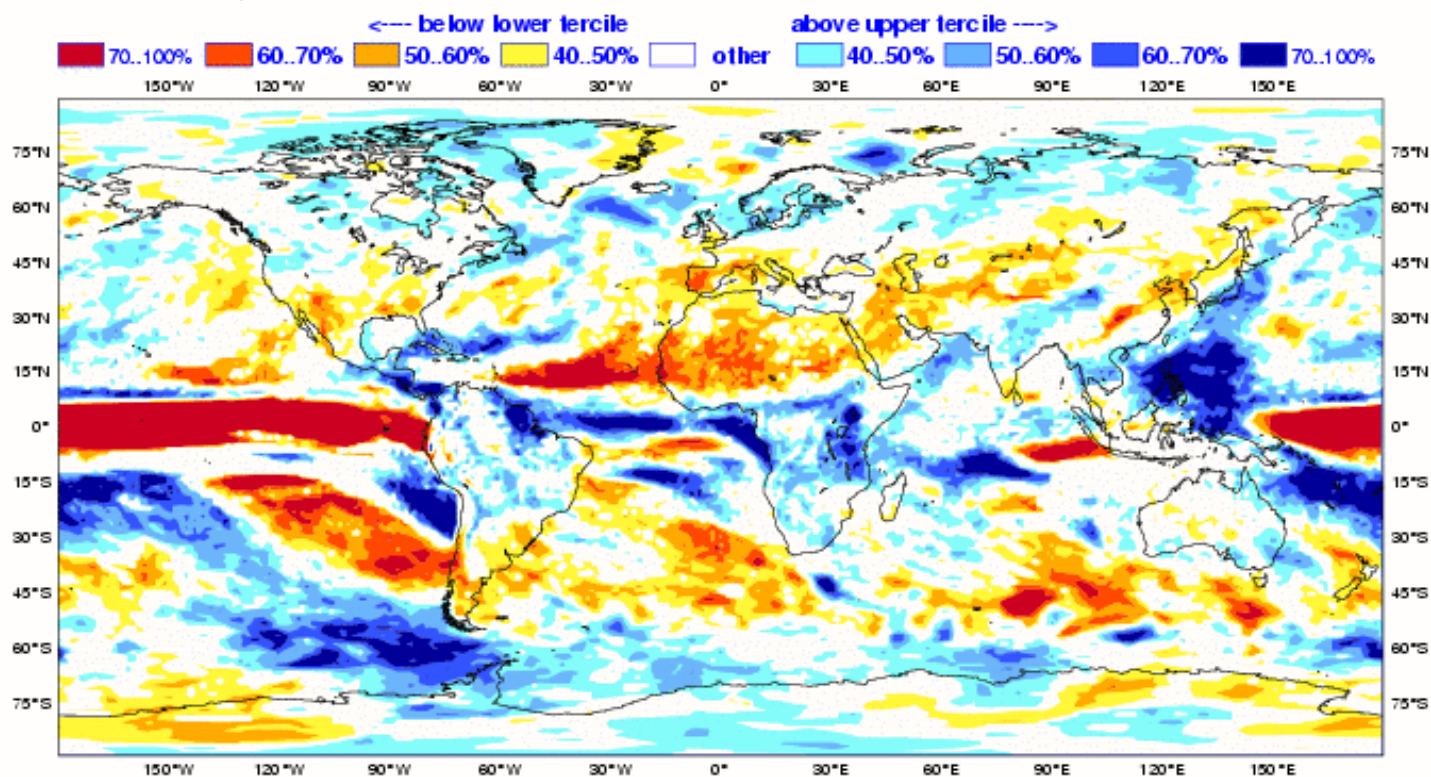
Products from Sys-3: 'tercile summary'

ECMWF Seasonal Forecast
Prob(most likely category of precipitation)

Forecast start reference is 01/09/07
Ensemble size = 41, climate size = 275

System 3
OND 2007

No significance test applied

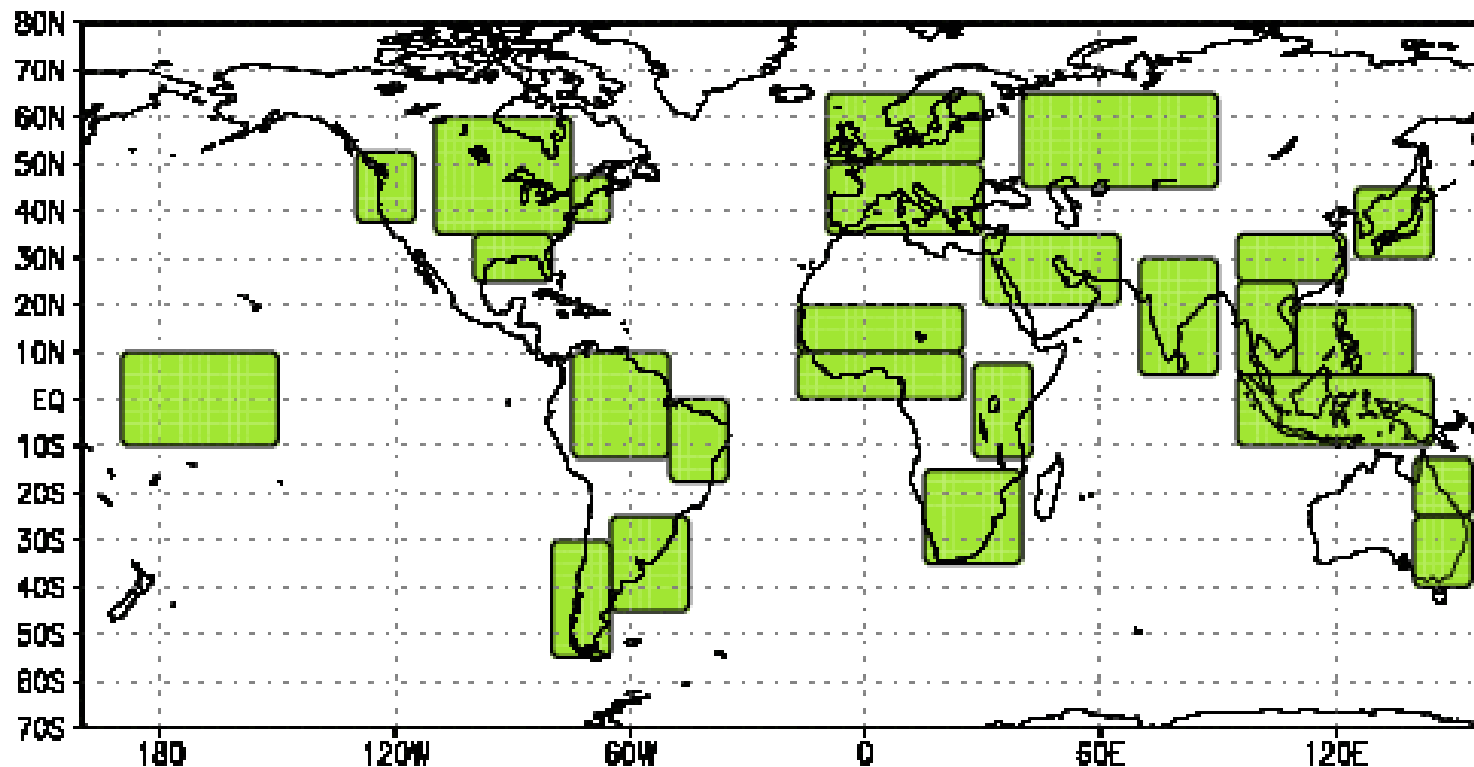


Forecast issue date: 15/09/2007



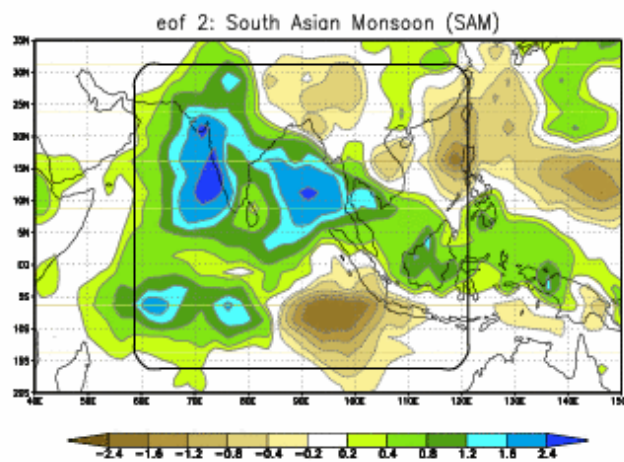
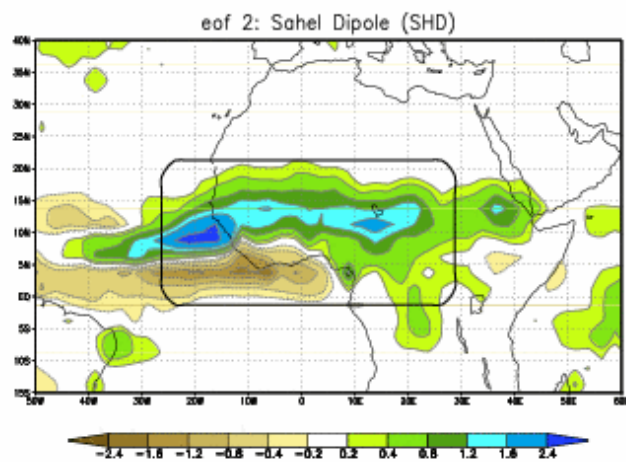
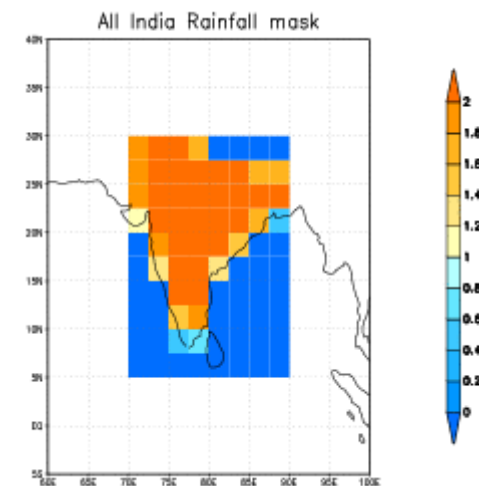
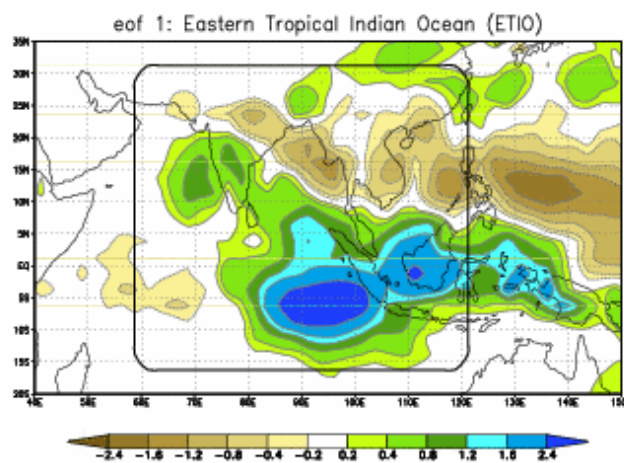
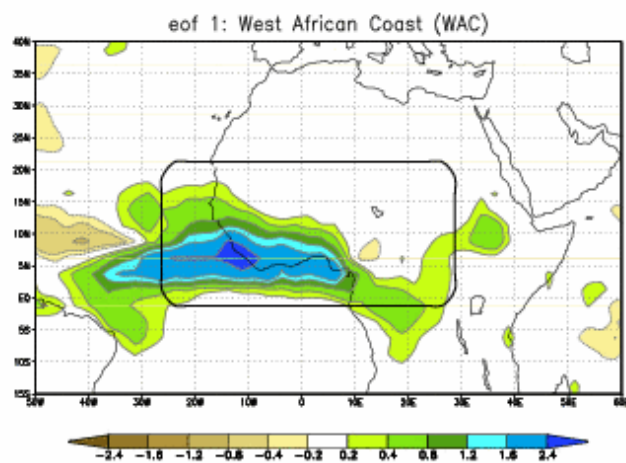


Climagrams : area-averages of 2mT and rainfall





Climagrams : monsoon indices / teleconnections



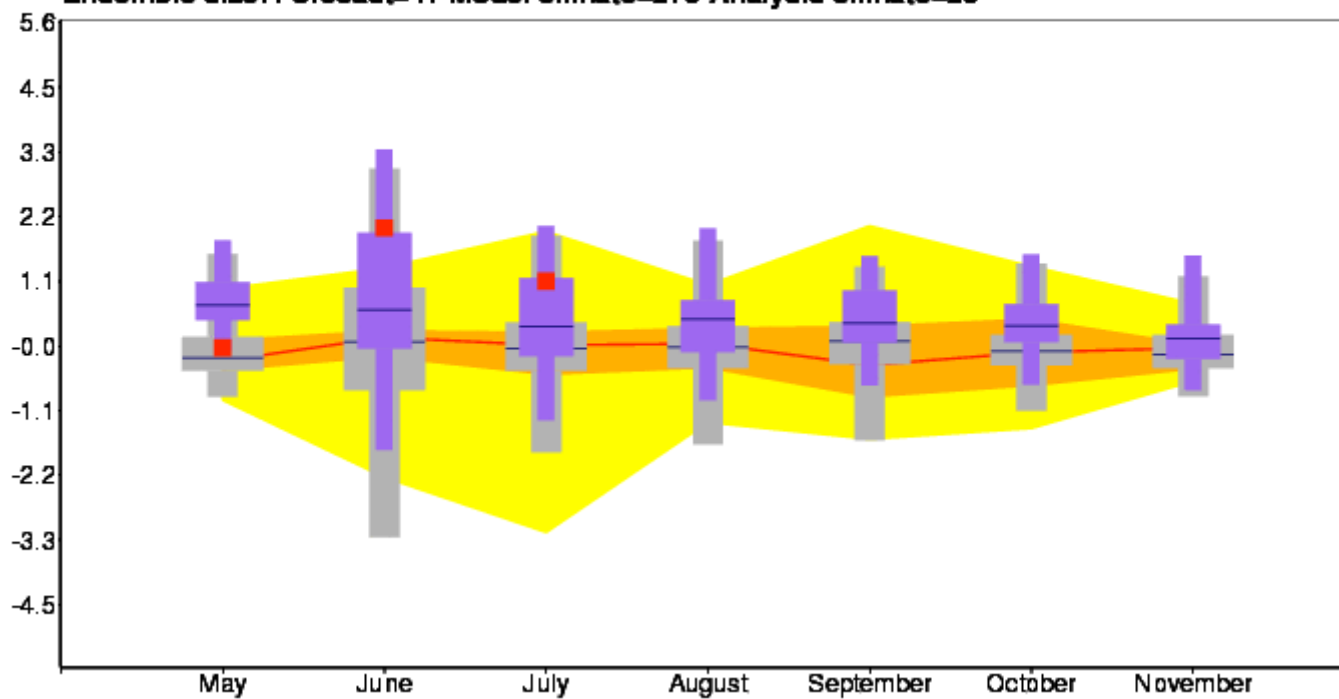


All India Rainfall: "climagram" from 1 May 2007

All-India Rainfall

Forecast initial date: 2007 501

Ensemble size: Forecast=41 Model climate=275 Analysis climate=25

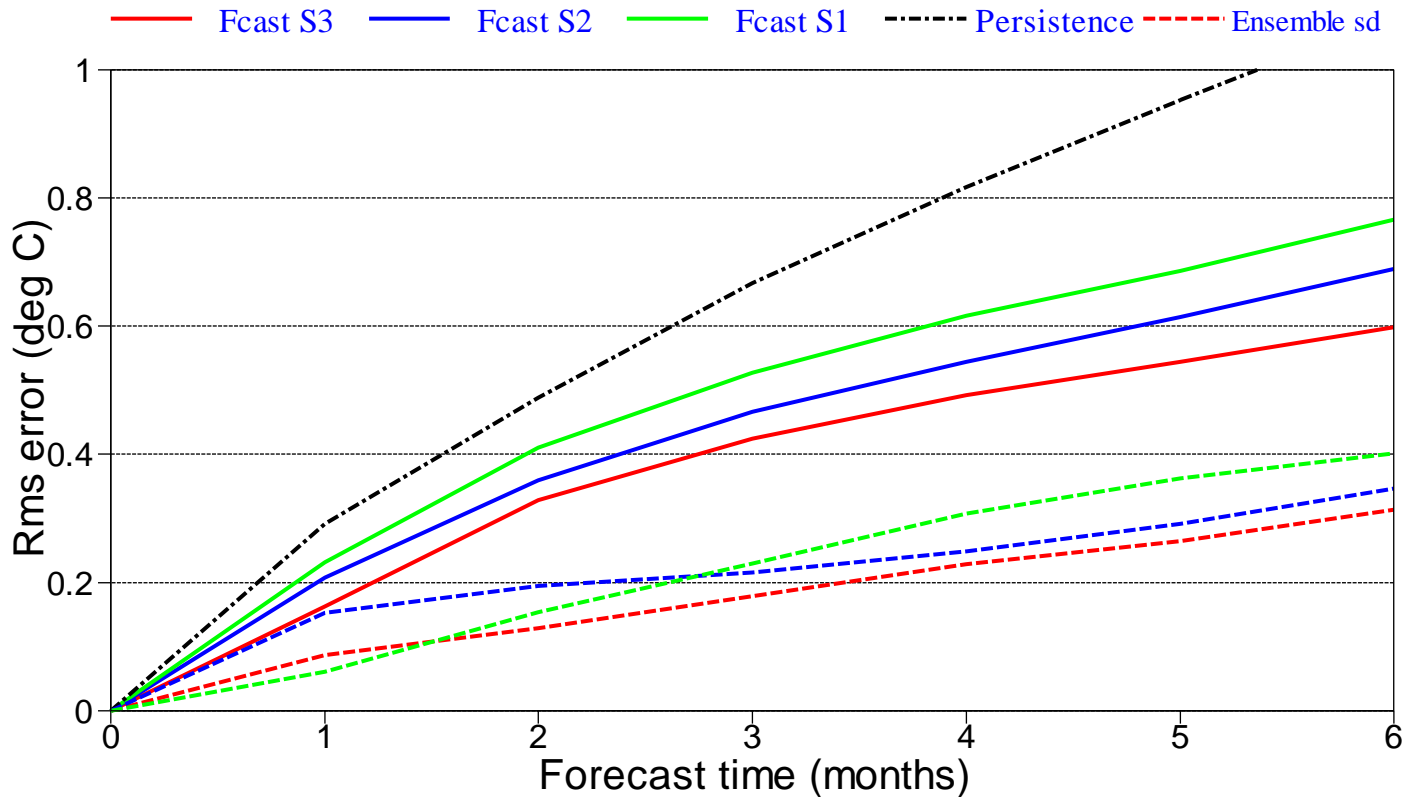




Nino3.4 rms error / spread in different ECMWF systems

NINO3.4 SST rms errors

192 start dates from 19870101 to 20021201
Ensemble sizes are 5 (0001), 5 (0001) and 5 (0001)



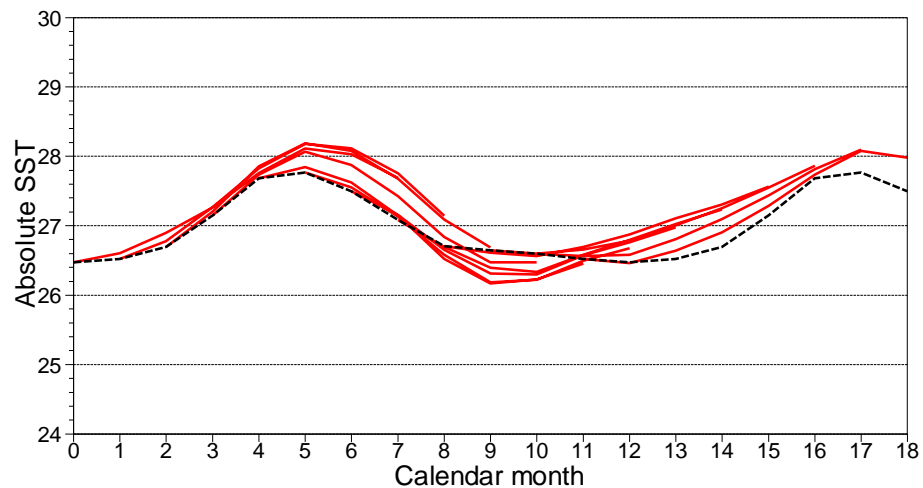
Rms error of forecasts has been systematically reduced (solid lines)

.. but ensemble spread (dashed lines) is still substantially less than actual forecast error.



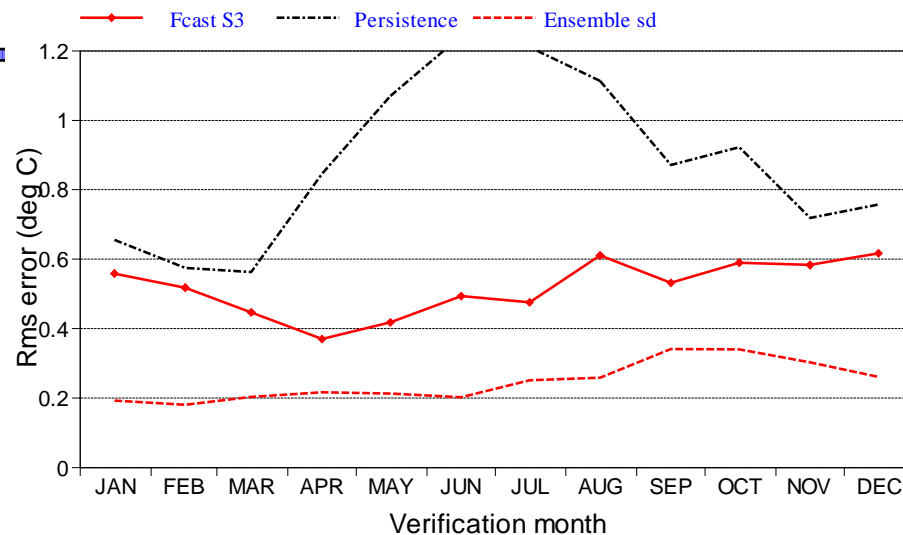
Nino 3.4

NINO3.4 mean absolute SST



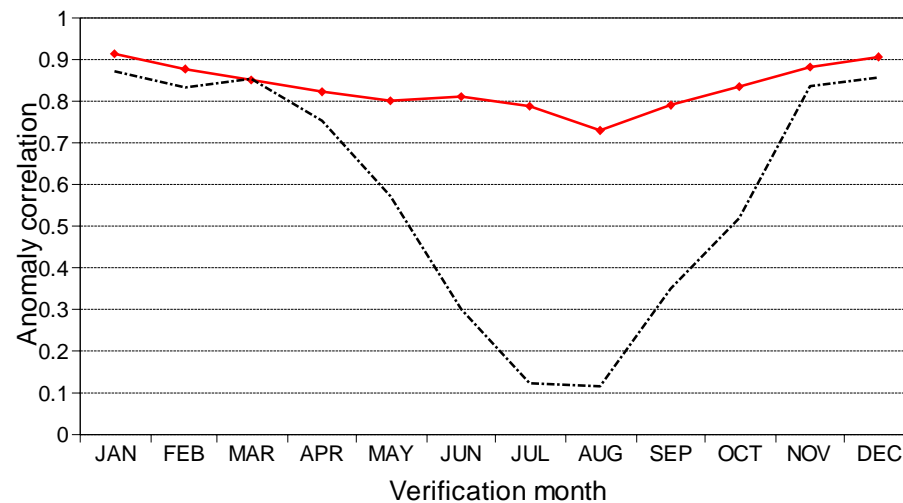
NINO3.4 SST rms errors at 5 months

300 start dates from 19810101 to 20051201
Ensemble size is 11



NINO3.4 SST anomaly correlation at 5 months

wrt NCEP adjusted OIv2 1971-2000 climatology

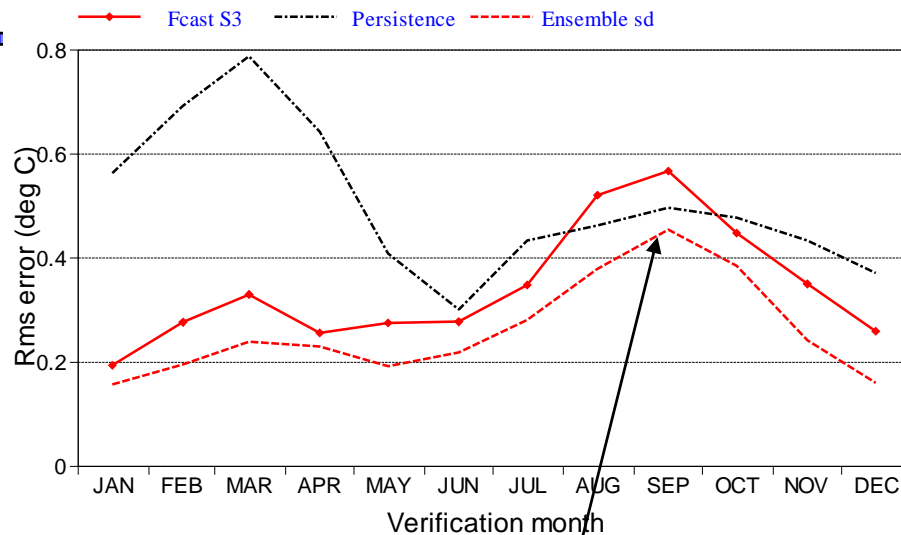




Eastern Indian Ocean

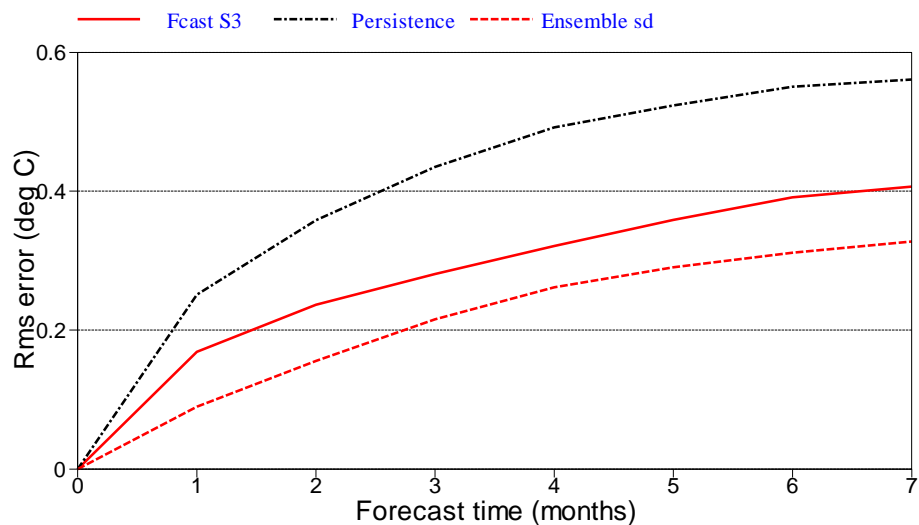
IND2 SST rms errors at 5 months

300 start dates from 19810101 to 20051201
Ensemble size is 11

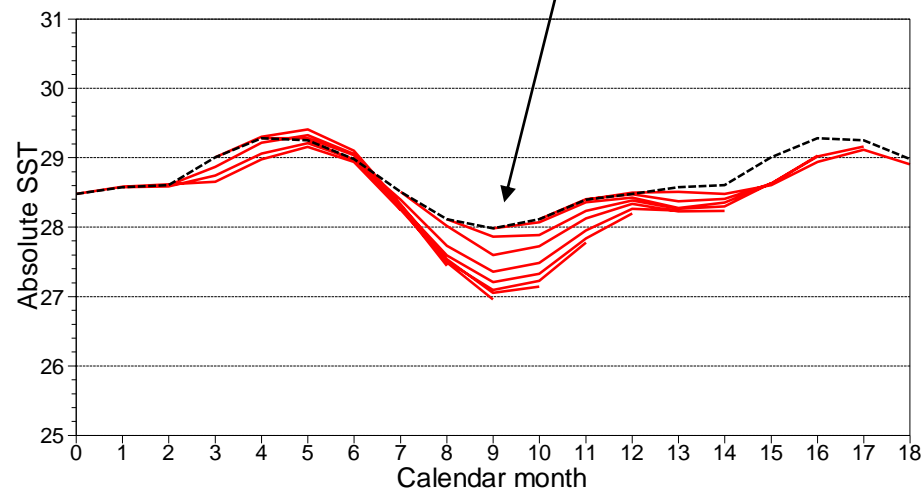


IND2 SST rms errors

300 start dates from 19810101 to 20051201
Ensemble size is 11



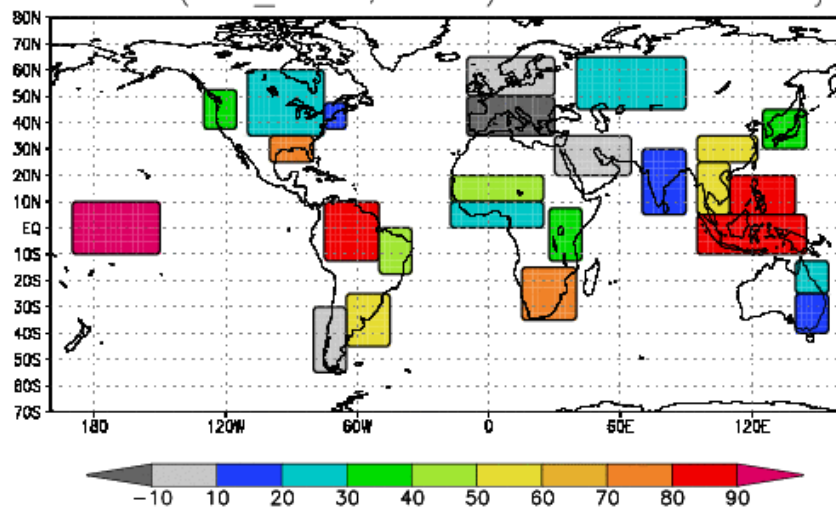
IND2 mean absolute SST



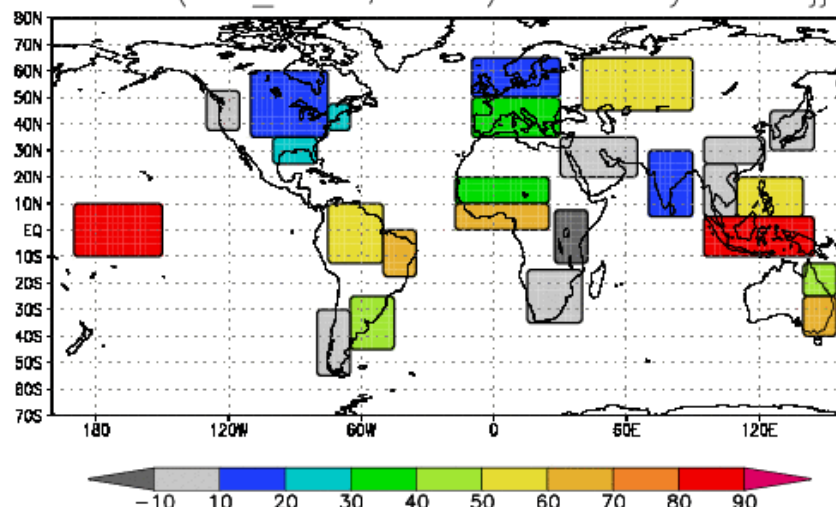


Anomaly correlation of seasonal-mean rainfall

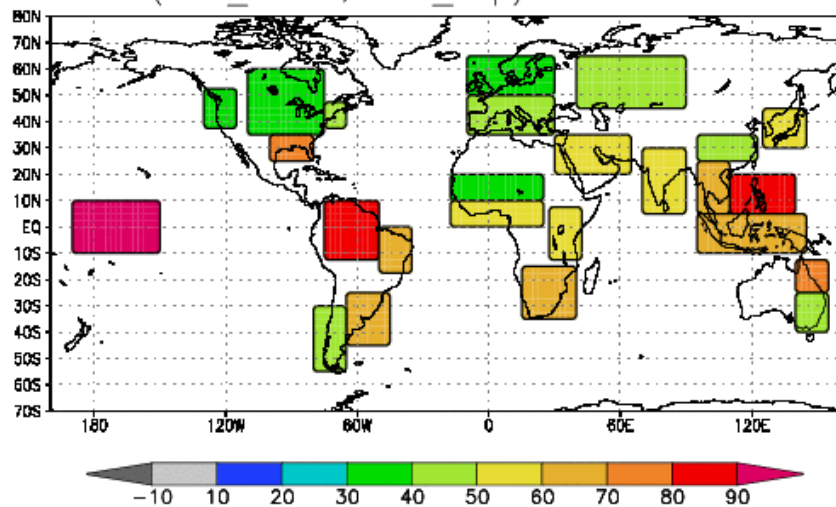
correl. (ENS_mean, GPCP) Init: nov Verif: djf



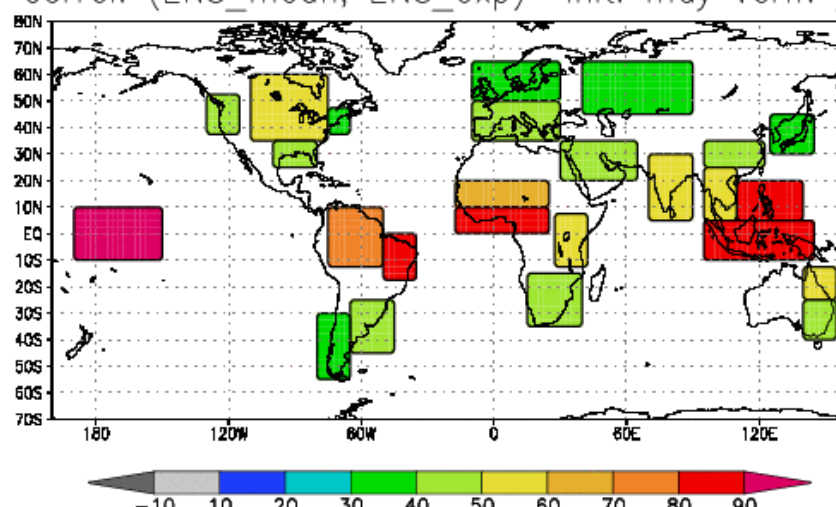
correl. (ENS_mean, GPCP) Init: may Verif: jja



correl. (ENS_mean, ENS_exp) Init: nov Verif: djf



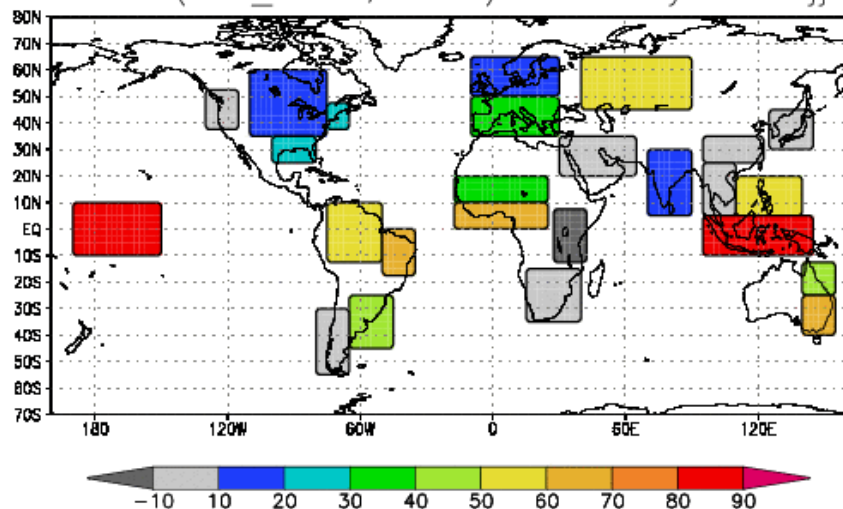
correl. (ENS_mean, ENS_exp) Init: may Verif: jja



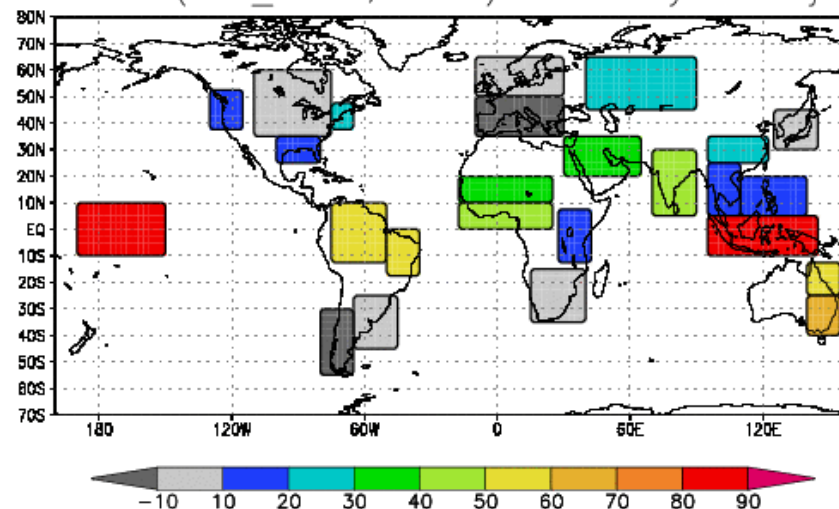


Anomaly correlation of seasonal-mean rainfall

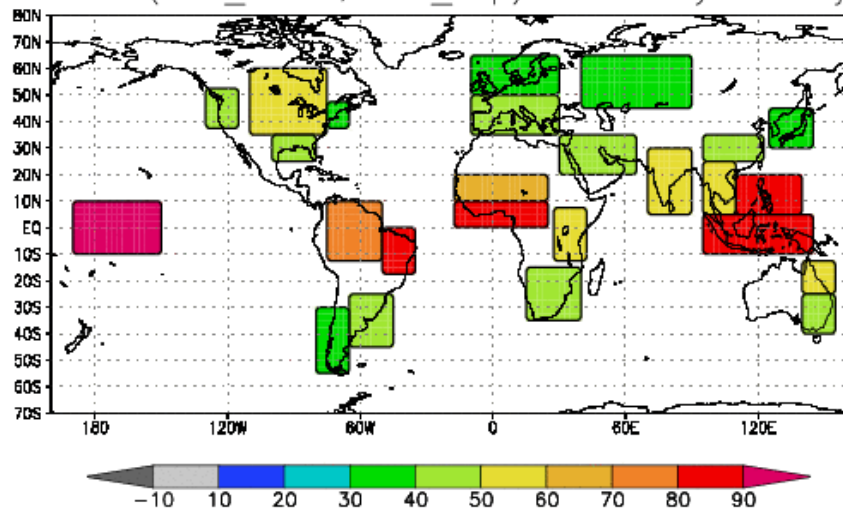
correl. (ENS_mean, GPCP) Init: may Verif: jja



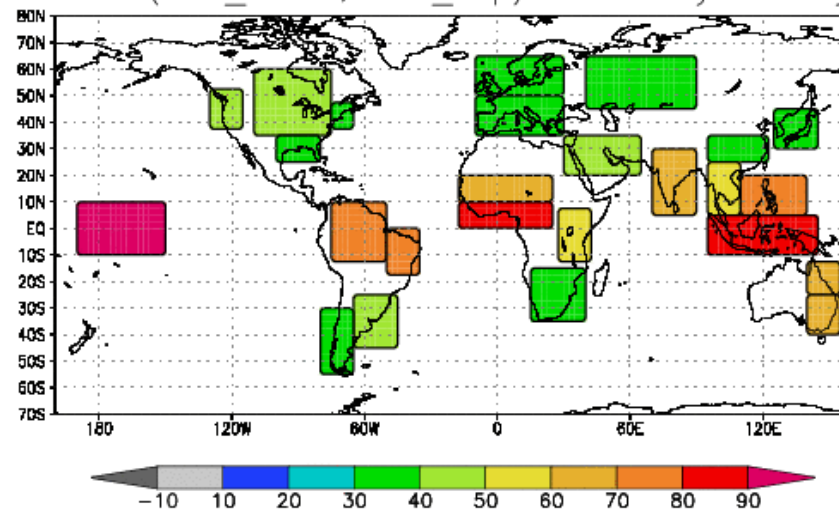
correl. (ENS_mean, GPCP) Init: may Verif: jas



correl. (ENS_mean, ENS_exp) Init: may Verif: jja

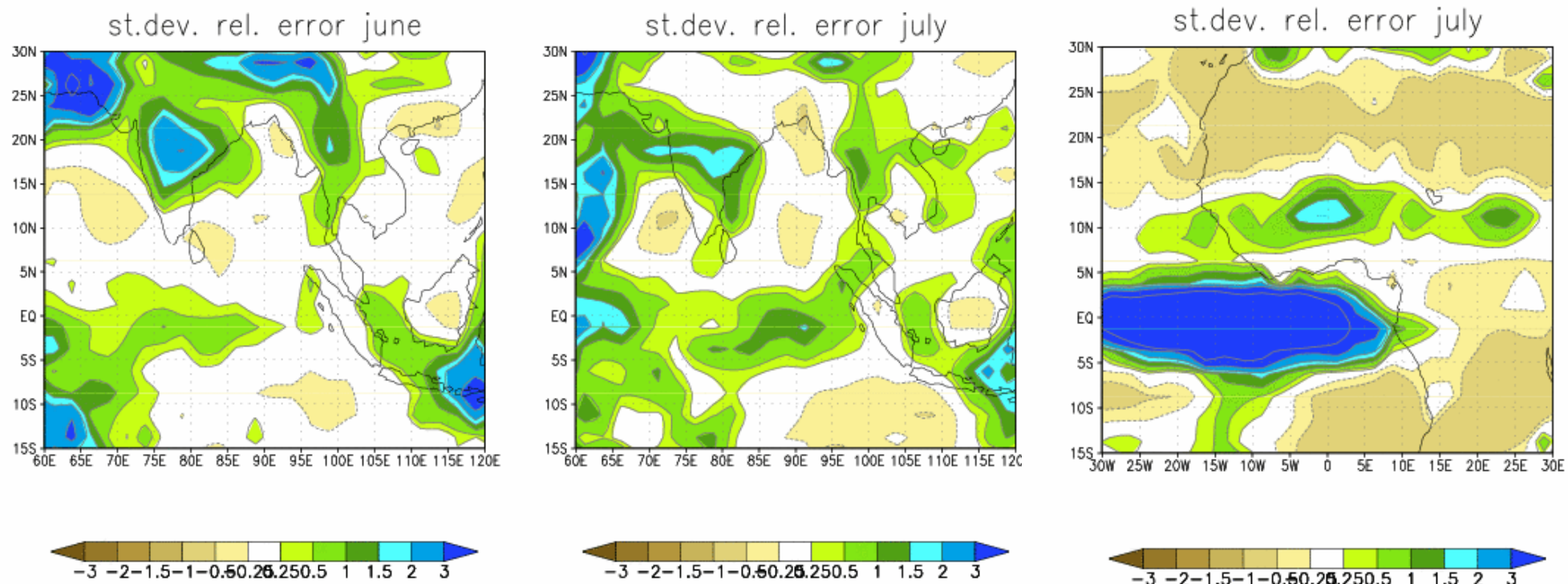


correl. (ENS_mean, ENS_exp) Init: may Verif: jas





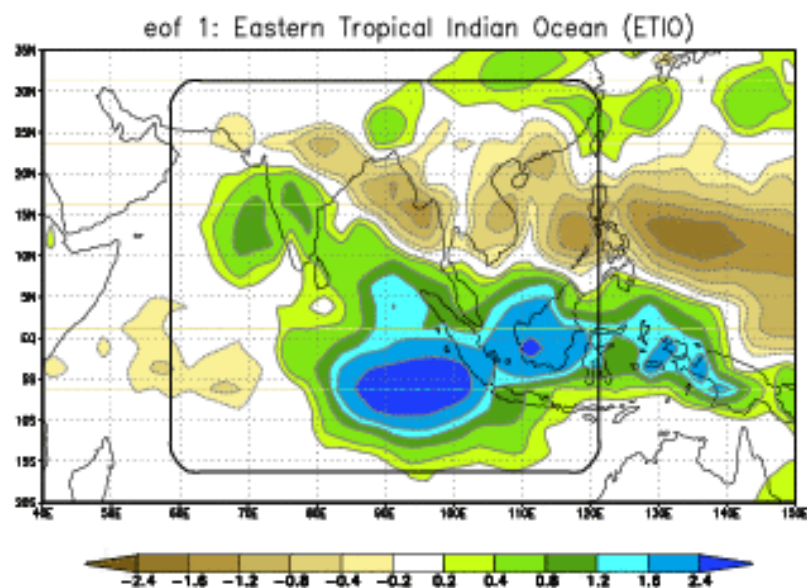
Errors in rainfall standard deviations



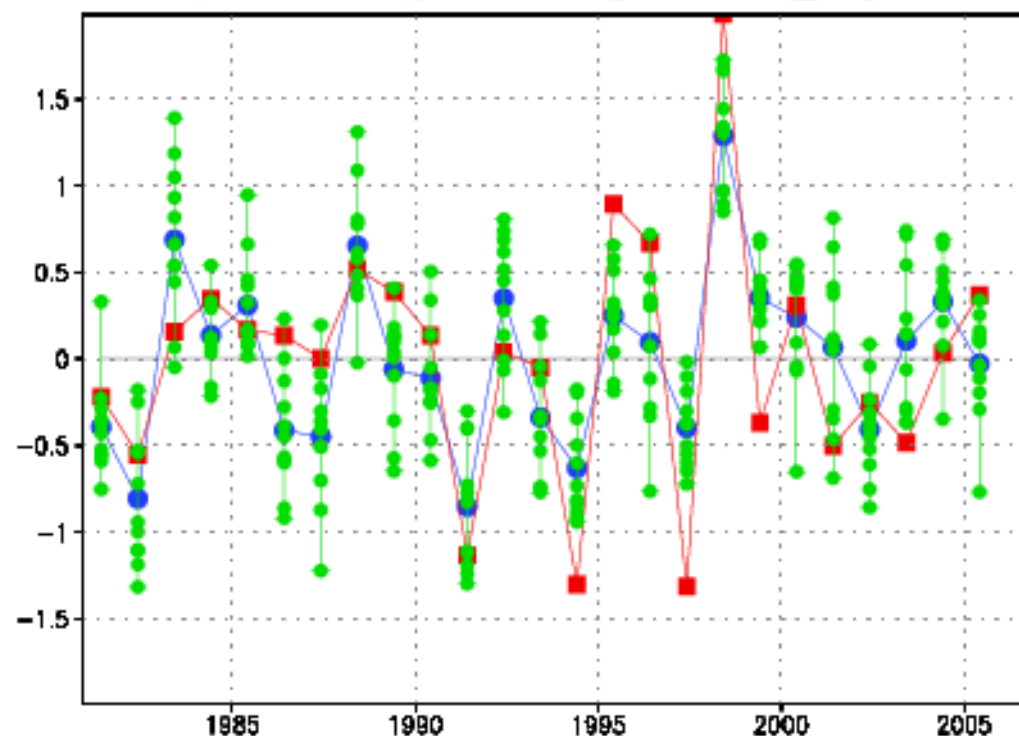
$$[\text{SD (Sys-3)} - \text{SD (GPCP)}] / \text{SD (GPCP)}$$

Predictability of teleconnection/EOF indices in S-3

Rainfall: East. Tropical Indian Ocean pattern (JJA)

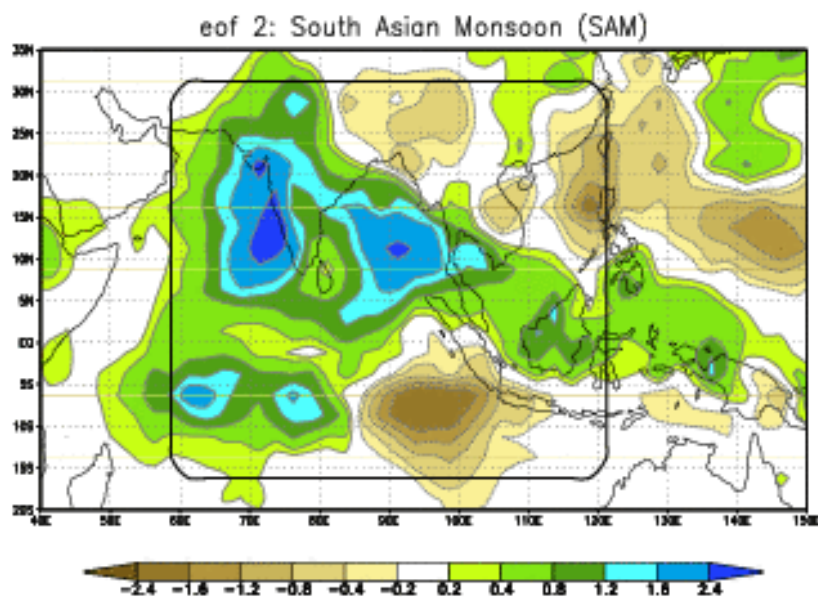


init: may Verif: jja Cor [an, ens_m] = 0.733

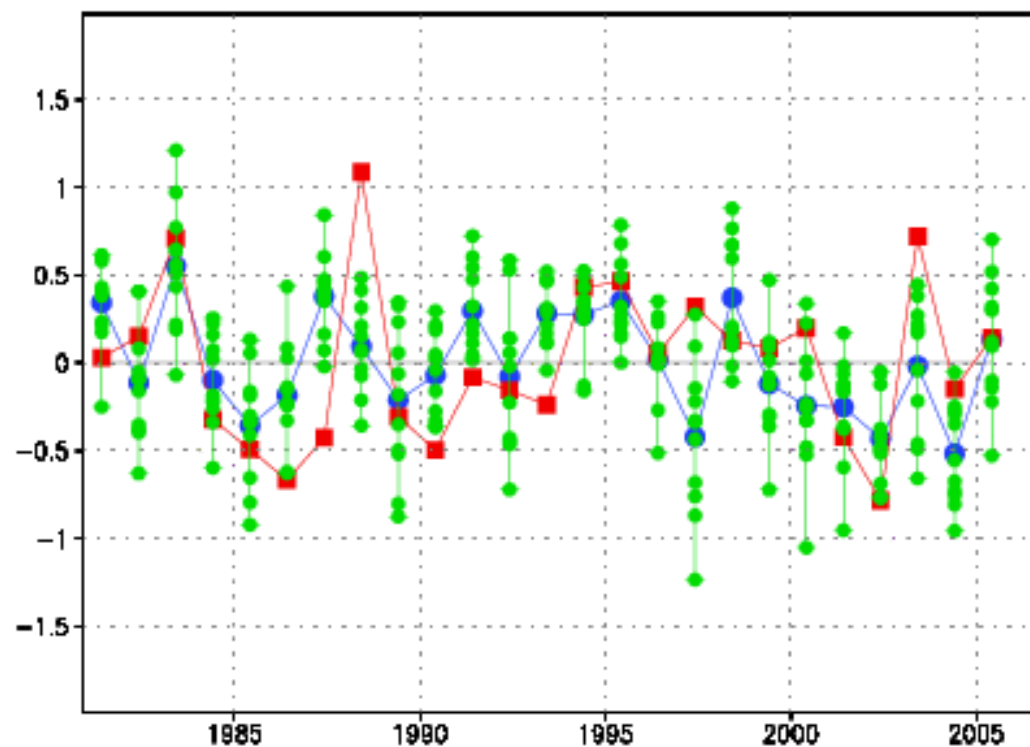


Predictability of teleconnection/EOF indices in S-3

Rainfall: South Asian monsoon pattern (JAS)

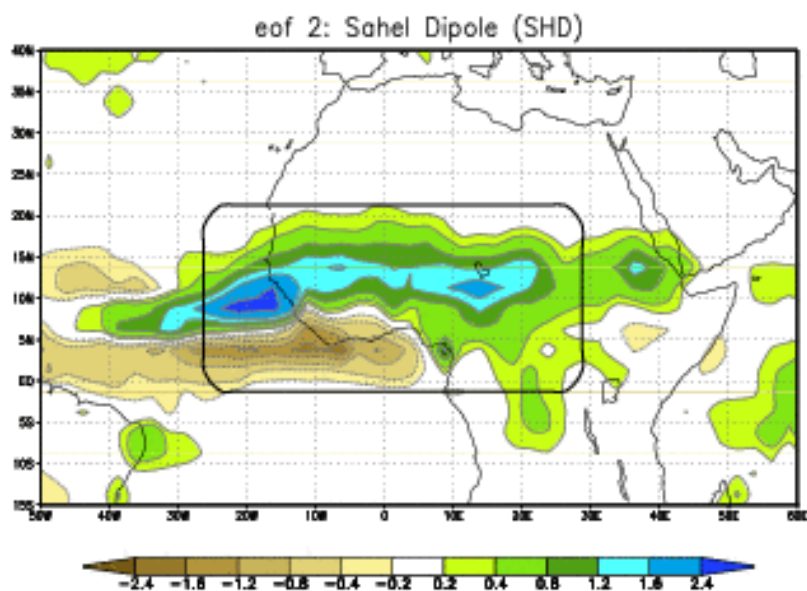


Init: may Verif: jas Cor [an, ens_m] = 0.411

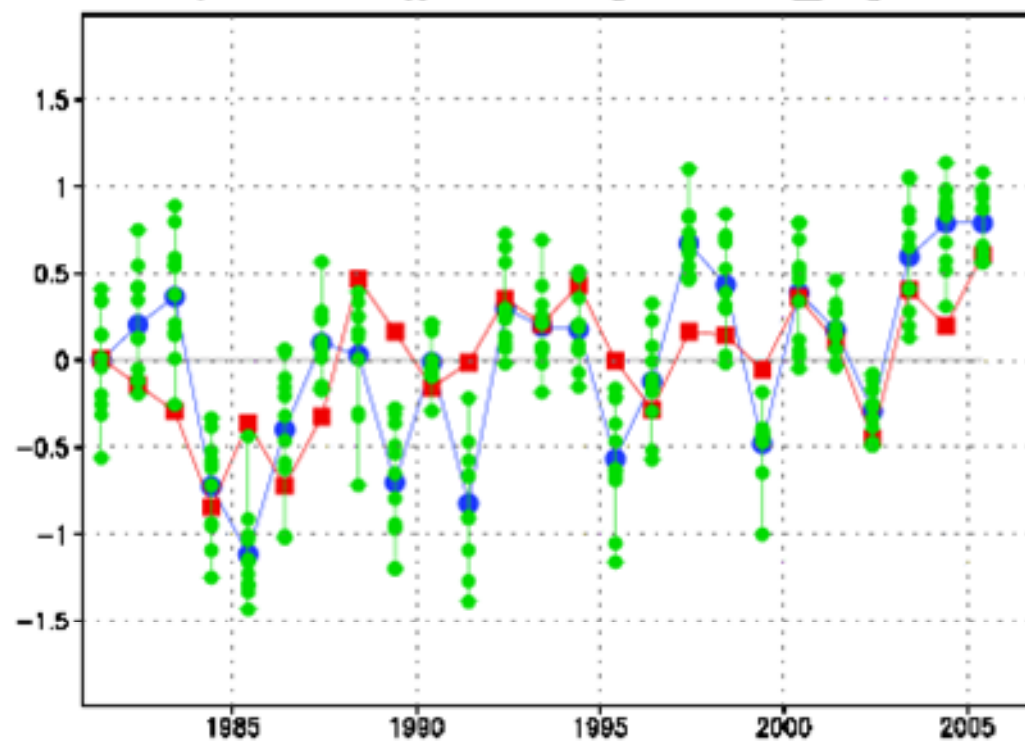


Predictability of teleconnection/EOF indices in S-3

Rainfall: Sahel / Guinea coast dipole (JJA)

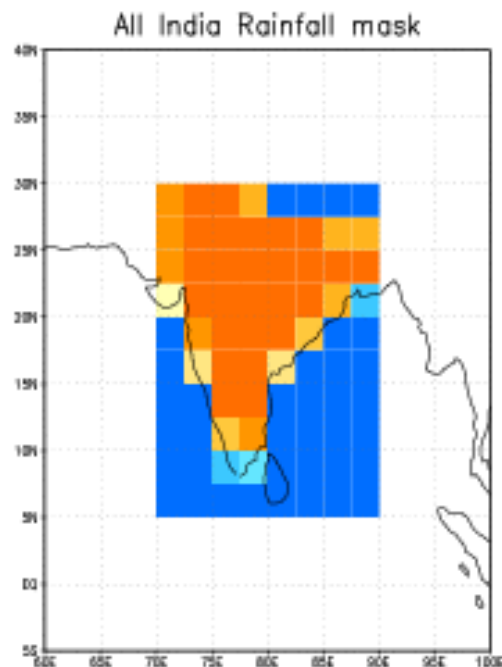


Init: may Verif: jja Cor [\bar{a}_n , ens_m] = 0.580





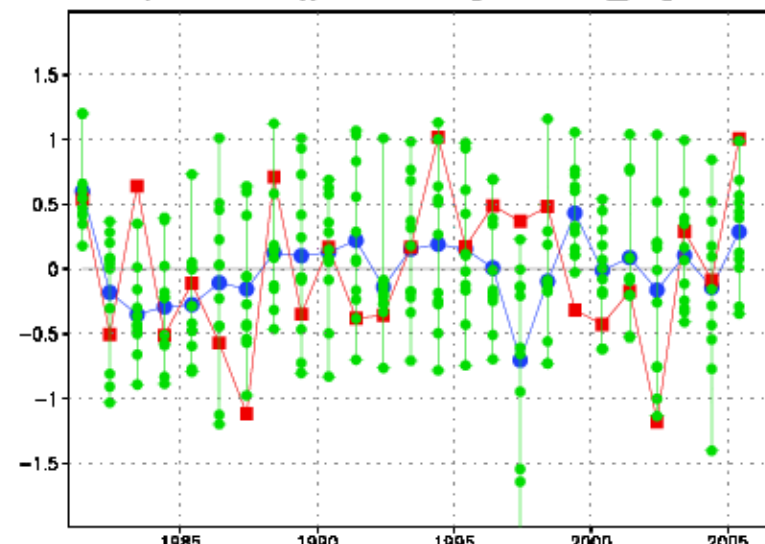
Predictability of AIR in S-3



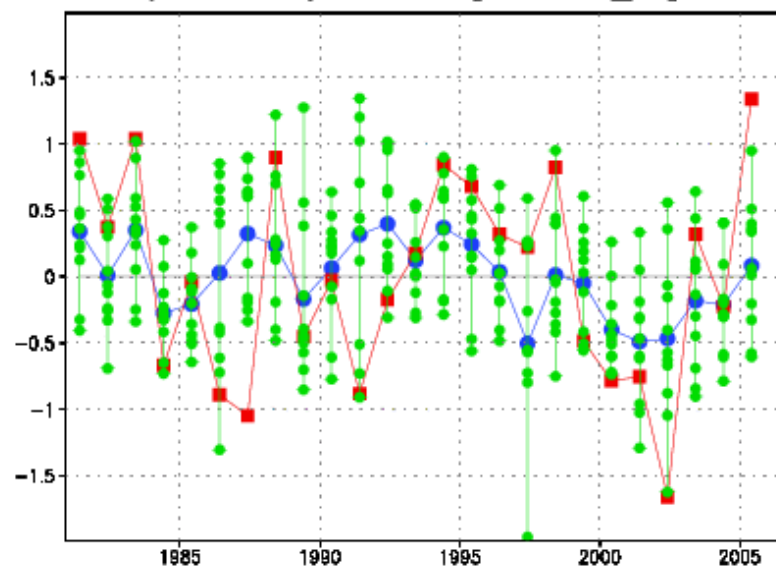
JJAS
CC = .25

JAS
CC = .46

prec average in air [70/90 ; 5/30]
Init: may Verif: jjas Cor [an, ens_m] = 0.254

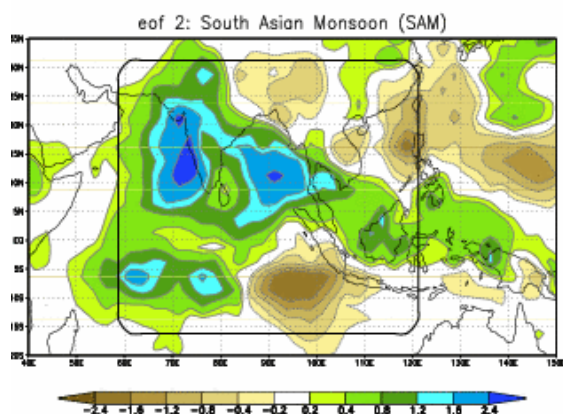
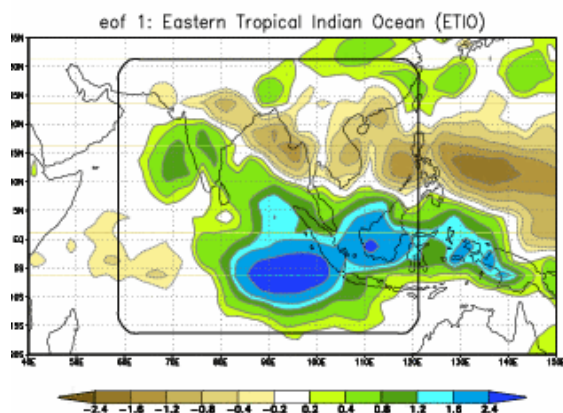
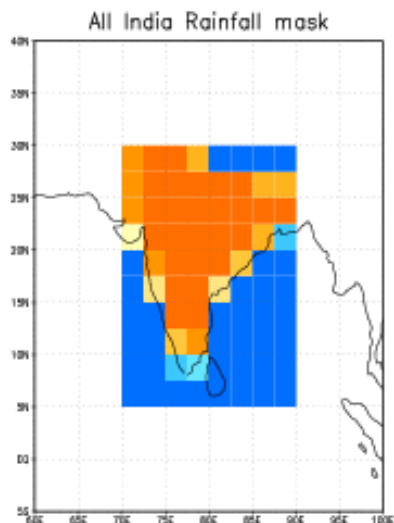


Init: may Verif: jas Cor [an, ens_m] = 0.460

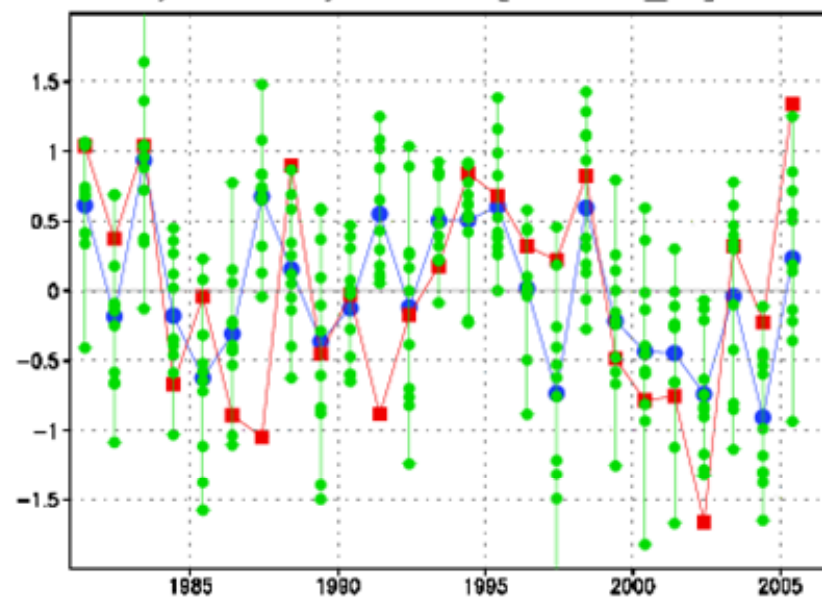




Predictability of AIR in S-3: EOF filtered JAS



prec projection on air [60/120 ; -15/30]
Init: may Verif: jas Cor [an, ens_m] = 0.504

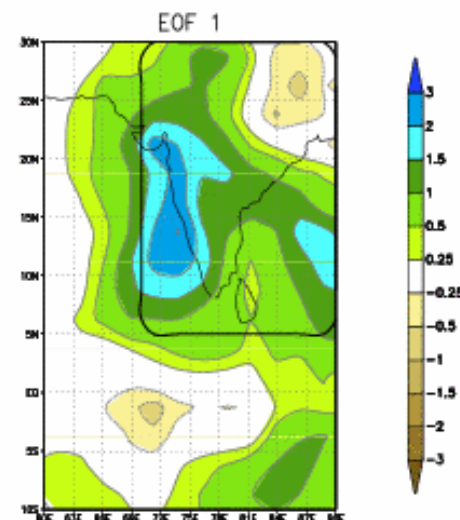
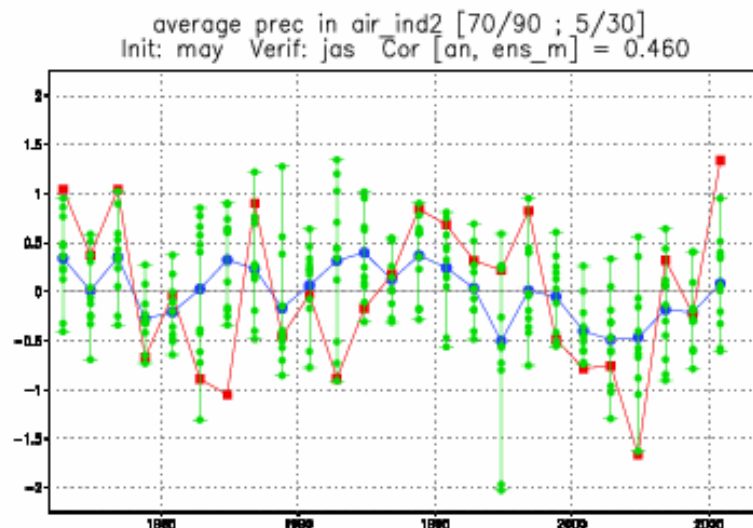


CC = .50

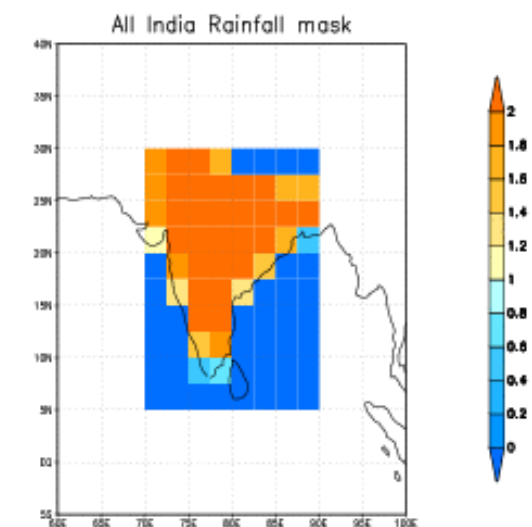
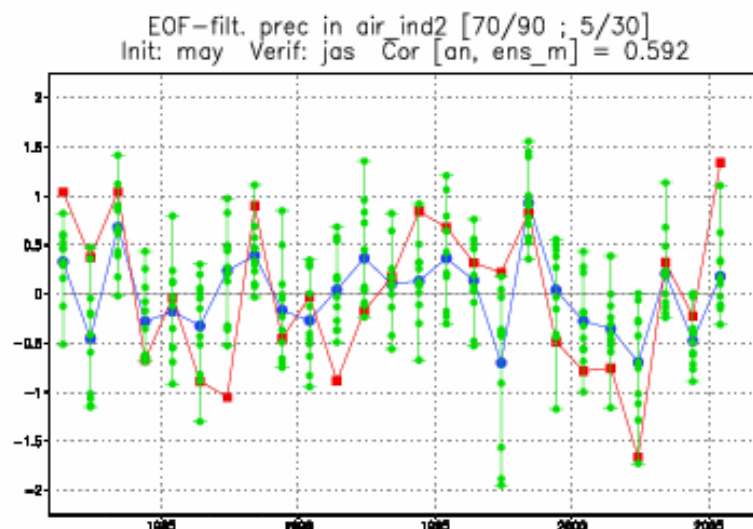


Predictability of AIR in S-3: EOF filtered JAS (2)

Unfiltered
CC = 0.46



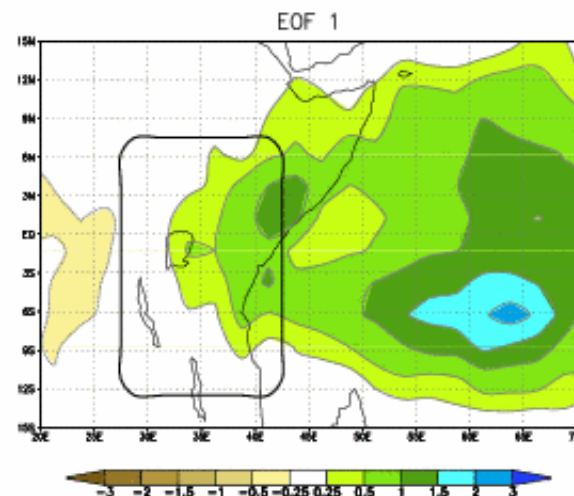
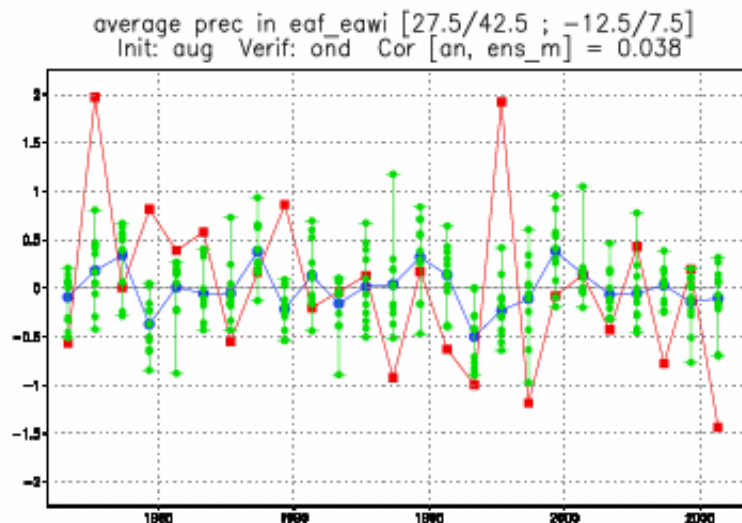
EOF proj.
CC = 0.59



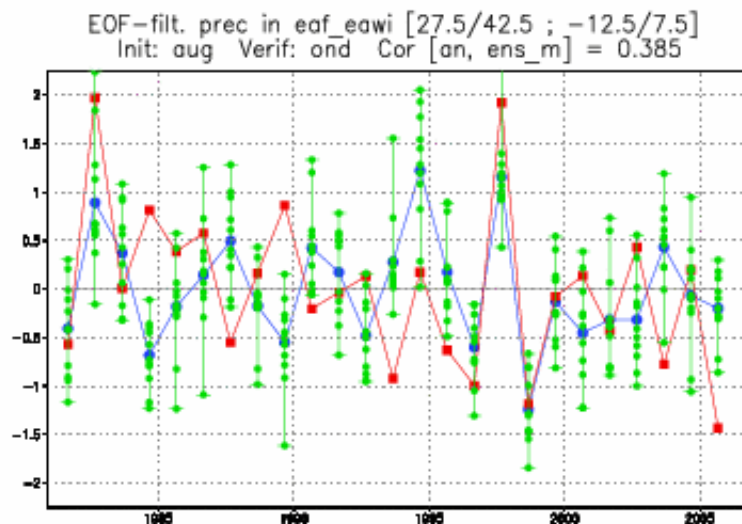


Predictability of East Africa short rains: EOF filtered OND

Unfiltered
CC = 0.04



EOF proj.
CC = 0.39



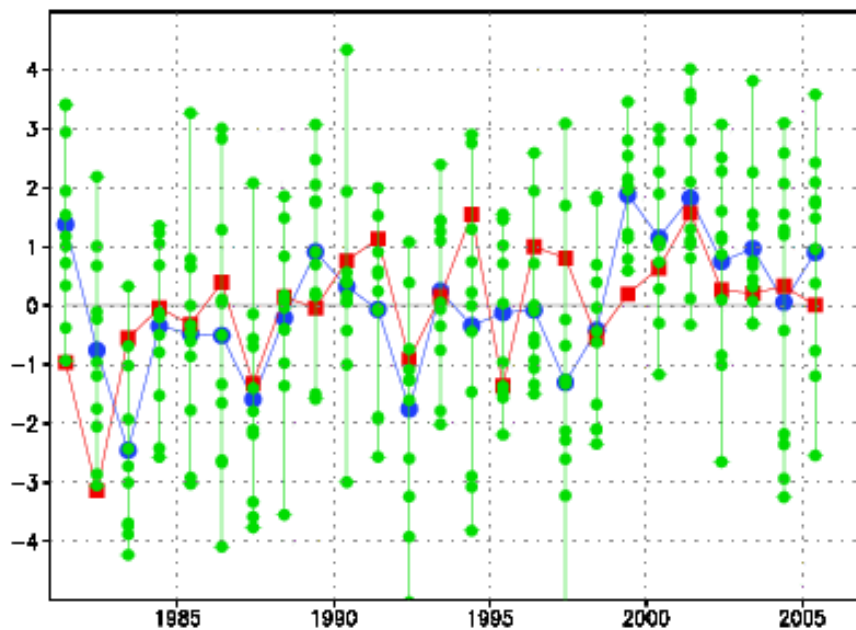


Monsoon onset in India: seasonal fc. for June

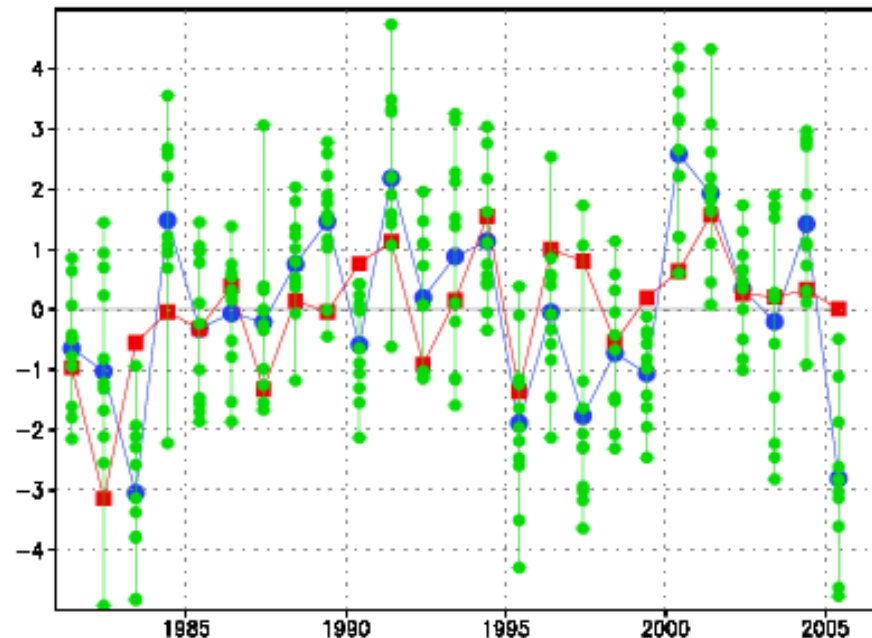
1-month-lead fc.
cc = 0.35

0-lead fc.
cc = 0.45

prec average in air [70/90 ; 5/30]
Init: may Verif: jun Cor [an, ens_m] = 0.349



prec average in air [70/90 ; 5/30]
Init: jun Verif: jun Cor [an, ens_m] = 0.445



Forecast anomaly amplitude is ~ 2 x obs. !



Asian monsoon onset exp. with VarEPS-monthly

- VarEPS configuration with cycle 31r2
- 45-day integration from 15 May to end of June 1991-2007

Verification of all-India rainfall vs. GPCP data

- June mean rainfall
- Pentad-mean rainfall



Monsoon onset in India: VarEPS-monthly fc.

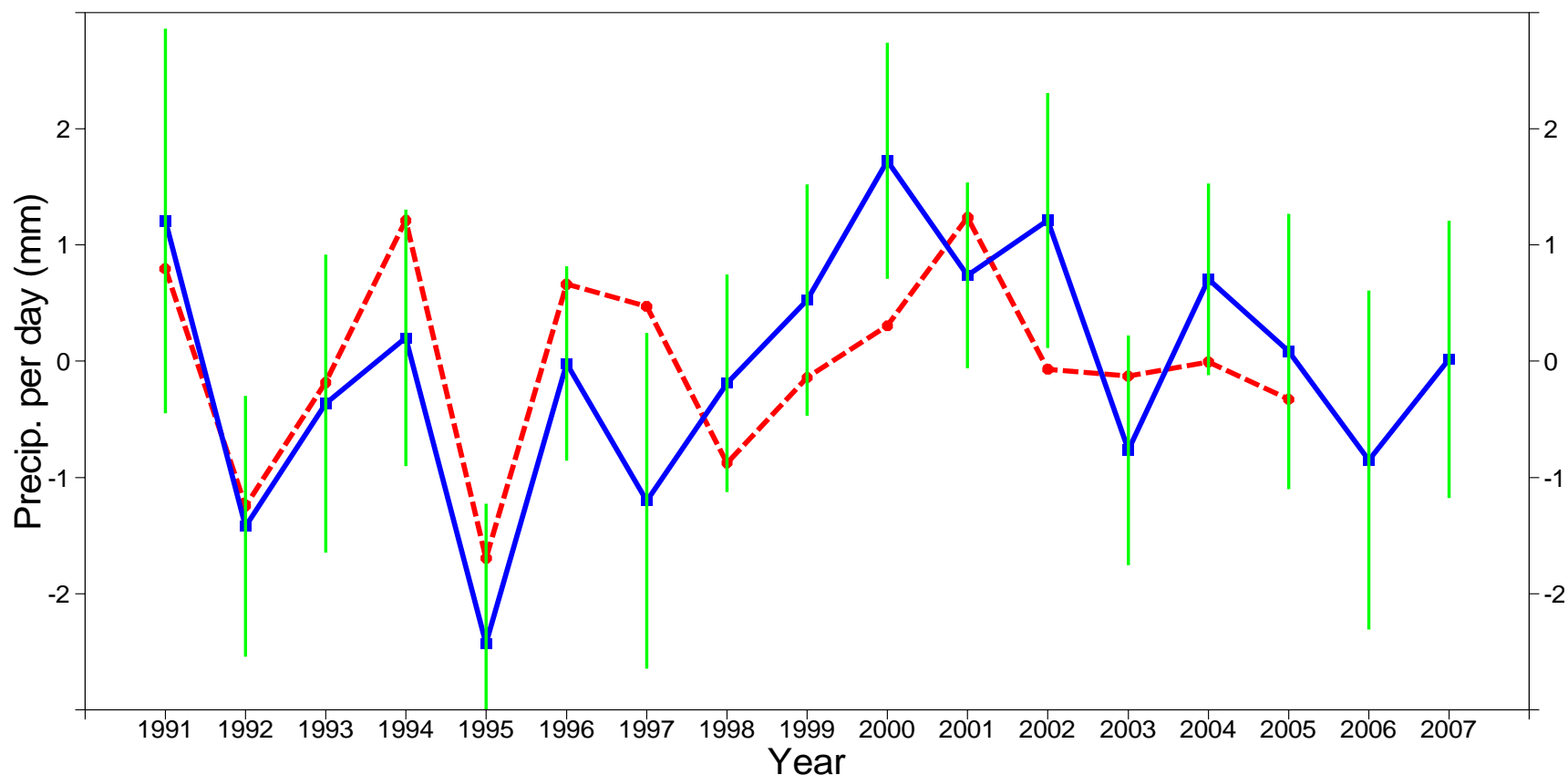
ECMWF Monthly Forecast
June Precip over India (70-85E,5-30N)

CC = 0.62

Forecast start reference is 15/05/yyyy
Calibration period = 1991-2005
Ensemble size = 10 (real time =140)

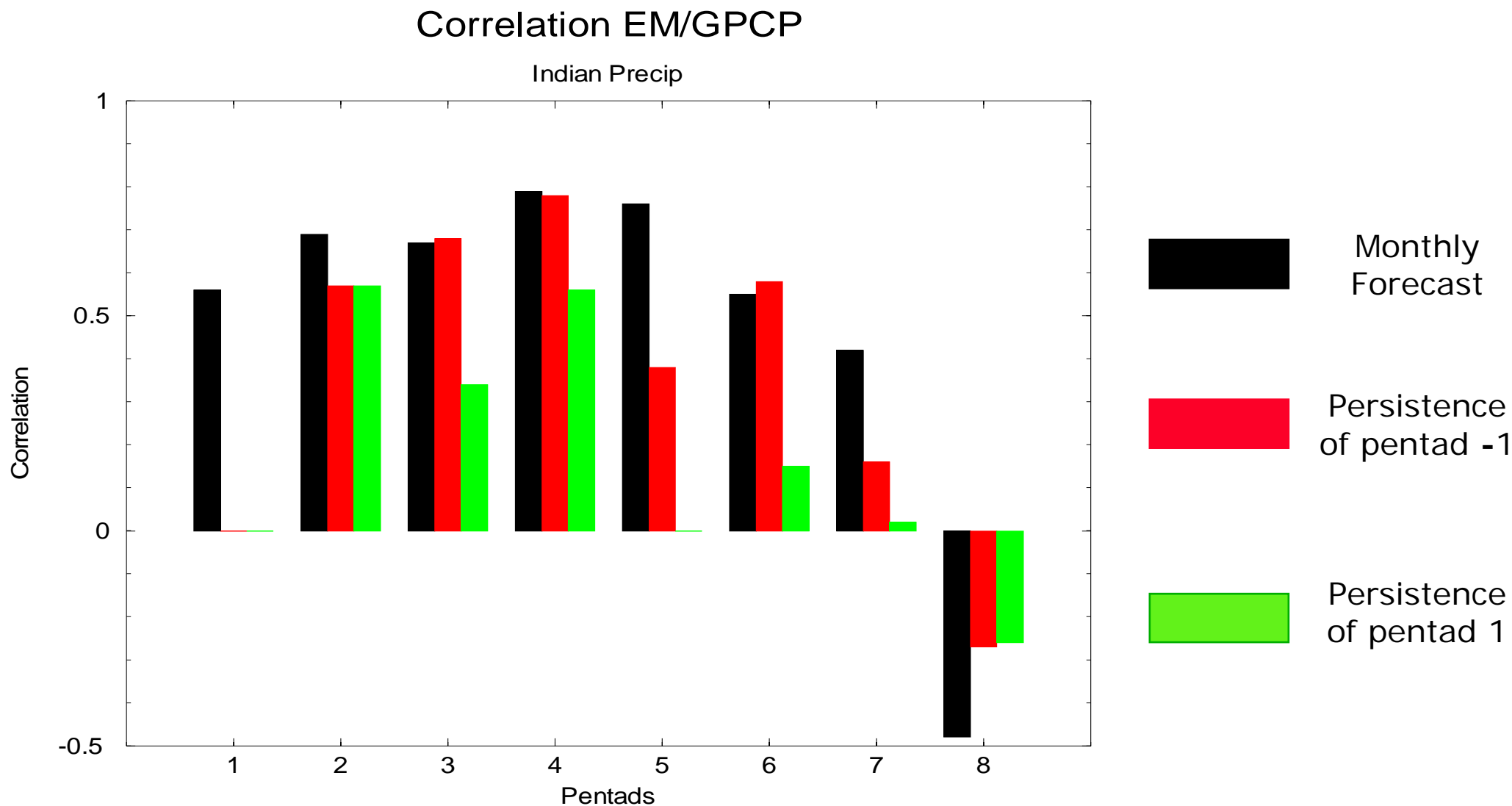
Correlation= 0.62(0.99)
RMS Error= 0.88(0.83)

---●--- Observations (GPCP) —■— FORECAST — Standard Deviation





Anomaly correl. of pentad rainfall over India



Monsoon onset predictions: early June pentads

Day 16-20: 1-5 June

CC = 0.79

Day 21-25: 6-10 June

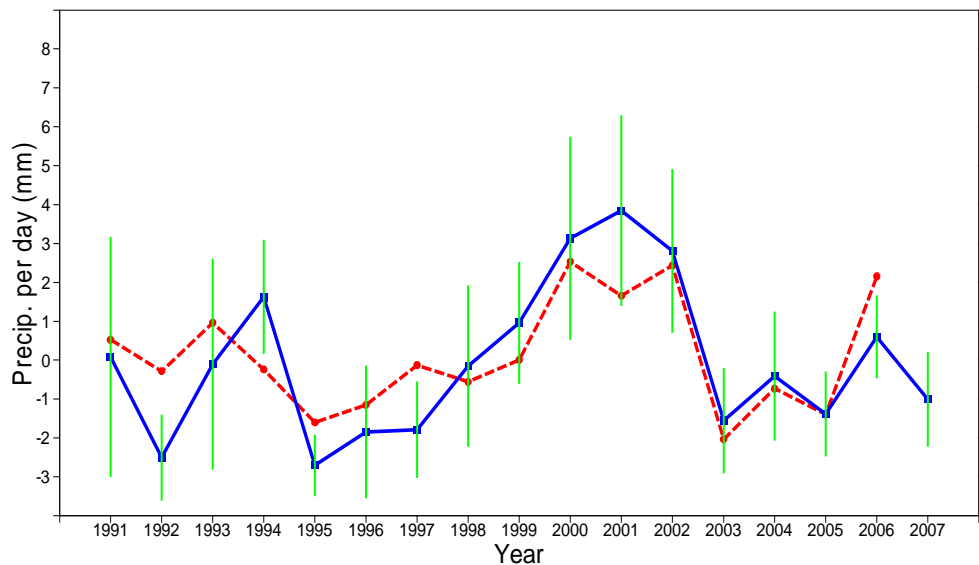
CC = 0.76

ECMWF Monthly Forecast
June Precip over India (70-85E,5-30N)

Forecast start reference is 15/05/yyyy
Calibration period = 1991-2006
Ensemble size = 10 (real time =150)

Correlation= 0.79(1.00)
RMS Error= 1.25(1.46)

--- ERA40 — FORECAST — Standard Deviation

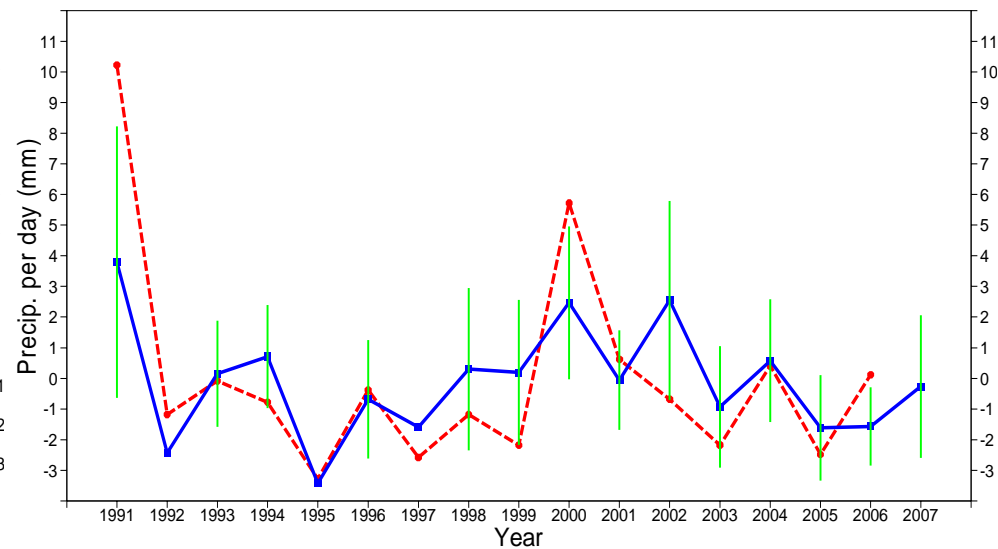


ECMWF Monthly Forecast
June Precip over India (70-85E,5-30N)

Forecast start reference is 15/05/yyyy
Calibration period = 1991-2006
Ensemble size = 10 (real time =150)

Correlation= 0.76(1.00)
RMS Error= 2.32(3.41)

--- ERA40 — FORECAST — Standard Deviation





Conclusions (1)

- SST predictions from the ECMWF seasonal forecast system-3 show higher skill than those from previous system, particularly in the tropical Pacific and eastern Indian Oc., but western Indian Oc. and tropical Atlantic are still not better than persistence in NH summer.
- Substantial model errors affect rainfall variability over tropical land.
- Predictive skill for seasonal rainfall is generally good over the Pacific and tropical S. America, poor along the coast of the Indian Ocean in early summer. Skill for All-India Rainfall increases in the latter part of the monsoon season.
- Seasonal forecasts over land can be improved by exploiting teleconnections with adjacent ocean regions.



Conclusions (2)

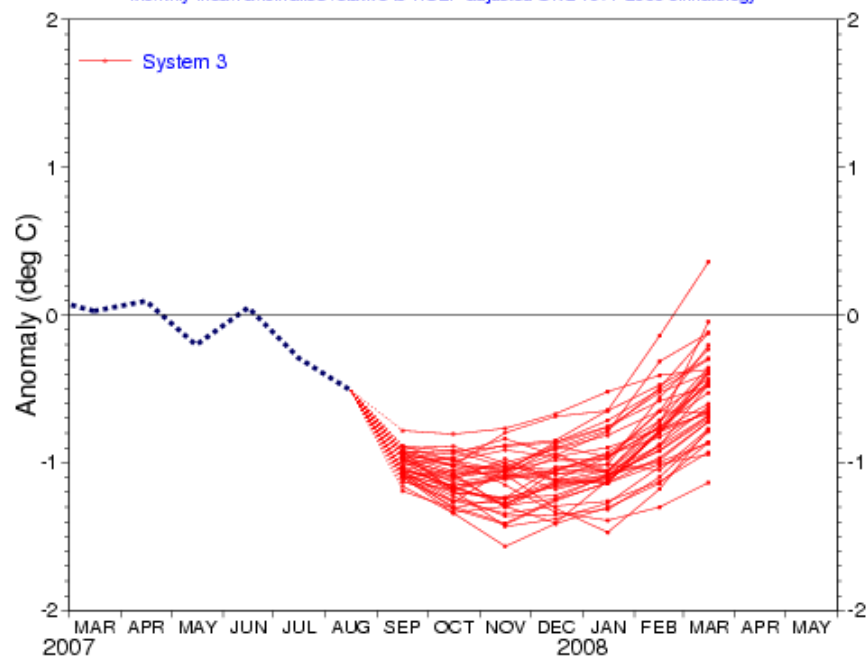
- Predictions from the VarEPS-monthly forecast system show useful skill at the beginning of the South-Asian monsoon season, even on a pentad time-scale.
- If a minimal amount of statistical post-processing is performed, and information from monthly and seasonal forecast systems are used on the appropriate scales, the skill of dynamical predictions of monsoon rainfall from the ECMWF systems compare favourably with that of purely statistical schemes.



Products from Sys-3: "plumes" for El Nino indices

NINO3.4 SST anomaly plume
ECMWF forecast from 1 Sep 2007

Monthly mean anomalies relative to NCEP adjusted OIv2 1971-2000 climatology

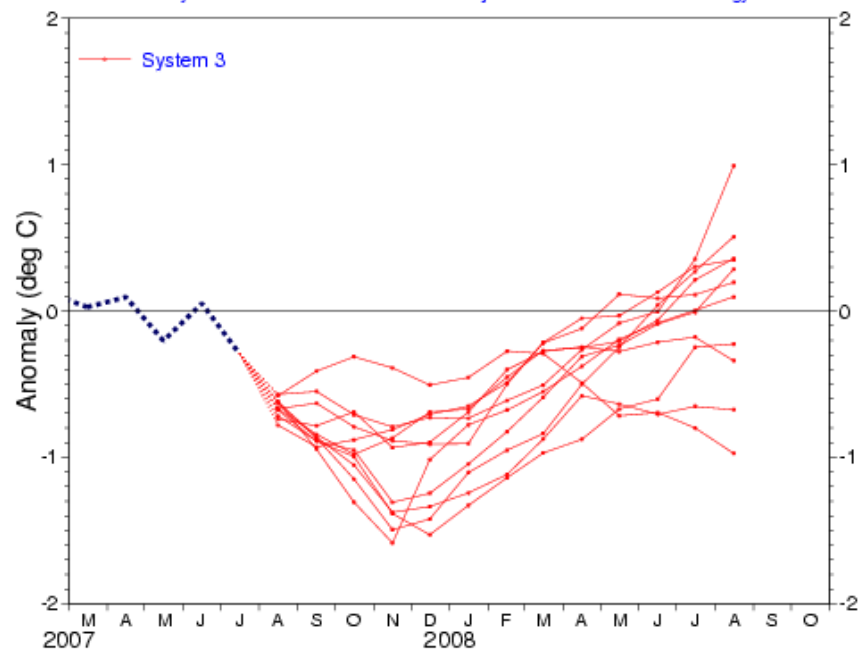


Forecast issue date: 15 Sep 2007



NINO3.4 SST anomaly plume
ECMWF forecast from 1 Aug 2007

Monthly mean anomalies relative to NCEP adjusted OIv2 1971-2000 climatology

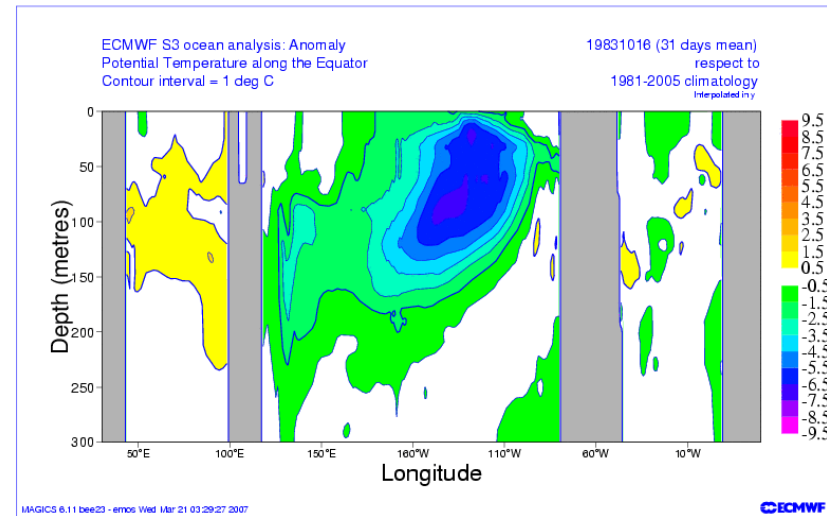
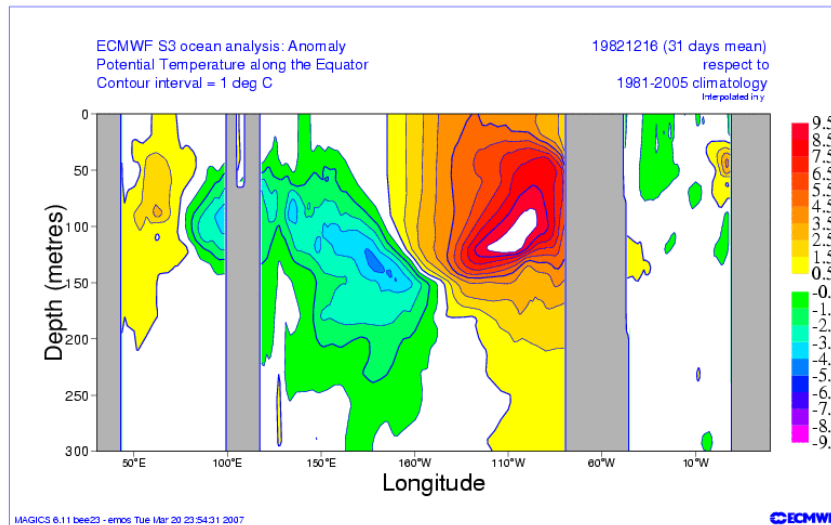
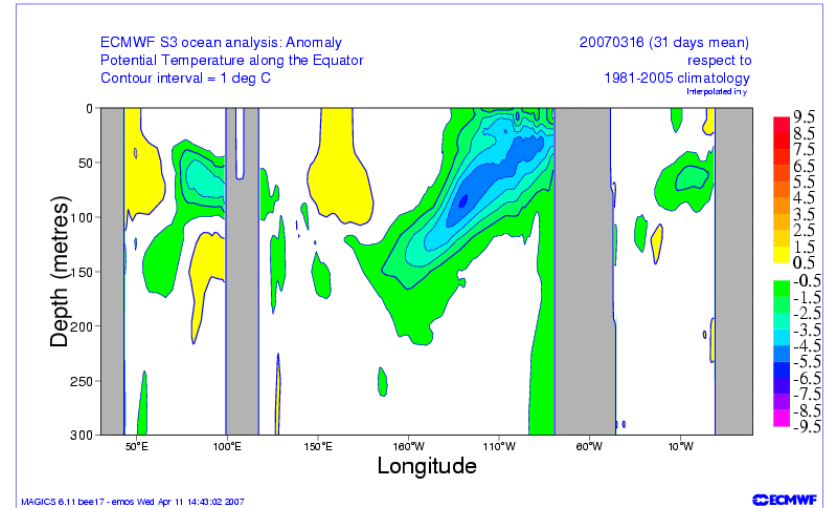
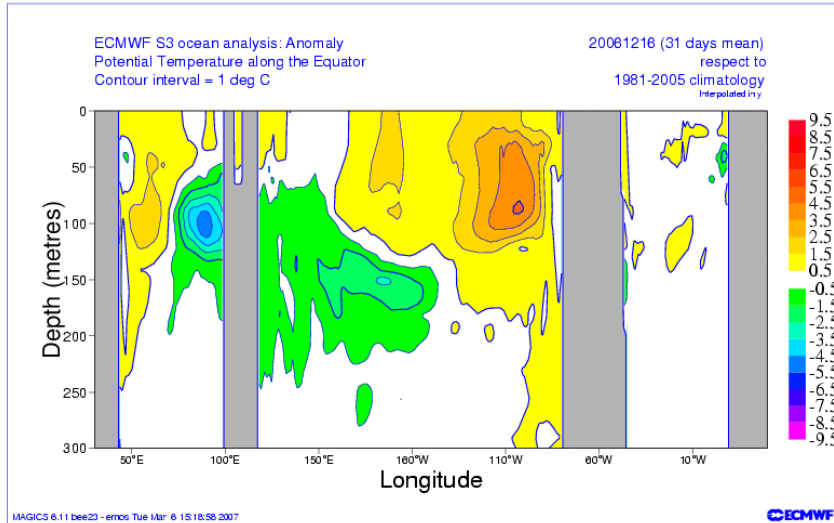


Forecast issue date: 15 Aug 2007



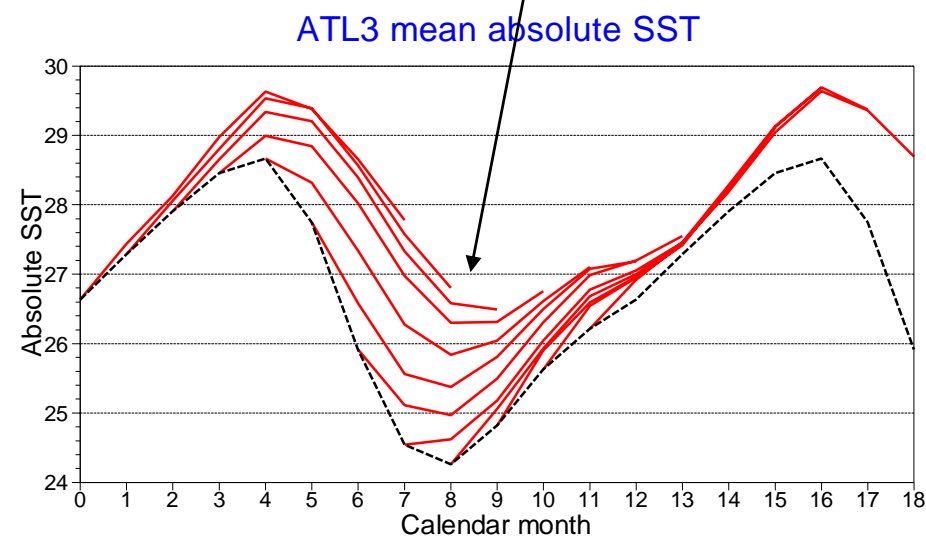
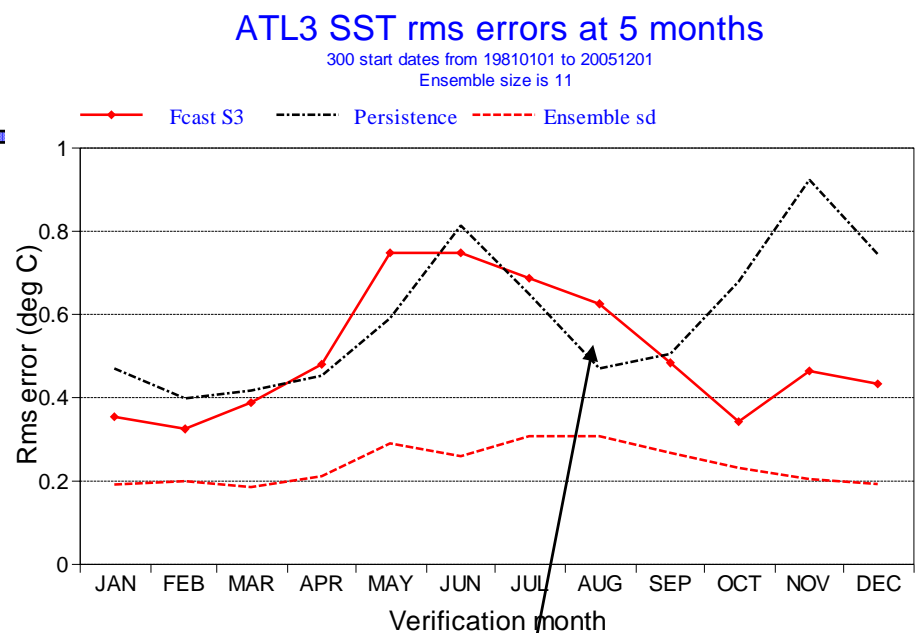
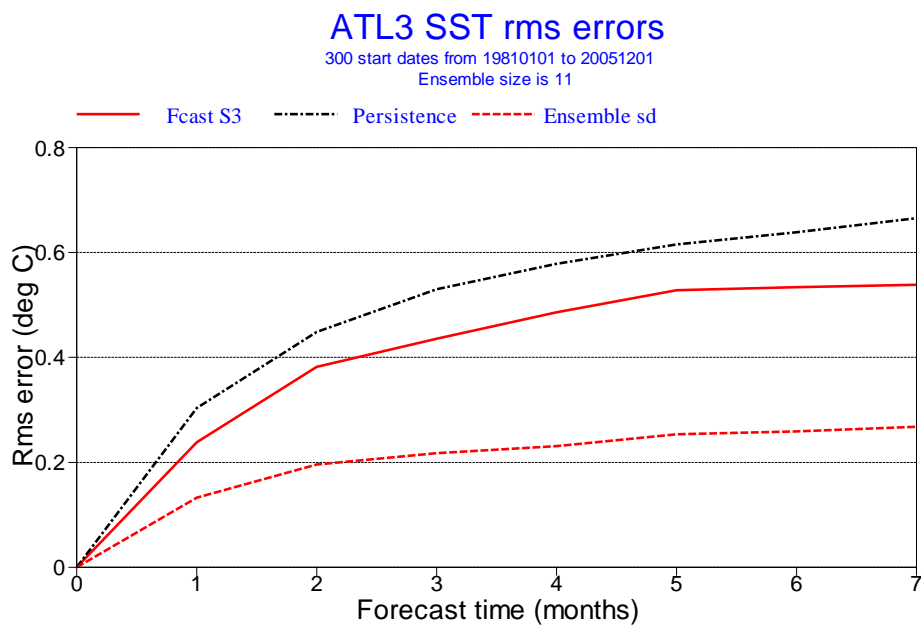


New products from Sys-3: ocean reanalysis





Equatorial Atlantic





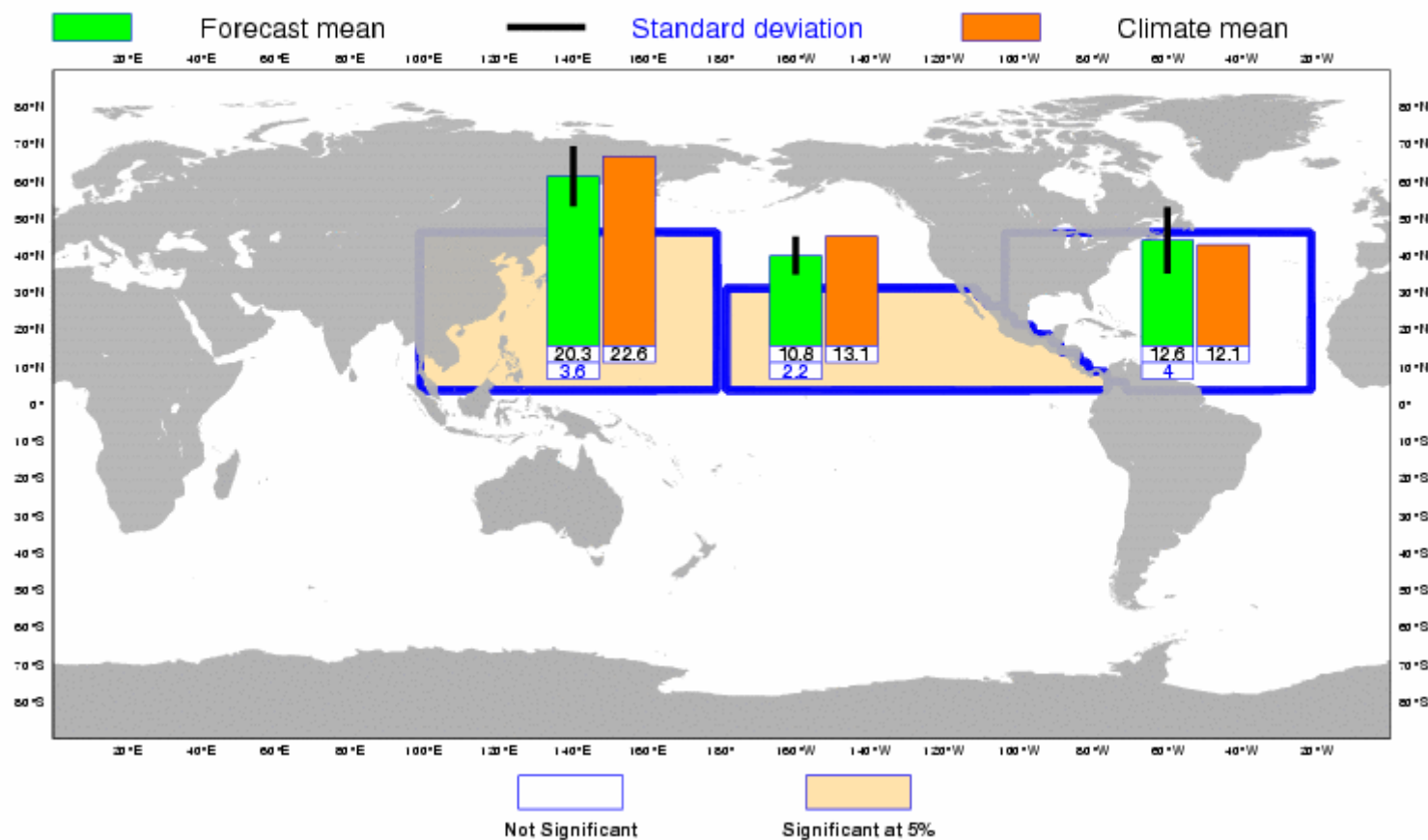
Products from Sys-3 : tropical storm frequency

ECMWF Seasonal Forecast Tropical Storm Frequency

Forecast start reference is 01/06/2007
Ensemble size = 41, climate size = 176

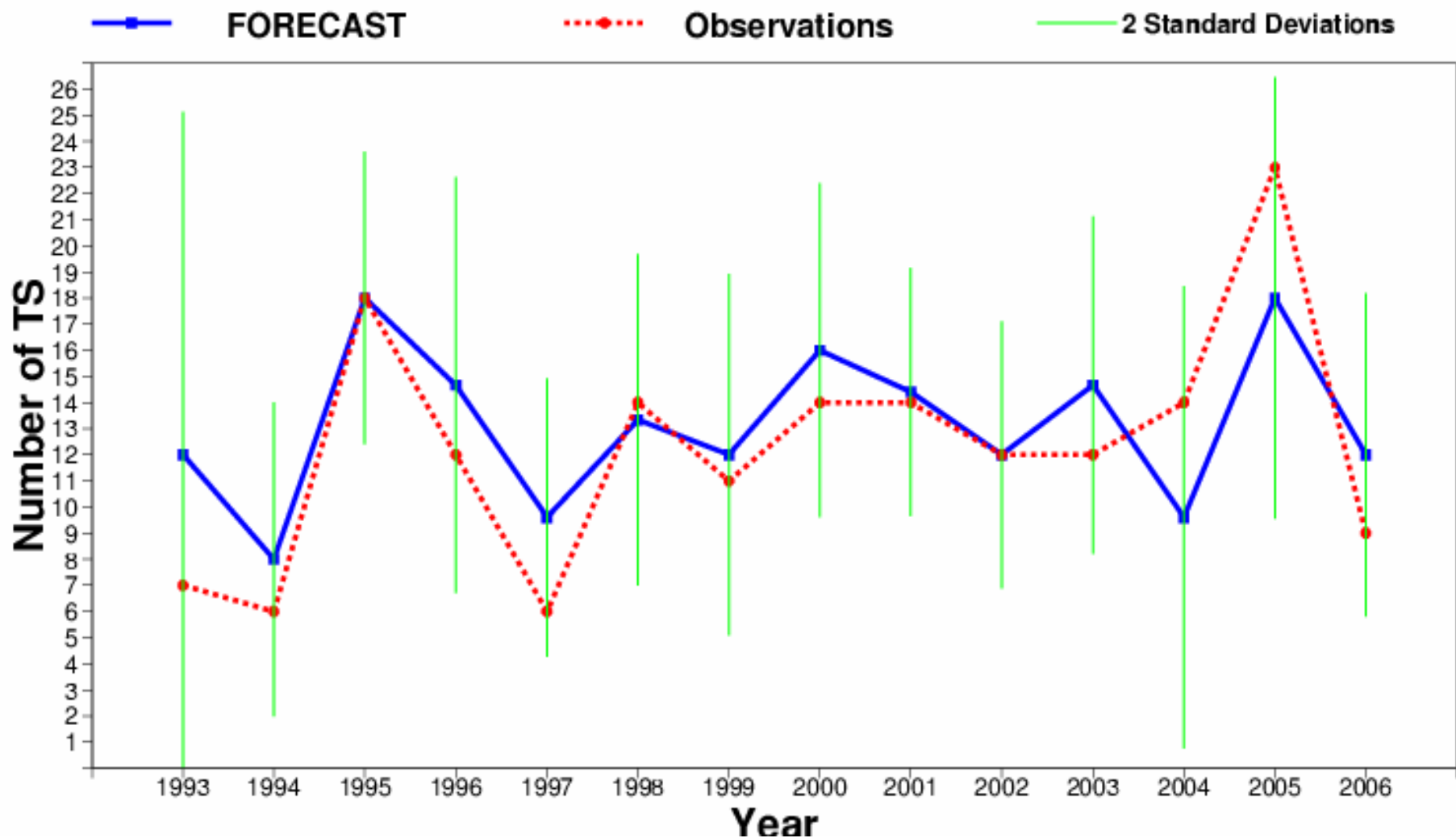
System 3 JASOND 2007

Climate = 1990-2005



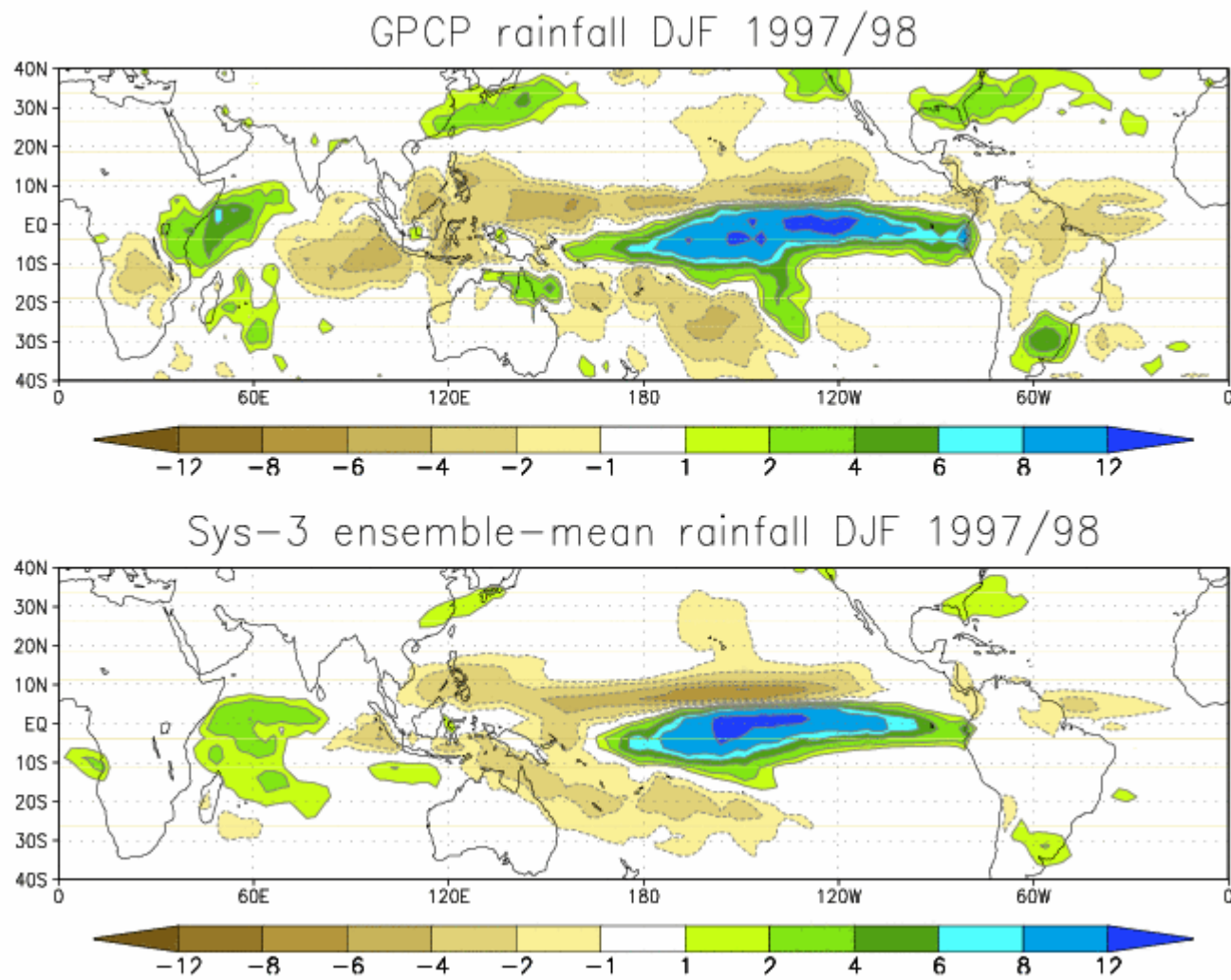


EUROSIP seasonal fc of tropical storms (from 1st June)





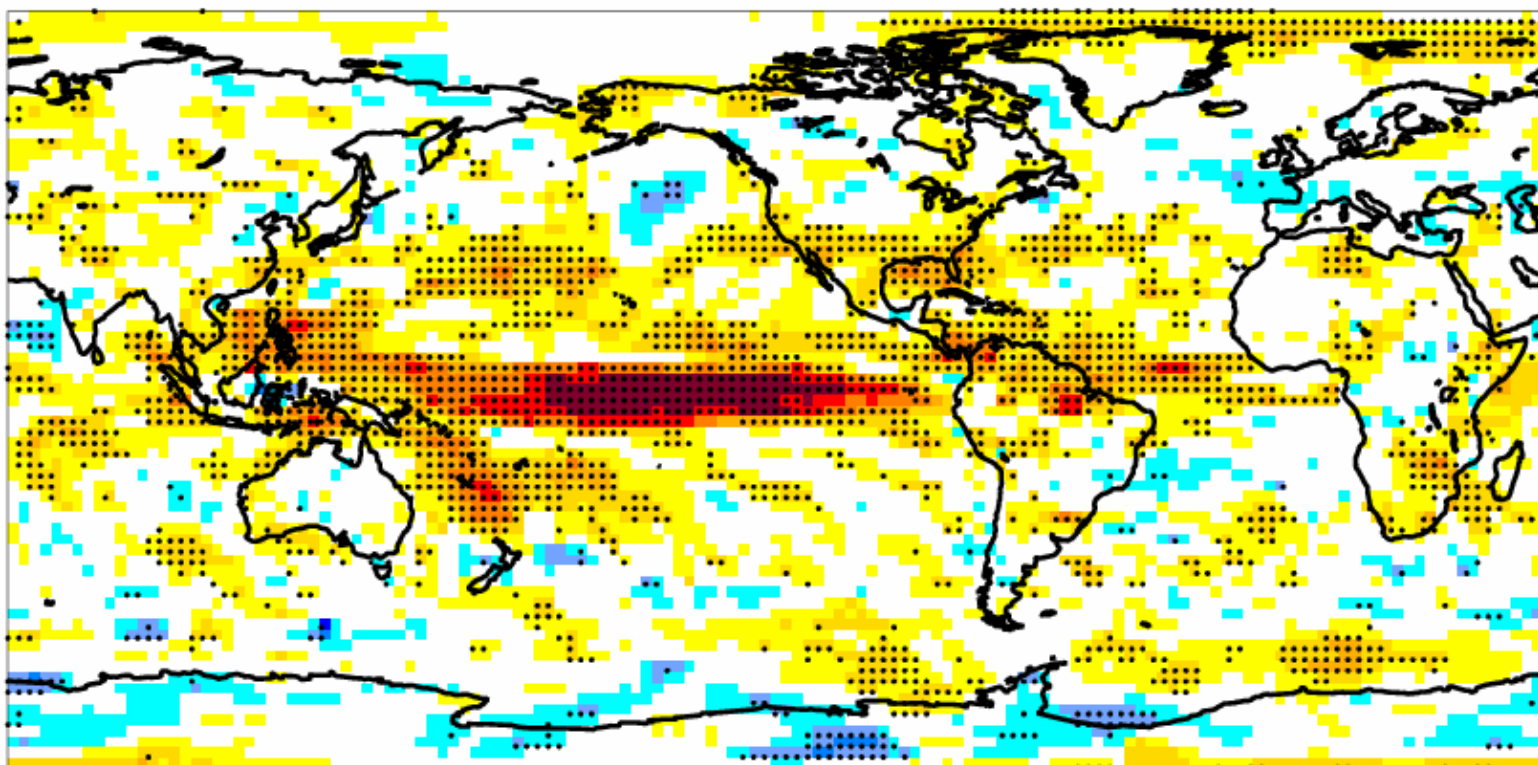
Can we predict rainfall over tropical continents?





ACC for seasonal-mean prec.: DJF from 1 Nov

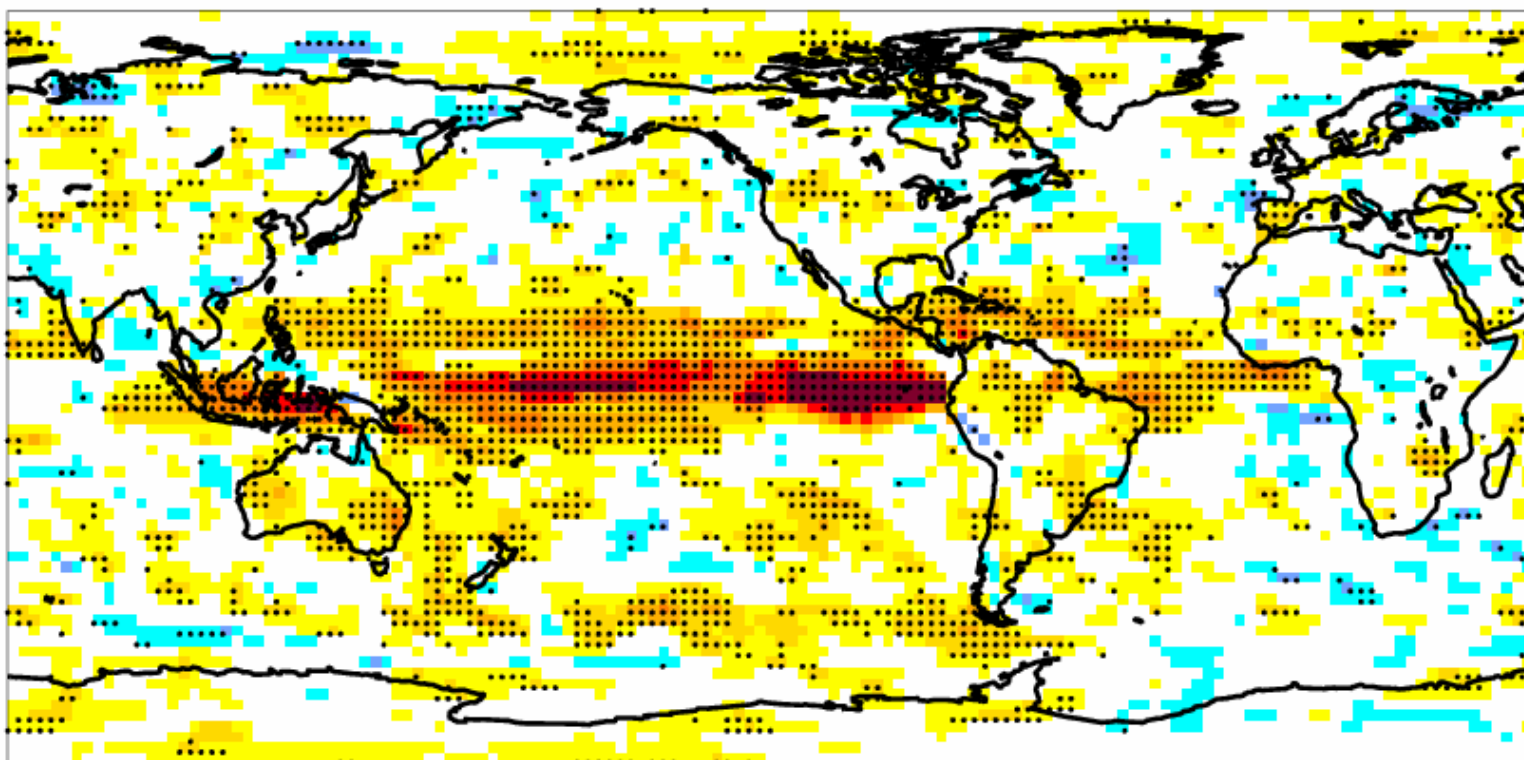
Anomaly Correlation Coefficient for CodOecmfE0001S003M001 with 11 ensemble members
Precipitation
Hindcast period 1981-2005 with start in November and averaging period 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)





ACC for seasonal-mean prec.: JJA from 1 May

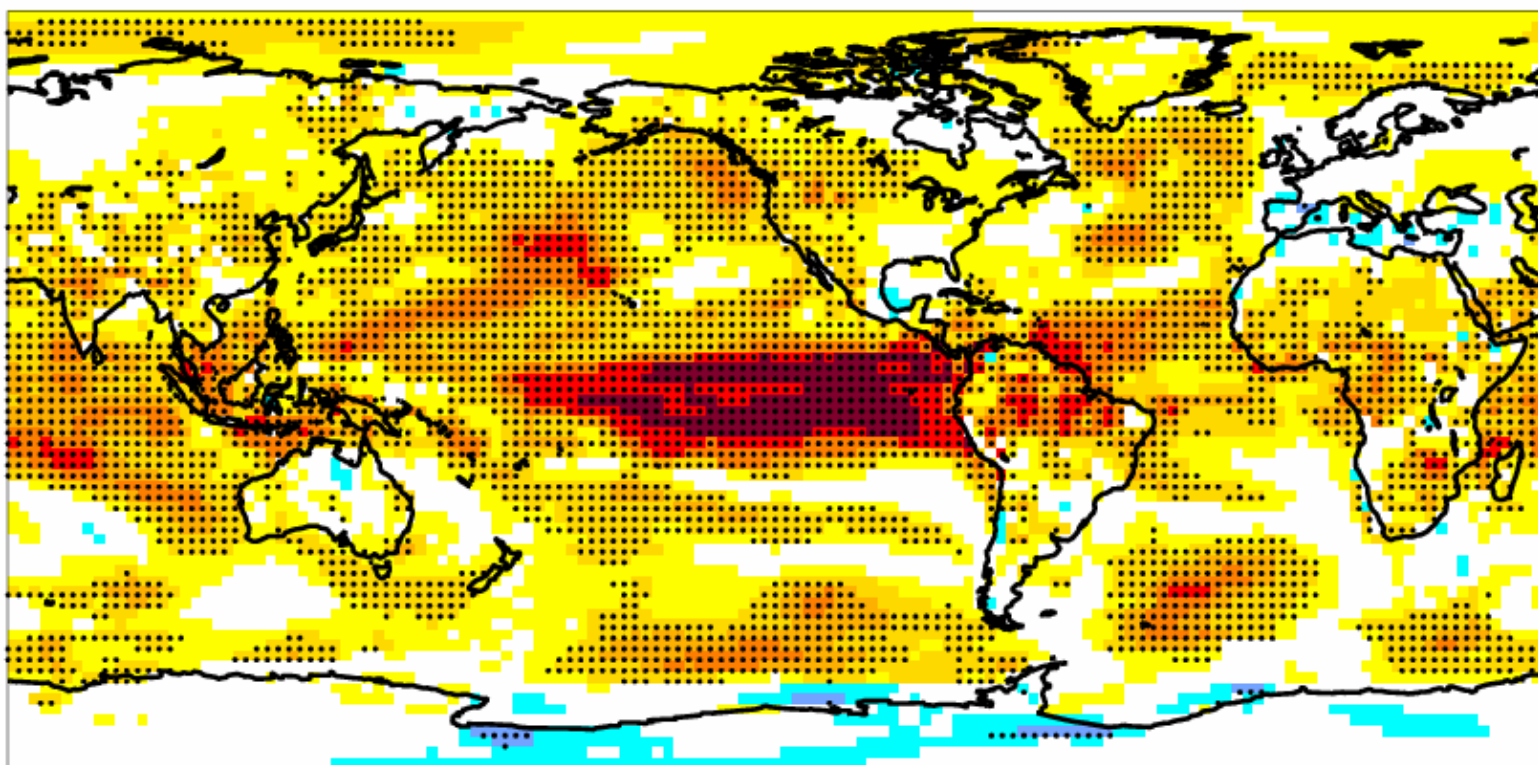
Anomaly Correlation Coefficient for CodOecmfE0001S003M001 with 11 ensemble members
Precipitation
Hindcast period 1981-2005 with start in May and averaging period 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)





ACC for seasonal-mean 2m-T: DJF from 1 Nov

Anomaly Correlation Coefficient for CodOecmfE0001S003M001 with 11 ensemble members
Near-surface temperature
Hindcast period 1981-2005 with start in November and averaging period 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)





ACC for seasonal-mean 2m-T: JJA from 1 May

Anomaly Correlation Coefficient for CodOecmfE0001S003M001 with 11 ensemble members
Near-surface temperature
Hindcast period 1981-2005 with start in May and averaging period 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)

