The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

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International Atomic Energy Agency

1956-26

Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

4 - 15 August 2008

MJO and monsoon simulations in the ECMWF VAREPS-monthly system.

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MJO and monsoon Simulations in the ECMWF VarEPS-Monthly System

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European Centre for Medium-Range Weather Forecasts

Outline

1. The ECMWF VarEPS-monthly forecasting system
2. MJO Prediction
3. Monsoon prediction
4. Conclusion

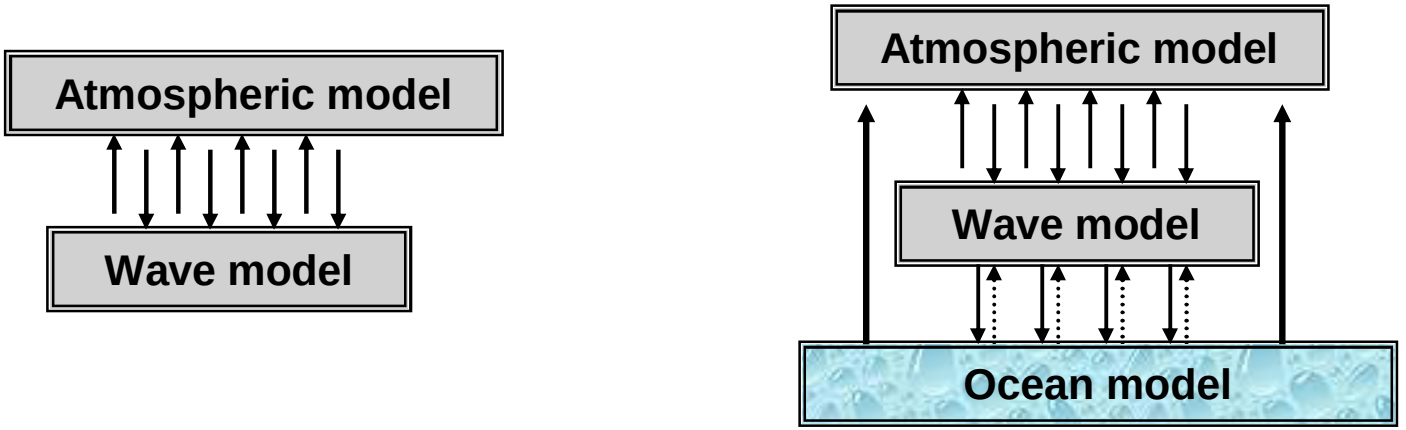
Ensemble Forecasting systems at ECMWF

ECMWF: Weather and Climate Dynamical Forecasts

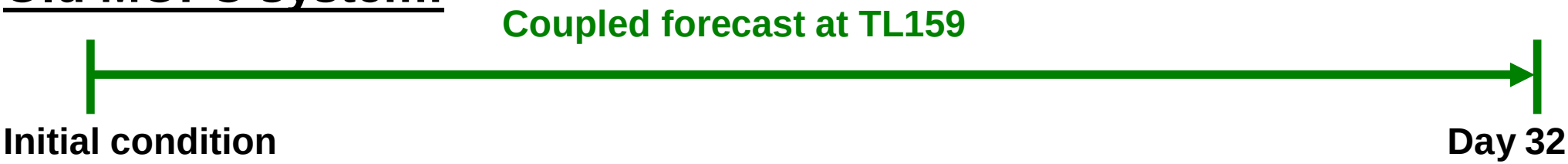
Product

Medium-Range Forecasts	Monthly Forecast	Seasonal Forecasts
Day 1-15	Day 10-32	Month 2-7

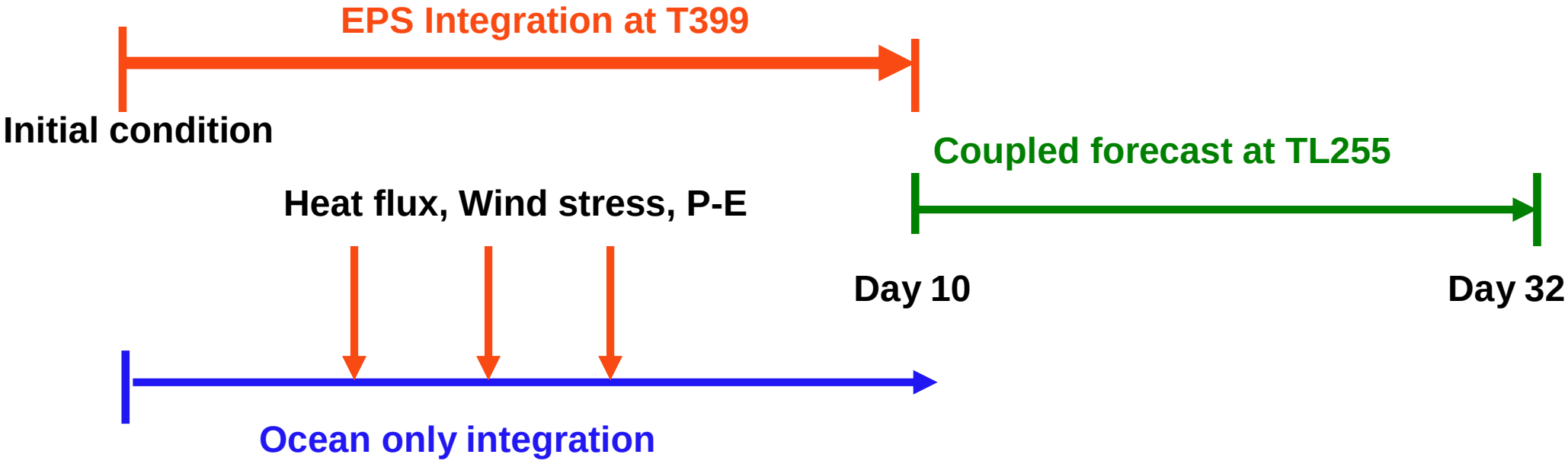
Tool



Old MOFC system:



Current system (VAREPS/Monthly):



The ECMWF VarEPS-monthly forecasts

- A 51-member ensemble is integrated for 32 days every week
- Atmospheric component: IFS with the latest operational cycle and with a T399L62 resolution till day 10 and T255L62 after day 10.
- Persisted SST anomalies till day 10 and ocean-atmosphere coupling from day 10 to day 32.
- Oceanic component: HOPE (from Max Plank Institute) with a zonal resolution of 1.4 degrees and 29 vertical levels
- Coupling: OASIS (CERFACS). Coupling every 3 hours

The ECMWF monthly forecasting system

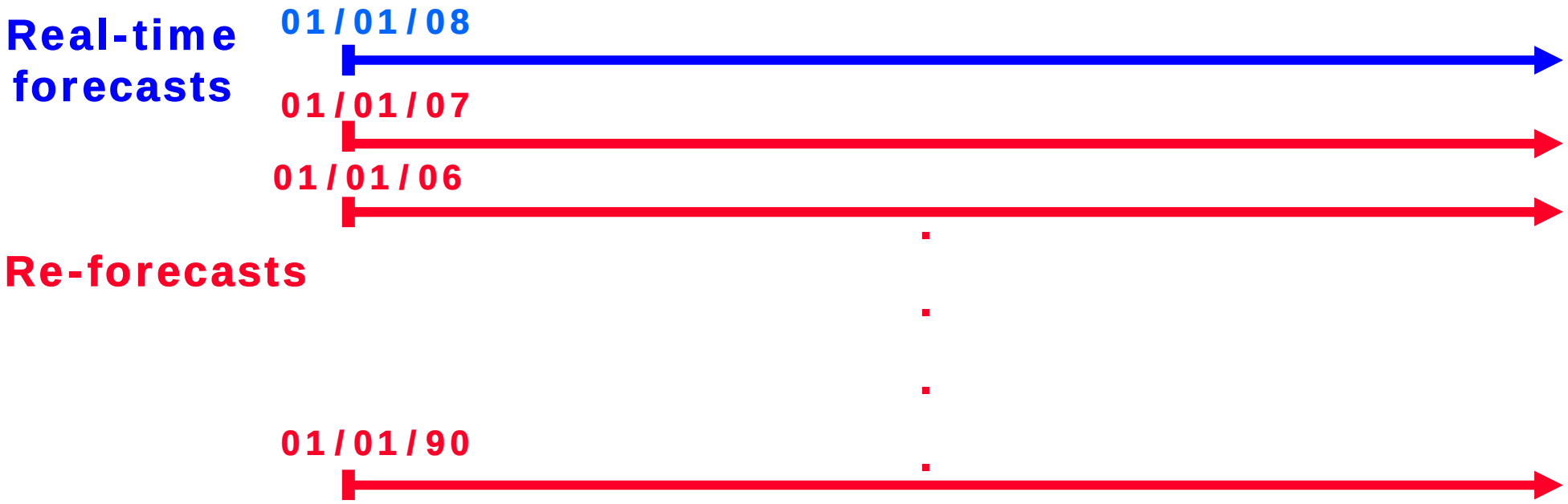
- Atmospheric initial conditions: ERA40 and ECMWF operational analysis

- Oceanic initial conditions: Last ocean analysis + accelerated analysis.

- Perturbations:
  - Atmosphere: Singular vectors + stochastic physics
  - Ocean: wind stress perturbations during data assimilation.

The ECMWF monthly forecasting system

- Background statistics:
  - 5-member ensemble integrated at the same day and same month as the real-time time forecast over the past 18 years.
  - This represents a 90-member ensemble
  - It runs once every week, 2 weeks in advance (5-week window)



The ECMWF monthly forecasting system

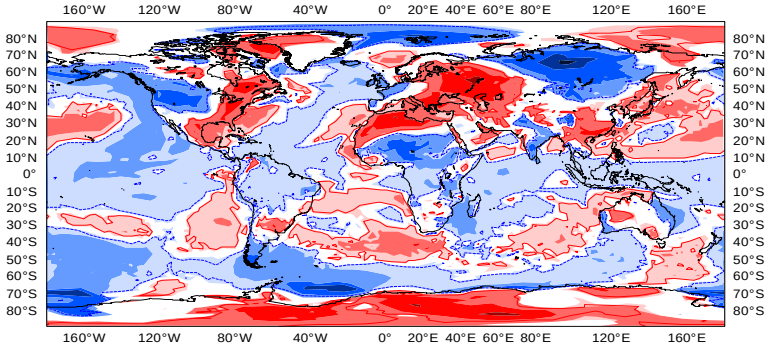
Anomalies (temperature, precipitation..)

ECMWF VAREPS-Monthly Forecasting System
2-meter Temperature anomaly
Forecast start reference is 03-04-2008
ensemble size = 51 ,climate size = 90

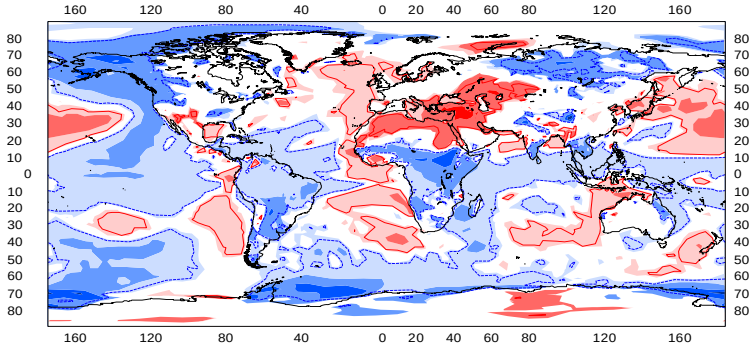
Shaded areas significant at 10% level
Contours at 1% level

<-10deg | -10.. -6 | -6.. -3 | -3.. -1 | -1.. 0 | 0.. 1 | 1.. 3 | 3.. 6 | 6.. 10 | > 10deg

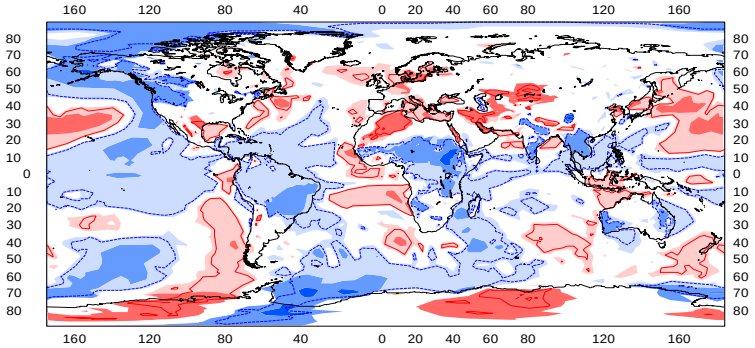
DAY 5-11: 07-04-2008/TO/13-04-2008



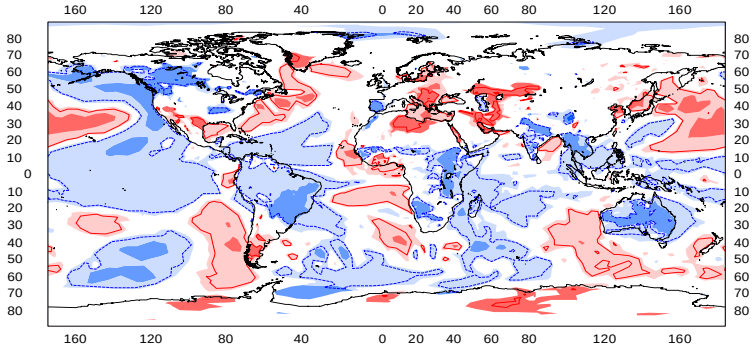
DAY 12-18 :14-04-2008/TO/20-04-2008



DAY 19-25 :21-04-2008/TO/27-04-2008



DAY 26-32:28-04-2008/TO/04-05-2008

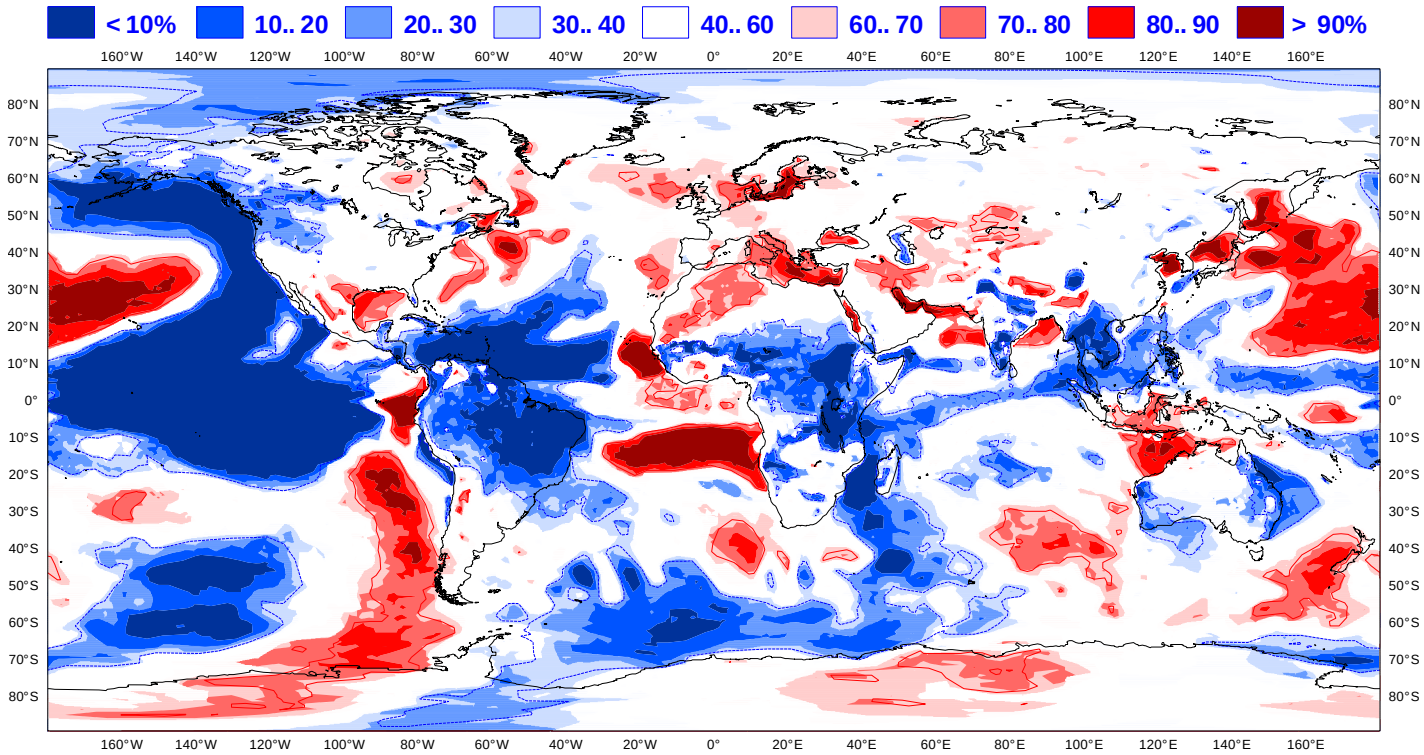


The ECMWF monthly forecasting system

Probabilities (temperature, precipitation..)

ECMWF VAREPS-Monthly Forecasting System
Prob(2-meter Temp. anom gt 0)
Forecast start reference is 03-04-2008
ensemble size = 51 ,climate size = 90

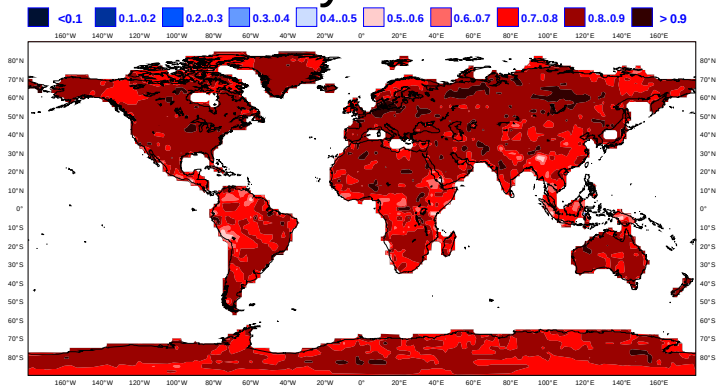
Day 19-25
21-04-2008/TO/27-04-2008
Shaded areas significant at 10% level
Contours at 1% level



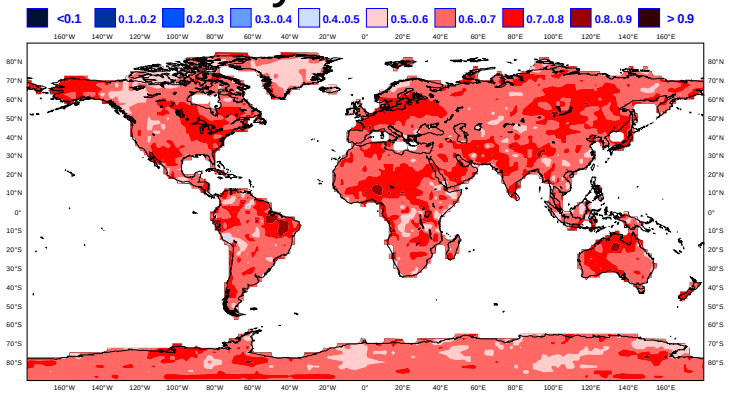
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile
191 cases

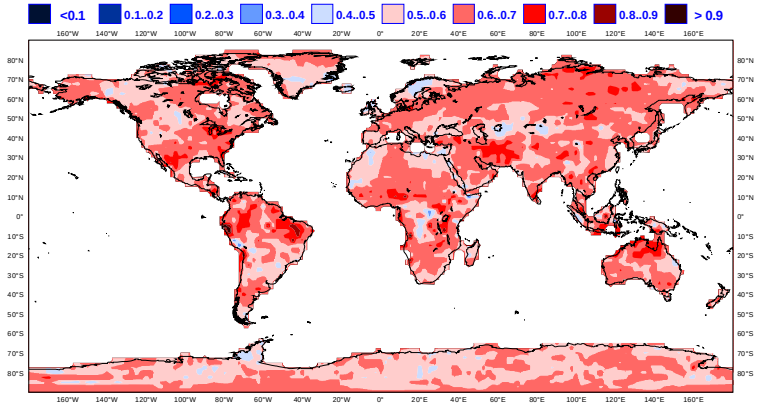
Day 5-11



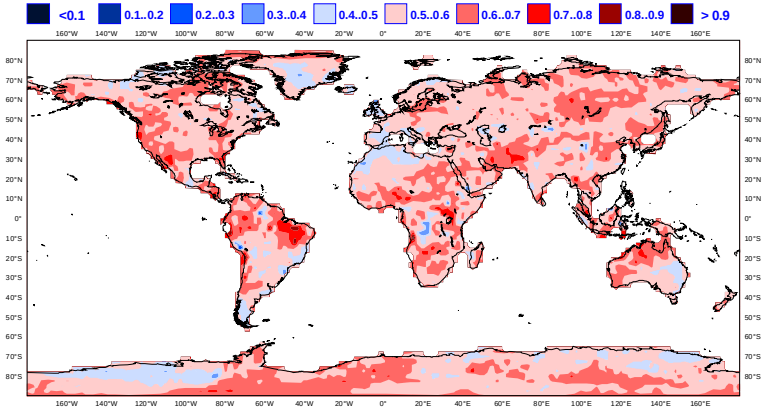
Day 12-18



Day 19-25



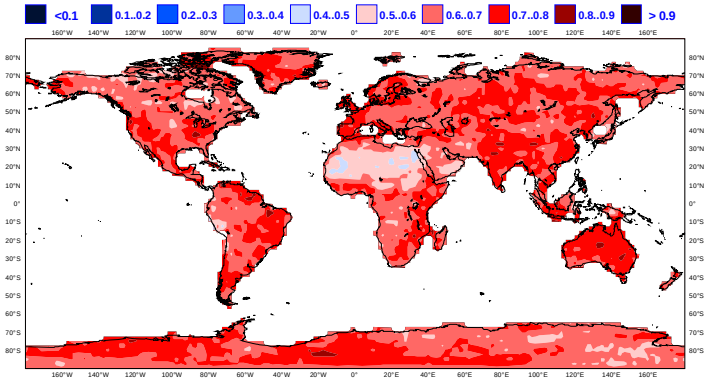
Day 26-32



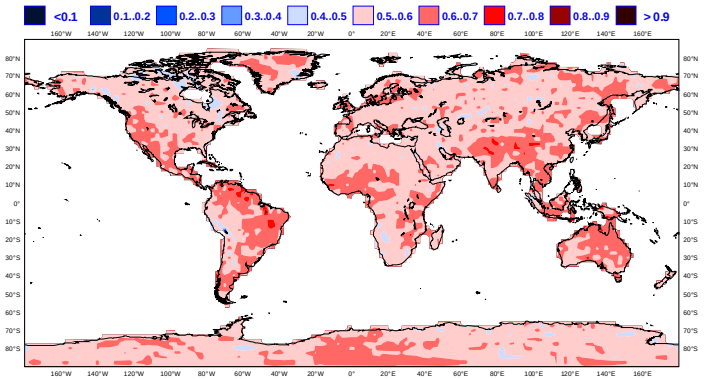
Skill of the ECMWF Monthly Forecasting System

ROC score: Precipitation in the upper tercile
191 cases

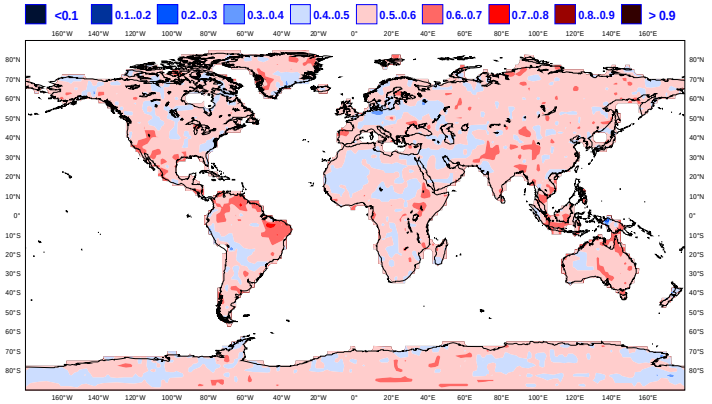
Day 5-11



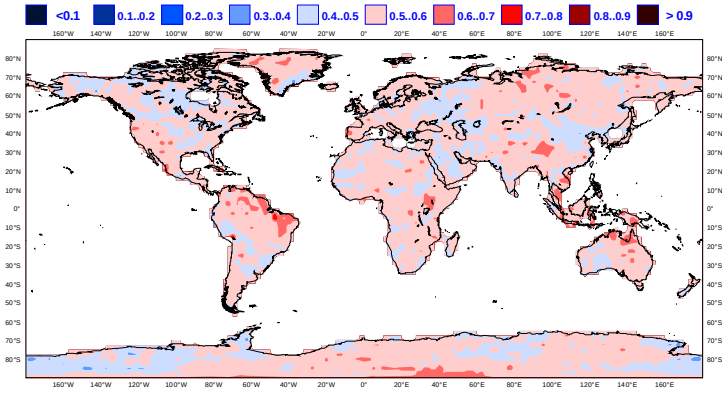
Day 12-18



Day 19-25

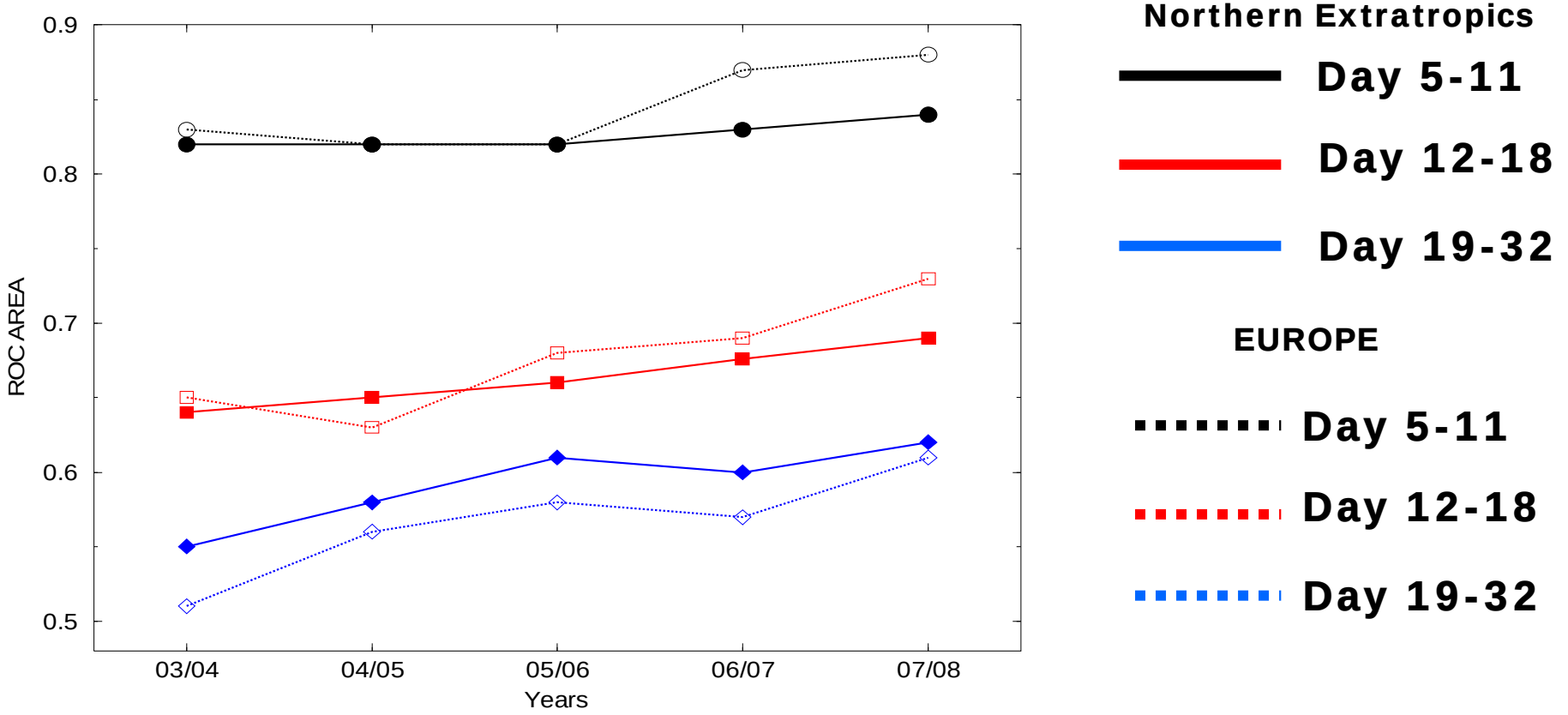


Day 26-32



3. Performance over the Northern Extratropics

ROC Area of the probability that 2-meter temperature in the upper tercile

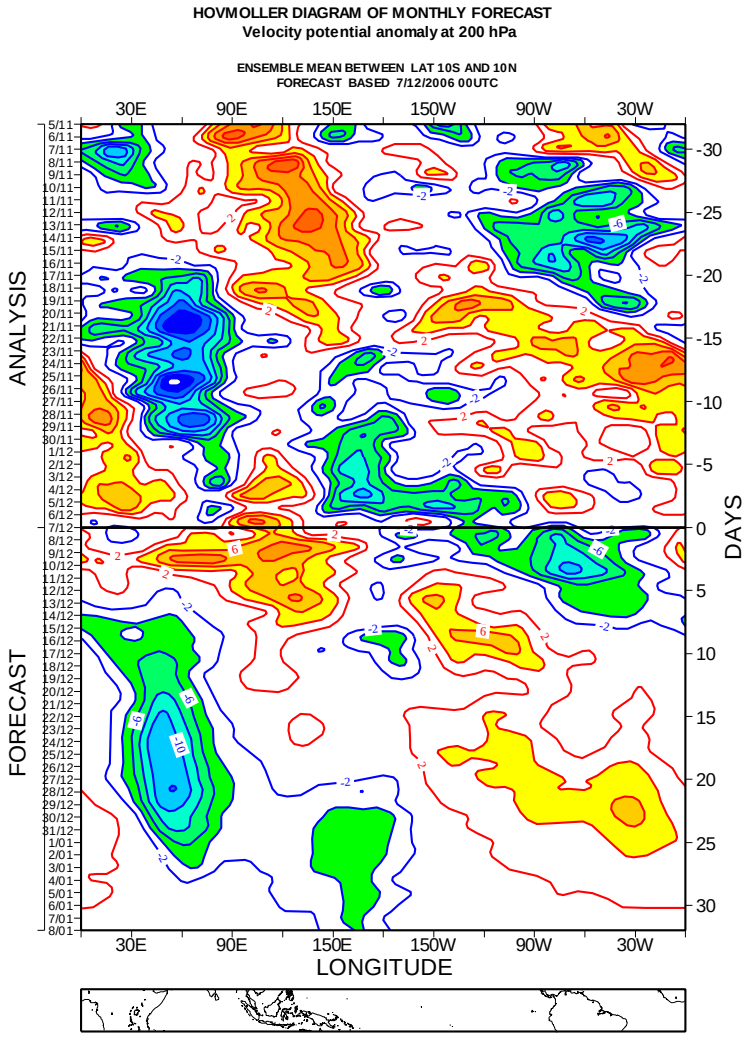


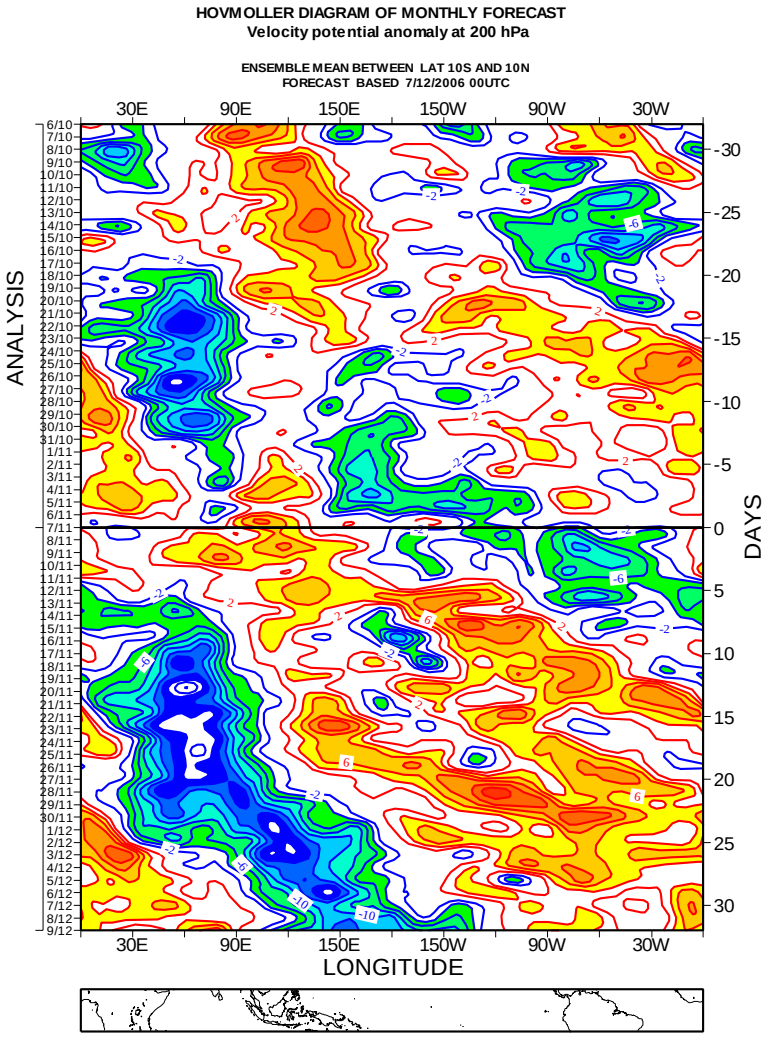
Outline

1. The ECMWF VarEPS-monthly forecasting system
2. MJO Prediction
3. Monsoon prediction
4. Conclusion

Prediction of the Madden Julian Oscillation (MJO)

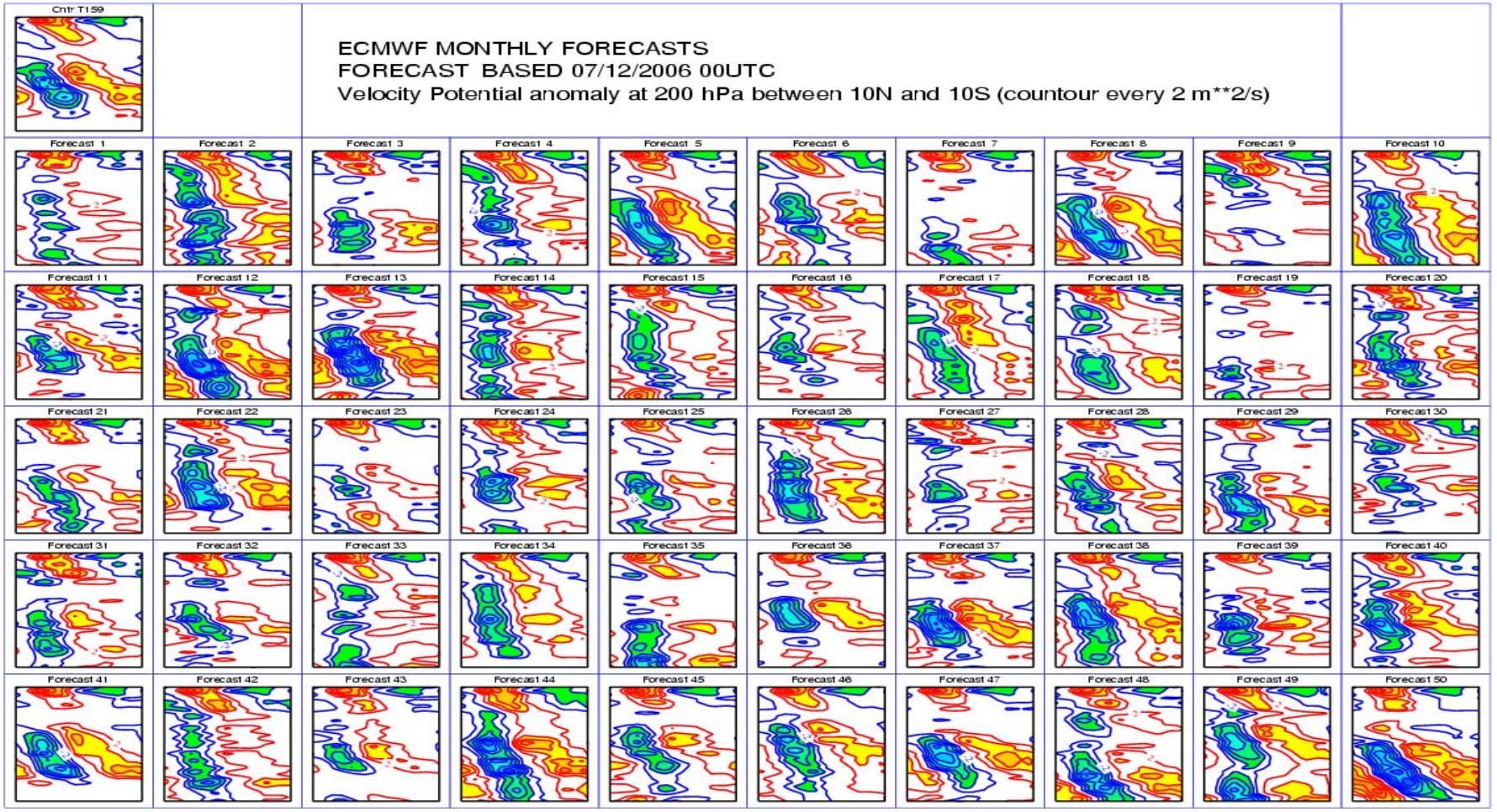
Monthly Forecast starting on 7 December 2007





Prediction of the Madden Julian Oscillation (MJO)

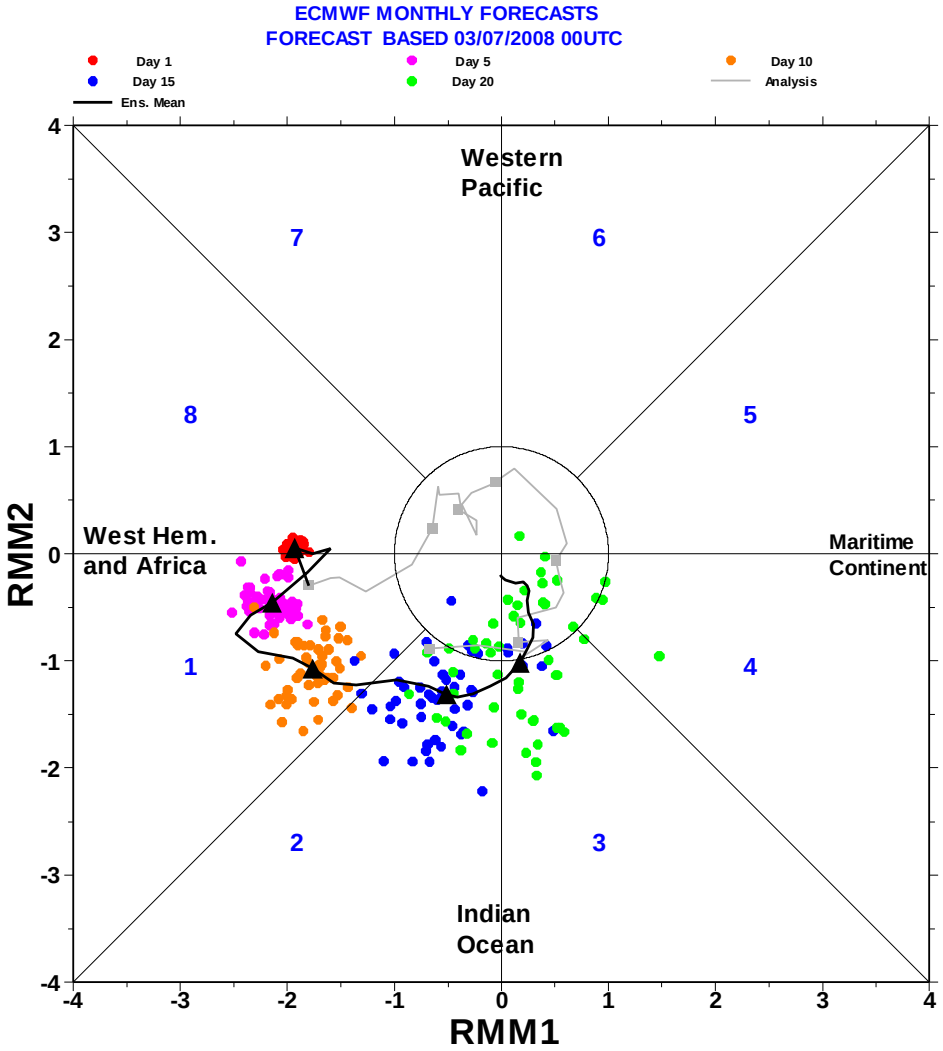
Monthly Forecast starting on 7 December 2007



MJO metric

- Forecast anomalies of OLR, U850, & U200 were obtained by subtracting the hindcast climatology of the respective fields from the forecast.
- The forecast anomalies were then averaged over latitudes (-15, 15).
- The forecast anomalies of the 3 fields were divided by the respective global standard deviations calculated from the NCEP reanalyses.
- The resulting anomalies were projected onto the first two EOF patterns, the latter being computed by Matt Wheeler from NCEP reanalyses.
- The two projection coefficient time series were further divided by the standard deviations of first two PC (also from NCEP reanalyses), to obtain the RMM12.
- To remove the interannual variability, a 120-day running mean of RMM12 is subtracted.

Operational MJO prediction



MJO Prediction

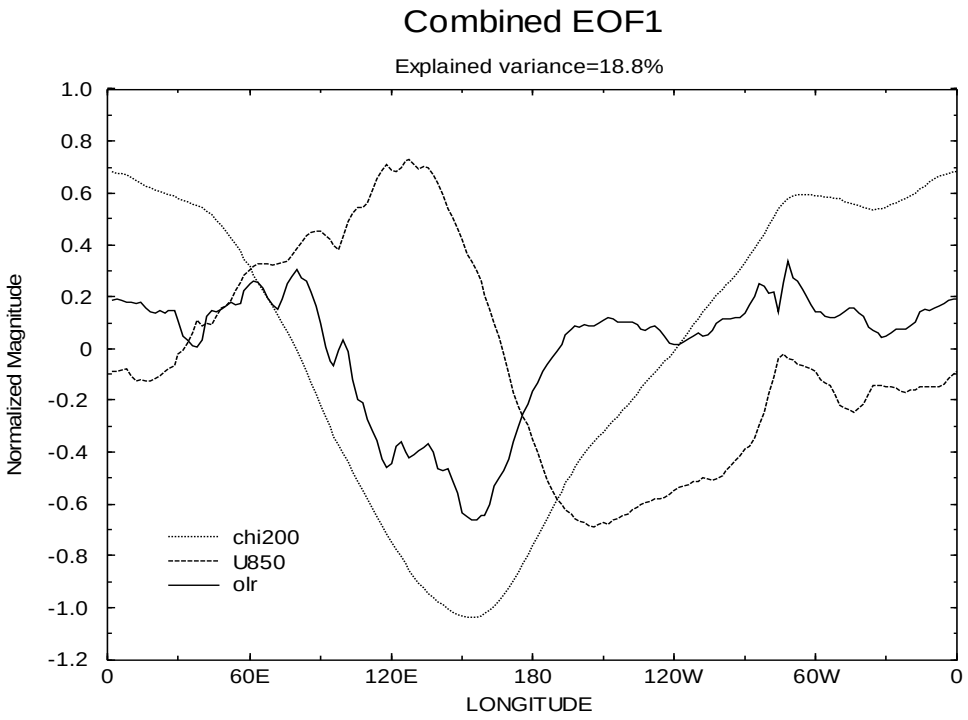
- **EXPERIMENT:** A 5-member ensemble has been run every day from 15 December 1992 to 31st January 1993.

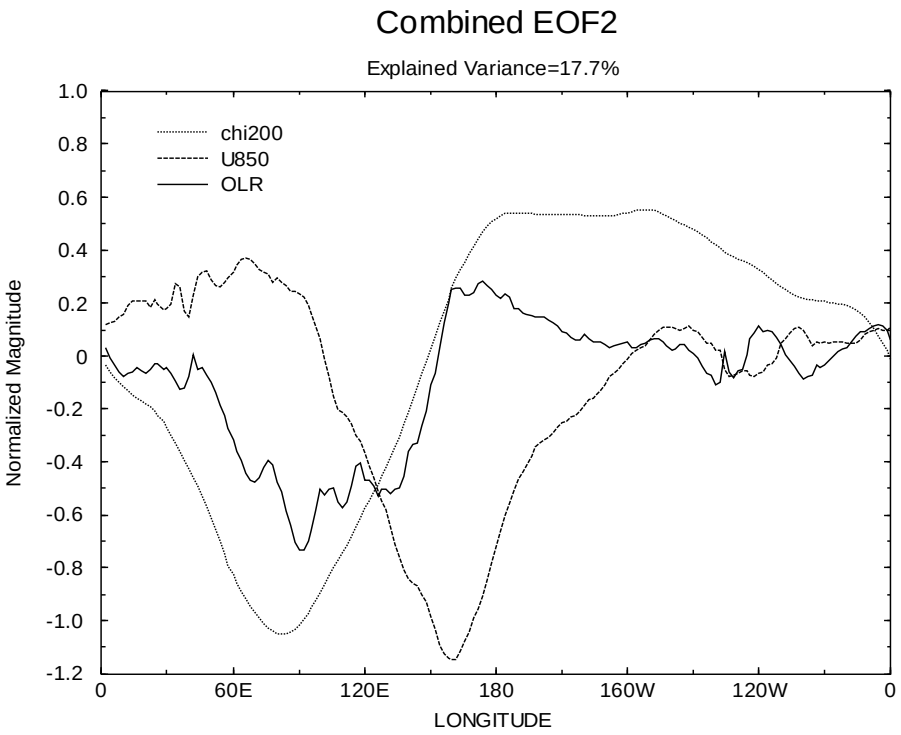
- The MJO diagnostic is based on the same method as in Wheeler and Hendon (2004). We use combined EOFs of:
  - Velocity potential anomalies at 200 hPa
  - Outgoing Long-Wave Radiations anomalies
  - Zonal wind at 850 hPa anomalies

- Anomalies are relative to the past 12 years climate. The fields have been averaged between 10N and 10S and normalized, before computing the combined EOFs.

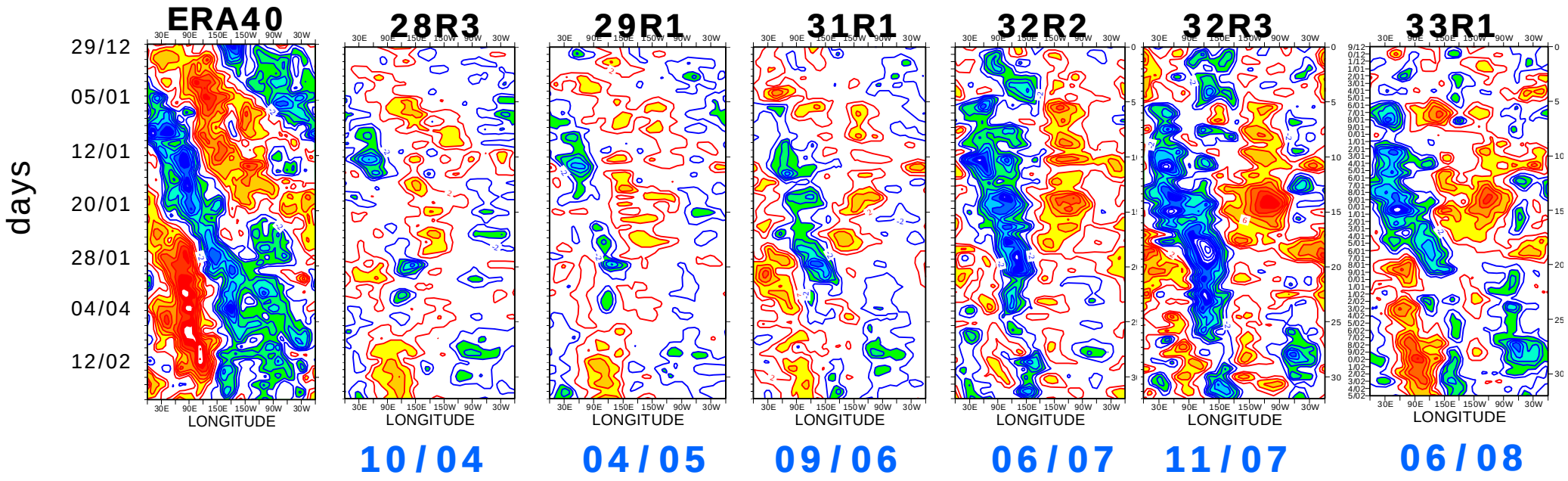
MJO Prediction

The combined EOFs have been computed on ERA40 daily data from 2002 to 2004.

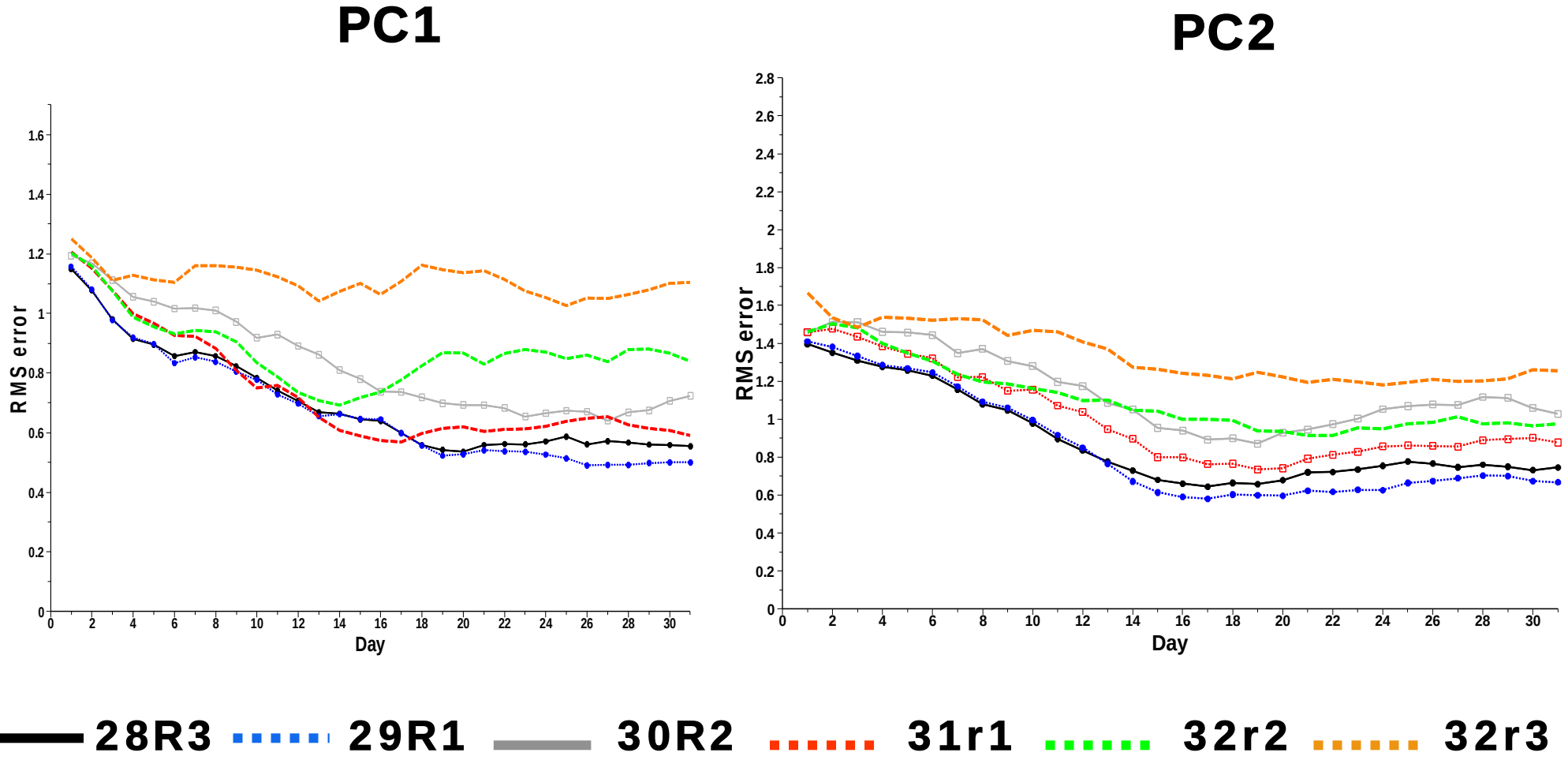




VP200 - Forecast range: day 15

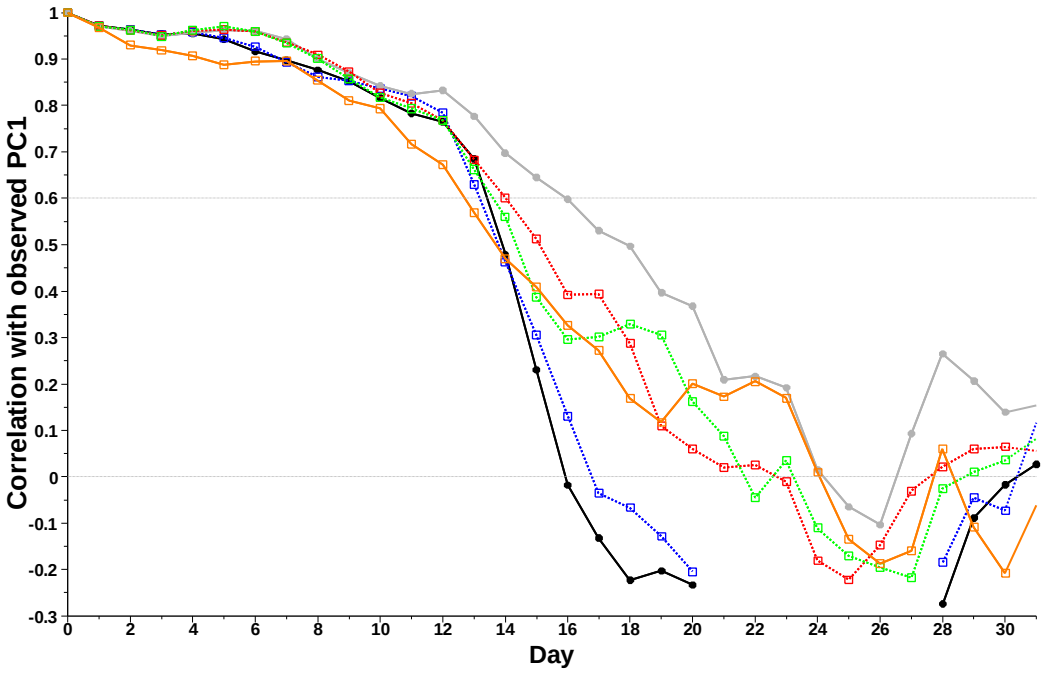


Amplitude of the MJO

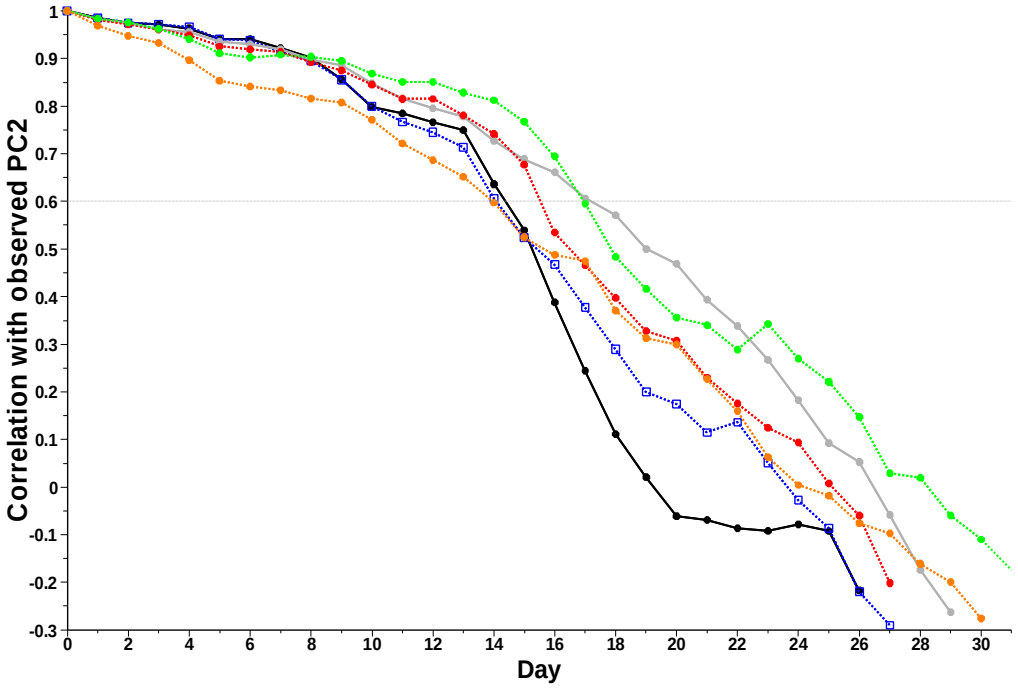


MJO Propagation

PC1

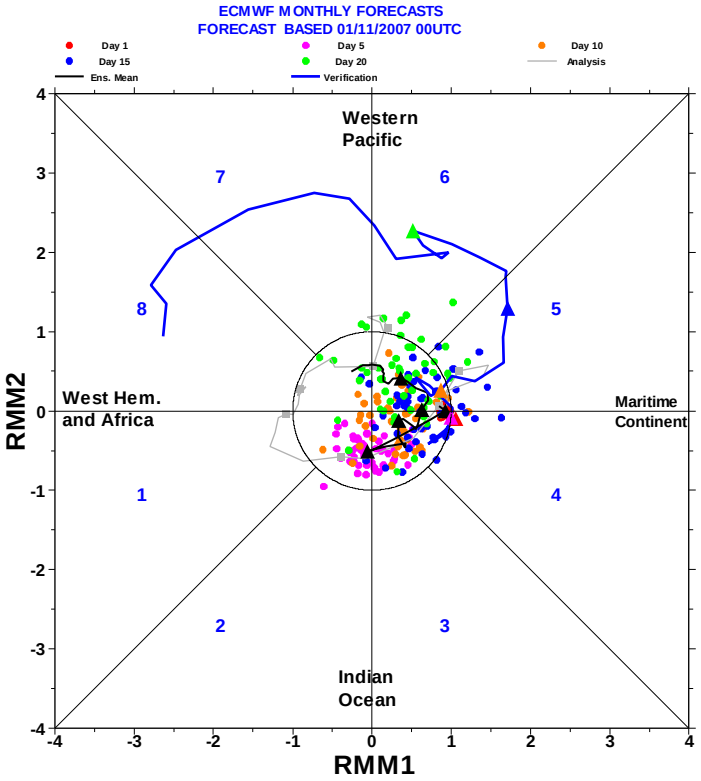


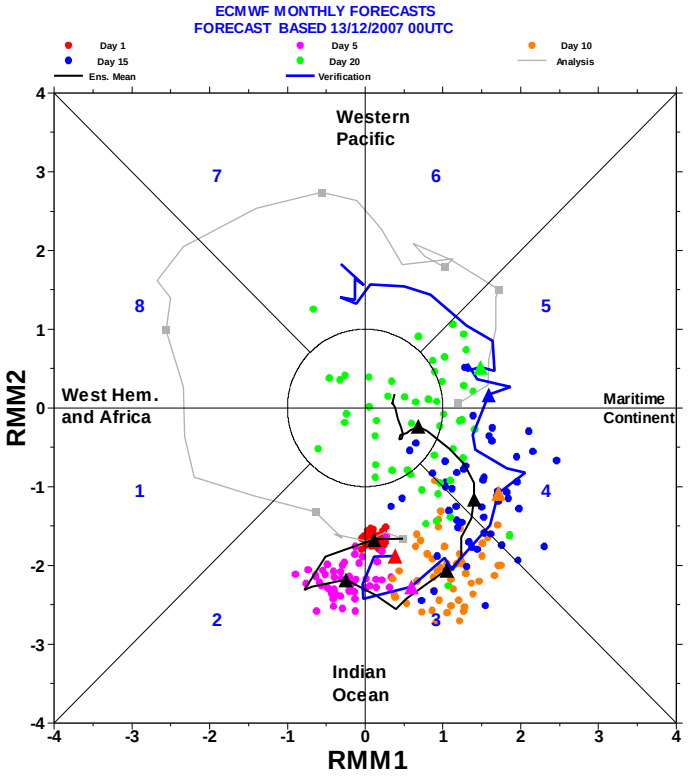
PC2

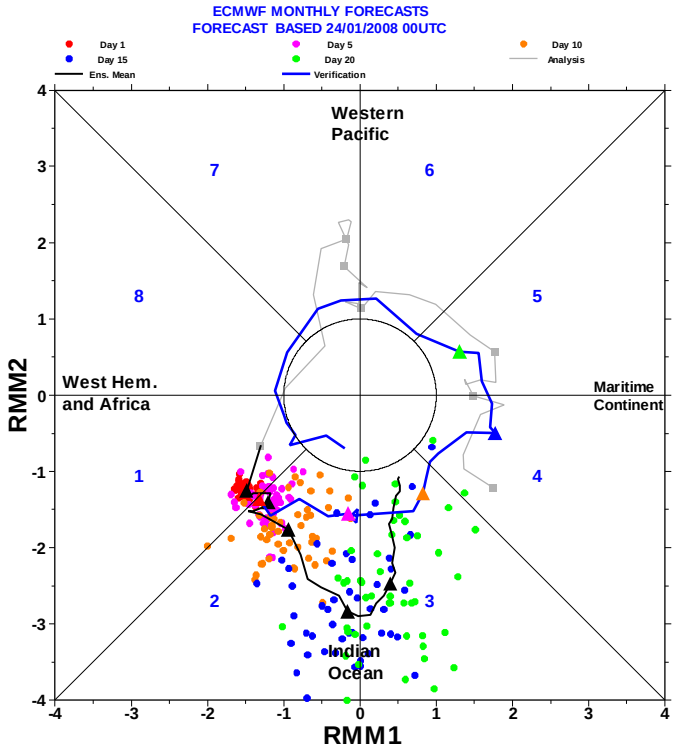


28R3 29R1 30R2 31r1 32r2 32r3

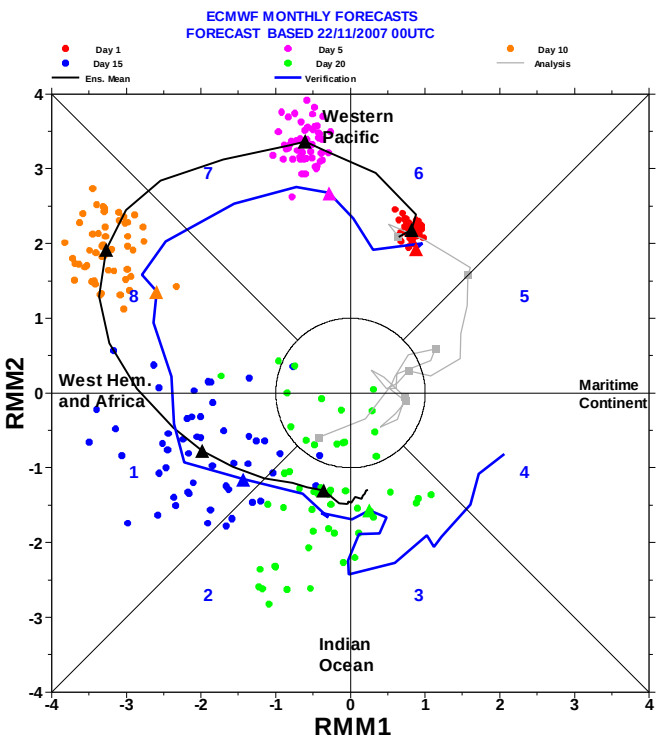
WINTER 2007/2008: CY32R3

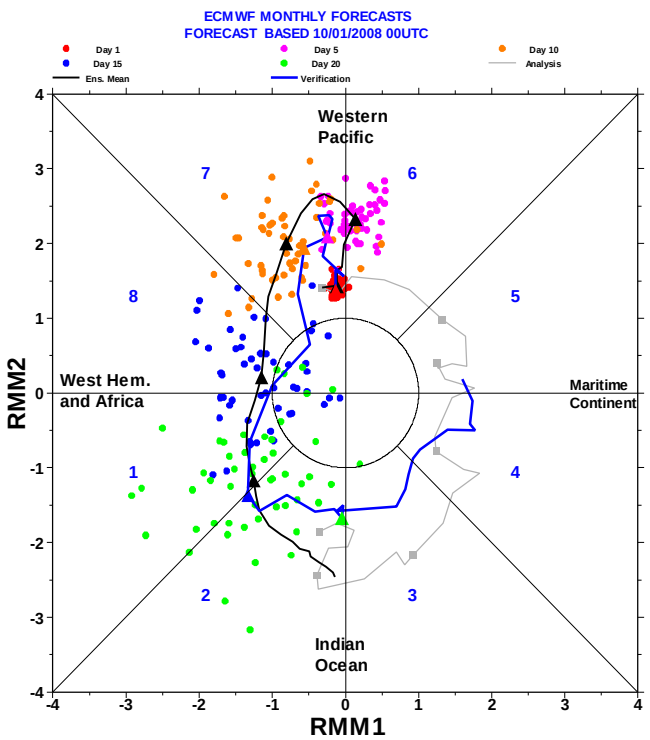


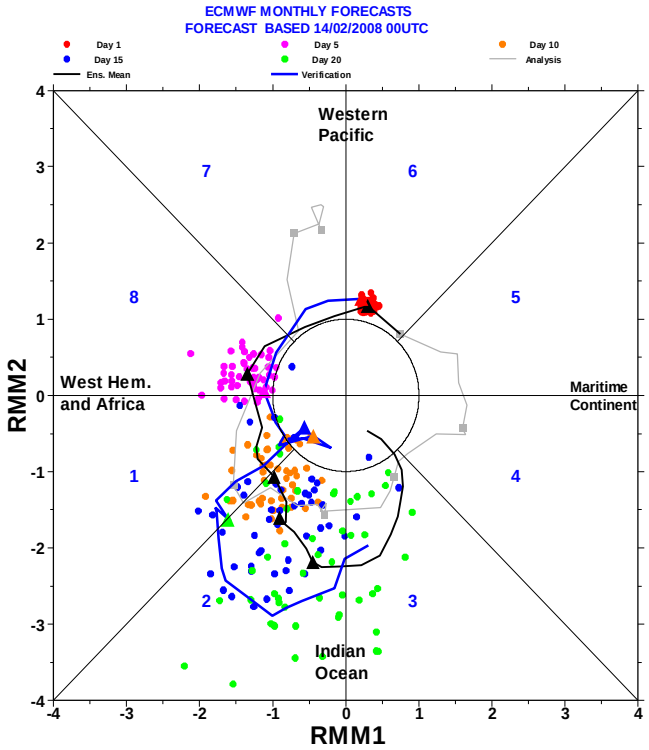




Winter 2007/2008: CY32R3

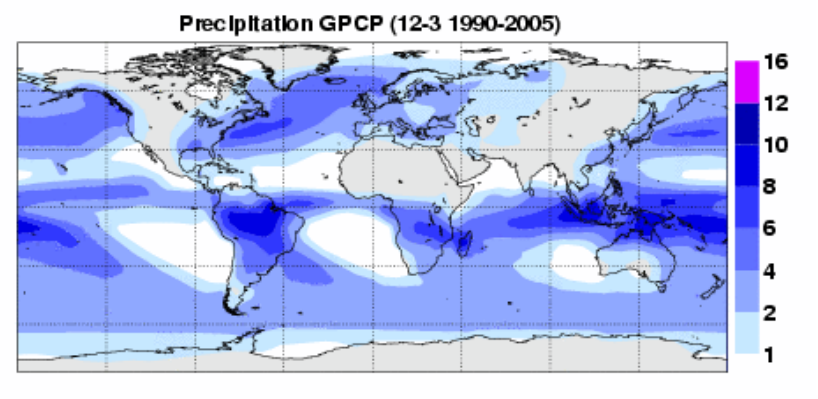


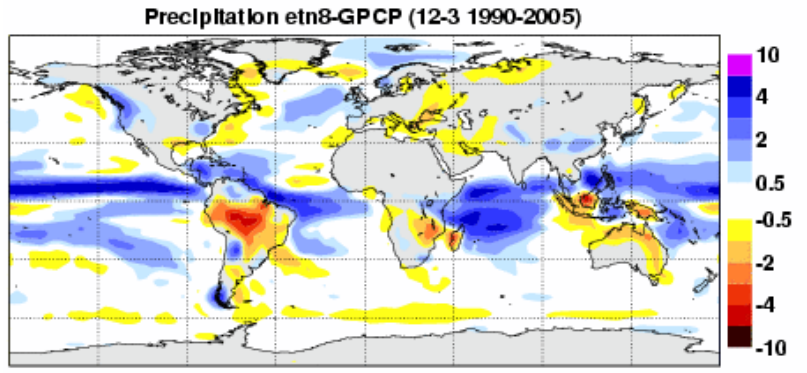


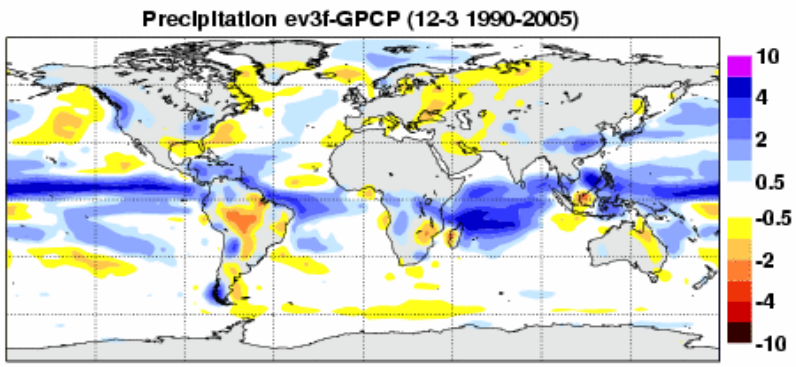


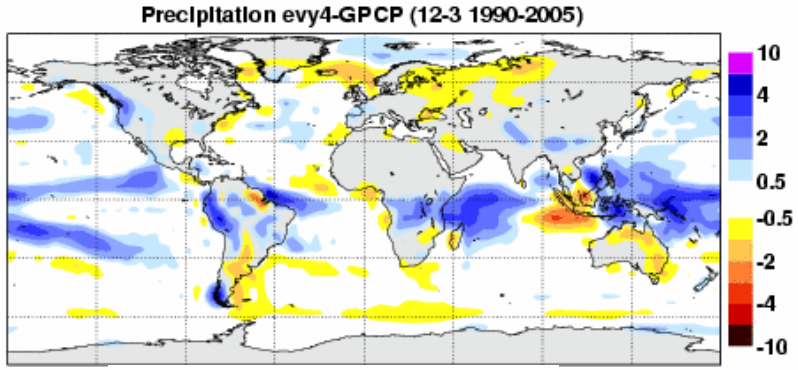
Forecast Biases and Convection

Precipitation for DJF against GPCP for different cycles: from 15 year 5 months integrations for 1990-2005.







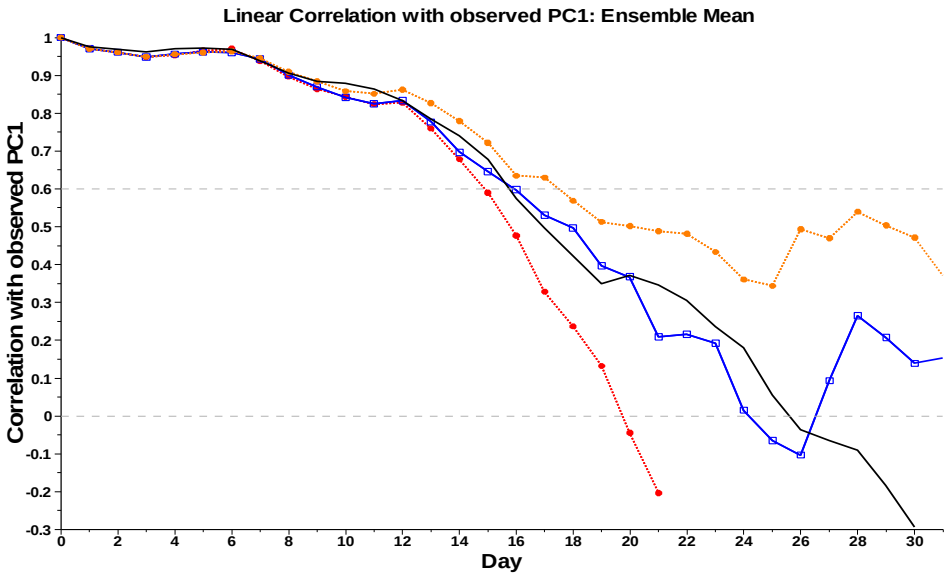


CY32R2 June 2007

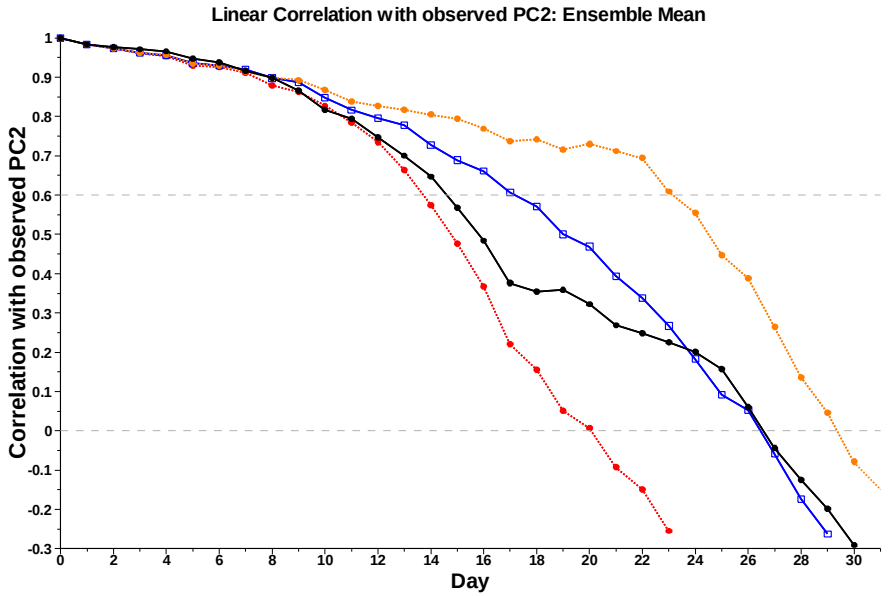
CY32R3 Nov 2007

MJO Prediction. CY30R2

PC1



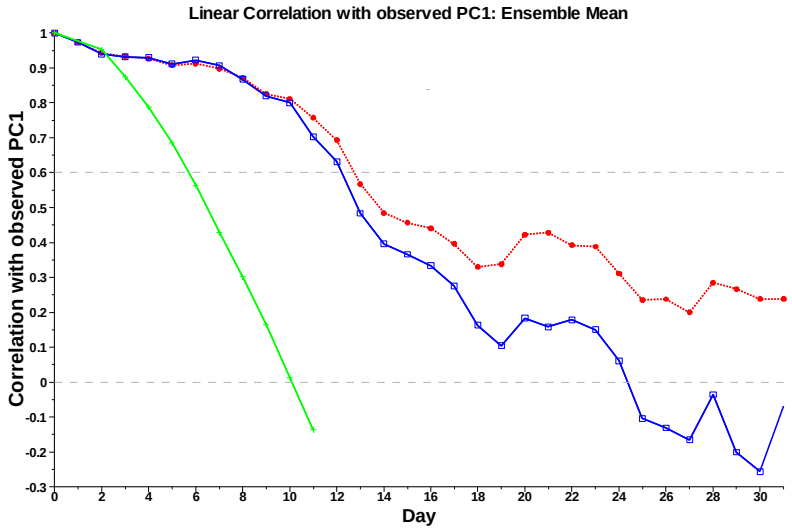
PC2



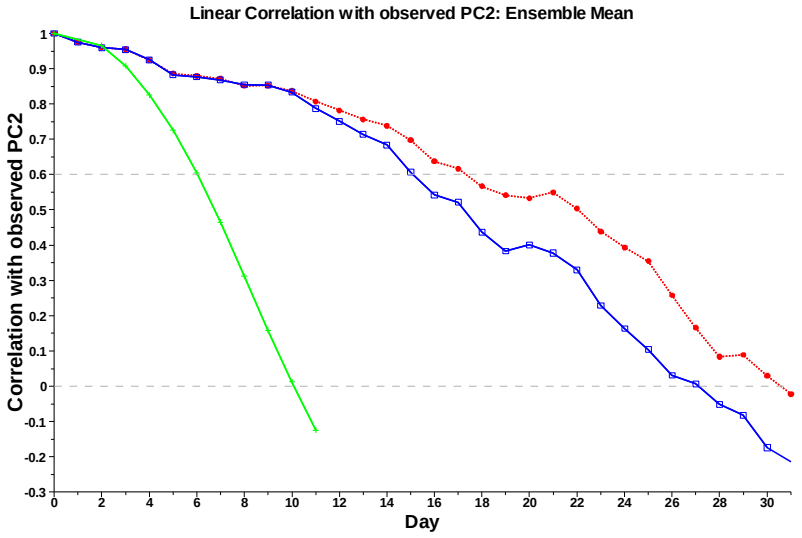
Persisted SSTs **Coupled** **VAREPS** **Ocean ML**

MJO Prediction. CY32R3

PC1



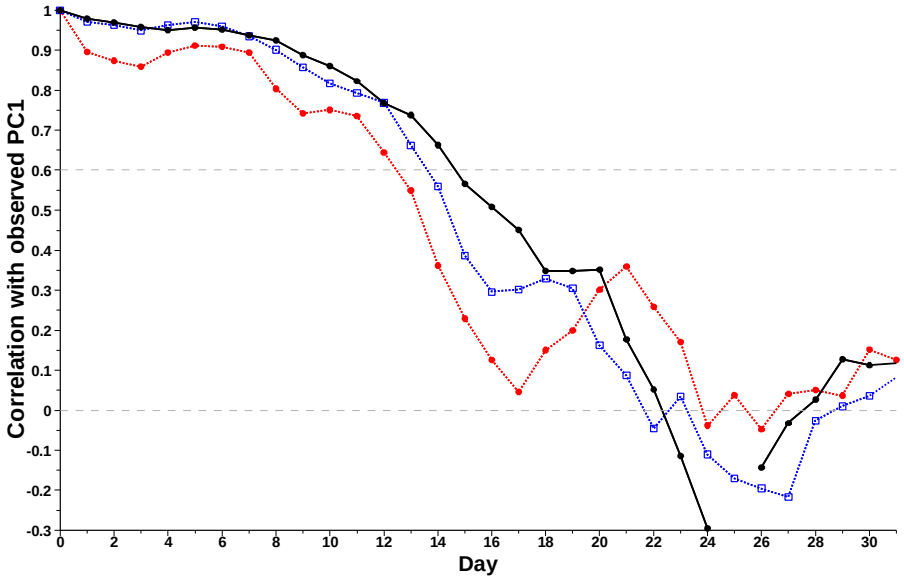
PC2



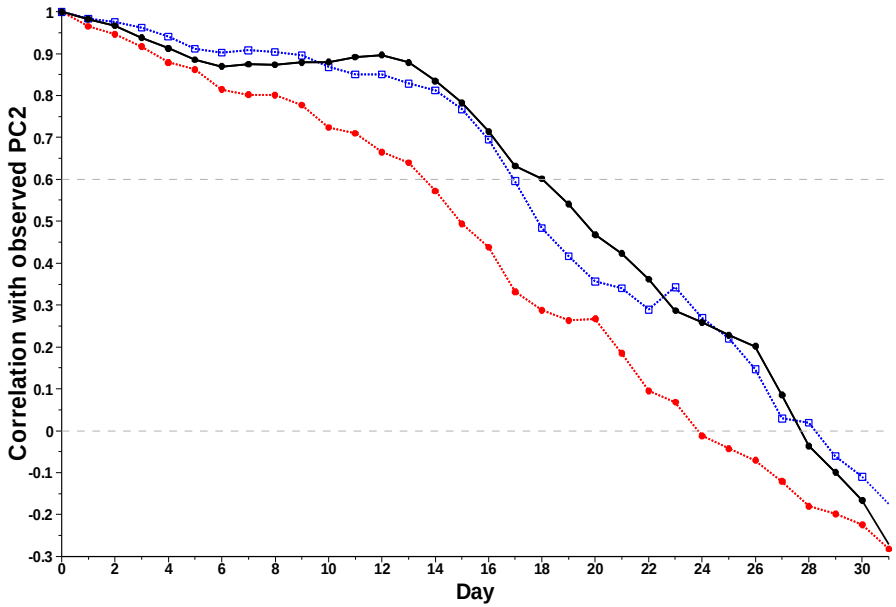
Ocean ML **Coupled** **Pers. Atm. Initial conditions**

Interim Reanalysis- Forecast scores

PC1



PC2



ER **E4** **EI**

Conclusion

- The model has some skill to predict the evolution of the MJO up to about 14 days. The amplitude of the MJO has improved since 2004, but the model has now difficulties to propagate the MJO across the Maritime continent.

- Using a high vertical resolution mixed layer model improves the MJO scores.

- MJO scores are improved when using the latest ECMWF reanalysis.

Outline

1. The ECMWF VarEPS-monthly forecasting system
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Operational Prediction

ECMWF VAREPS-Monthly Forecasting System

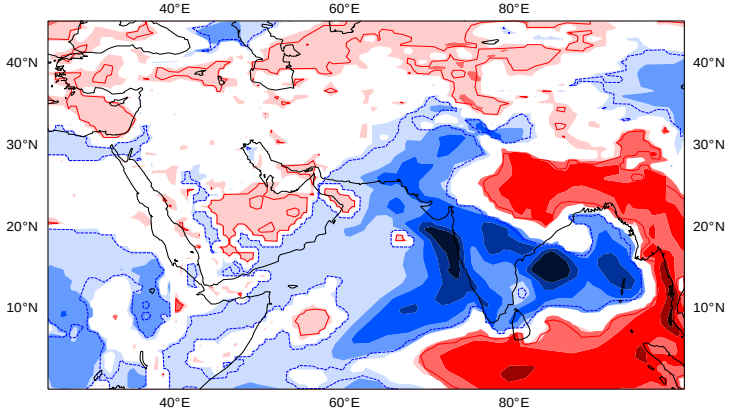
Precipitation anomaly

Forecast start reference is 24-07-2008
ensemble size = 51 ,climate size = 90

Shaded areas significant at 10% level
Contours at 1% level

<-90mm | -90..-60 | -60..-30 | -30..-10 | -10.. 0 | 0.. 10 | 10.. 30 | 30.. 60 | 60.. 90 | > 90mm

DAY 5-11: 28-07-2008/TO/03-08-2008



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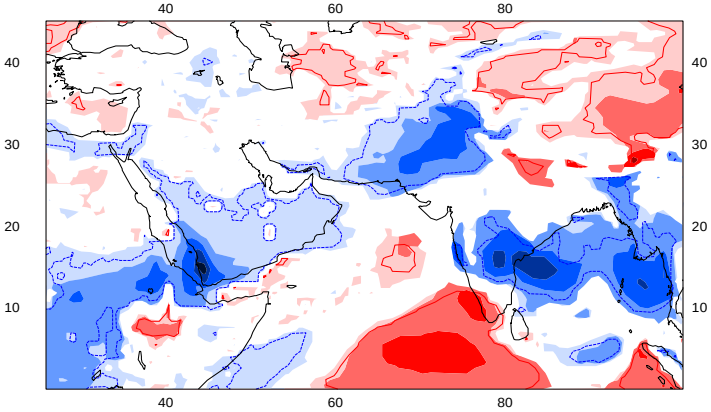

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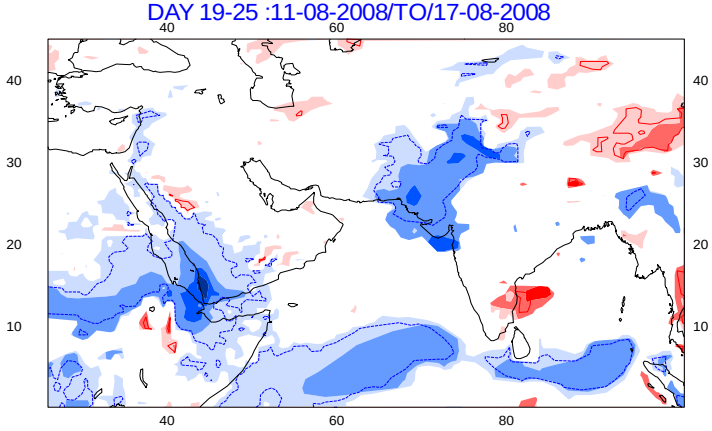
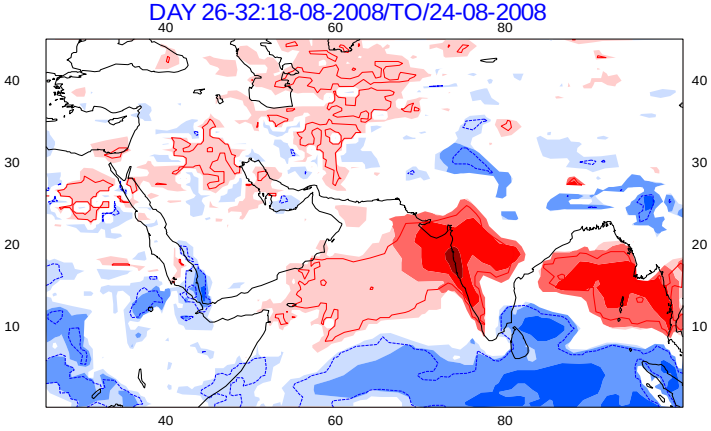
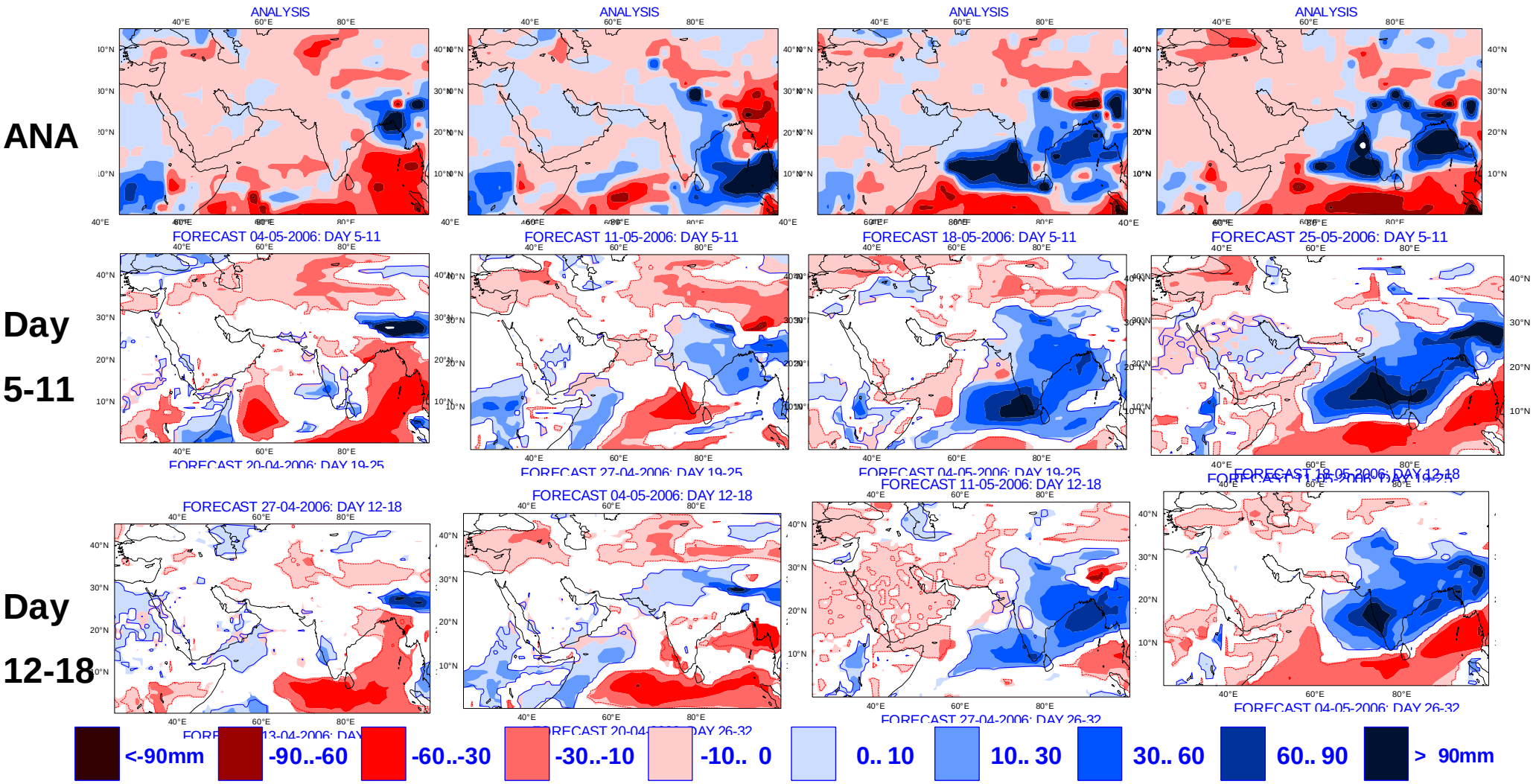


DAY 26-32:18-08-2008/TO/24-08-2008



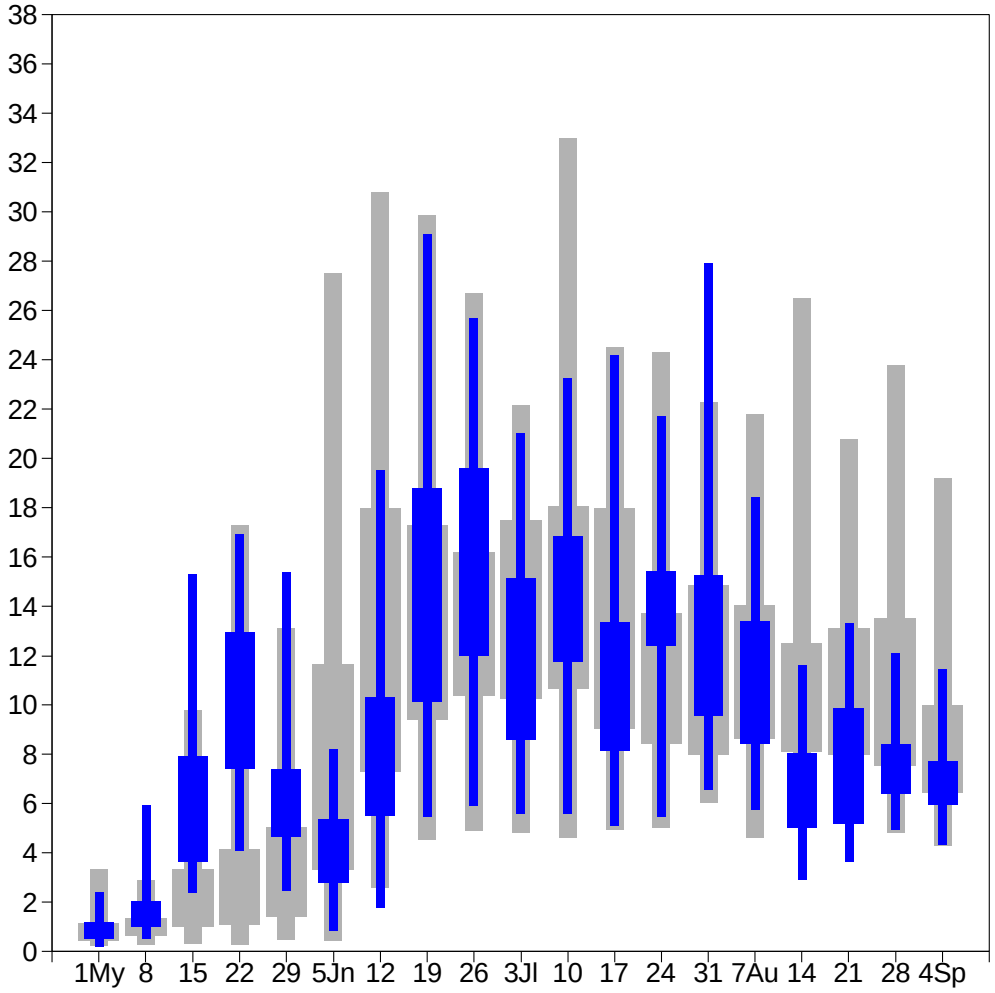
Example of Verification

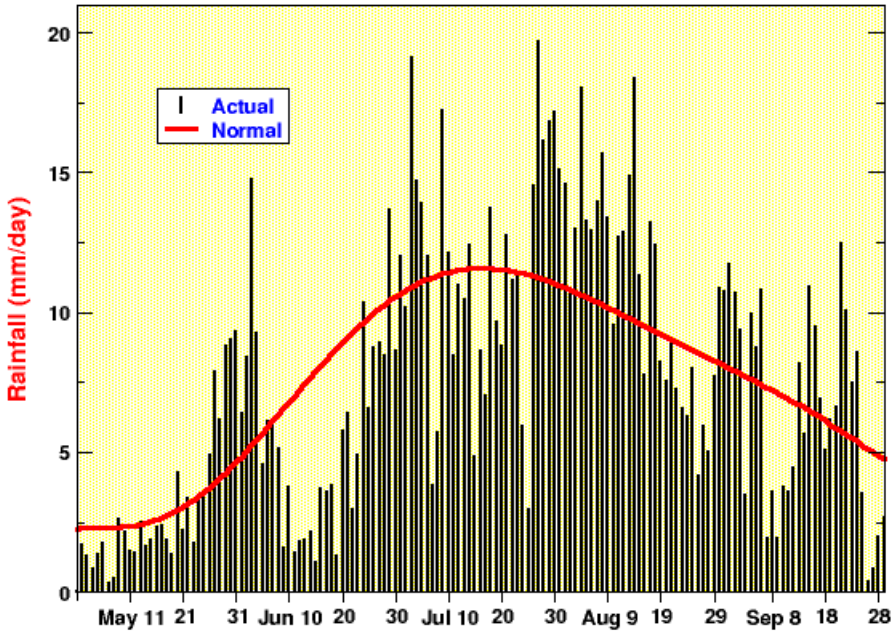


Indian monsoon 2006

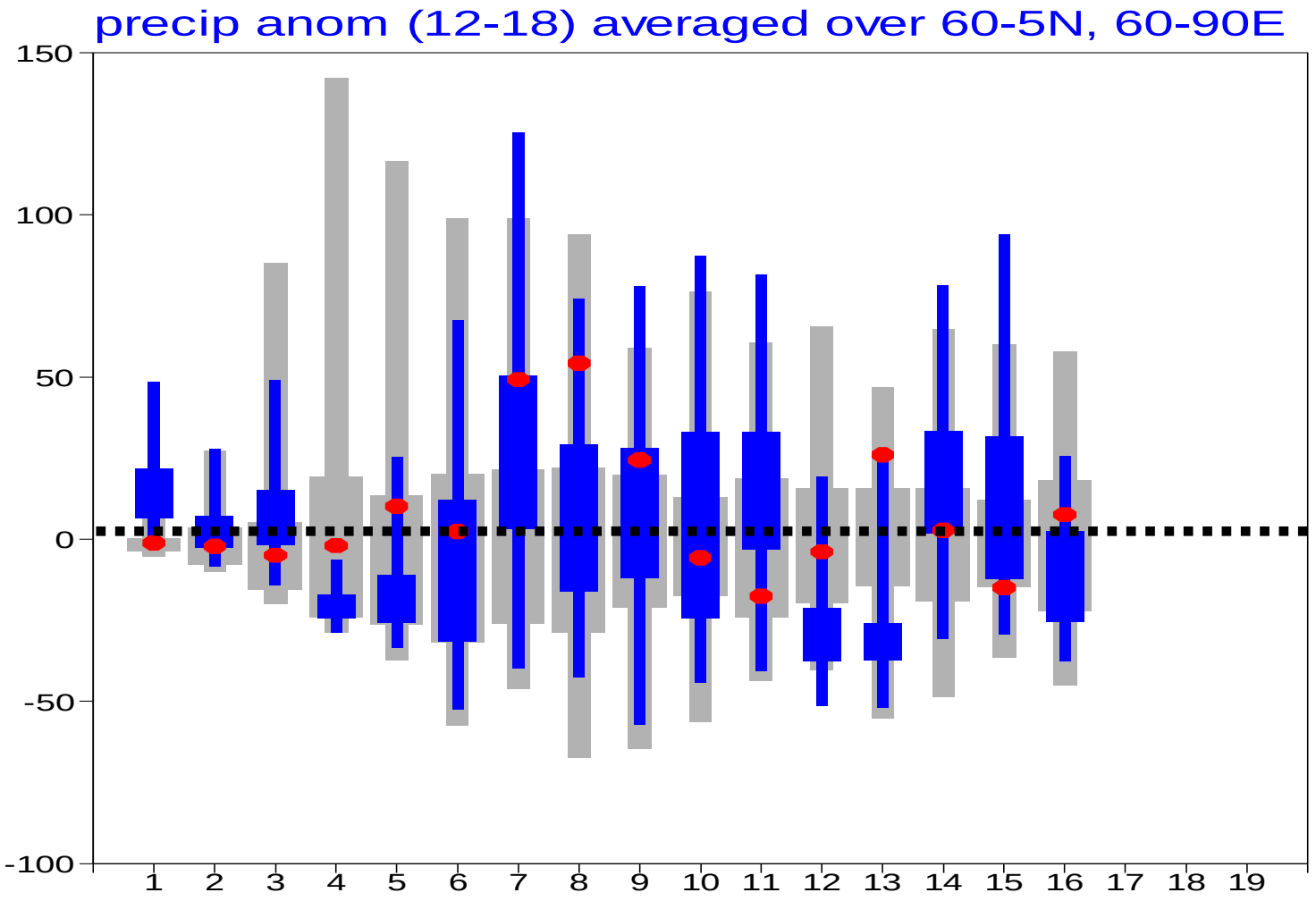
Forecast Day 12-18

[20-5N, 60-90E]



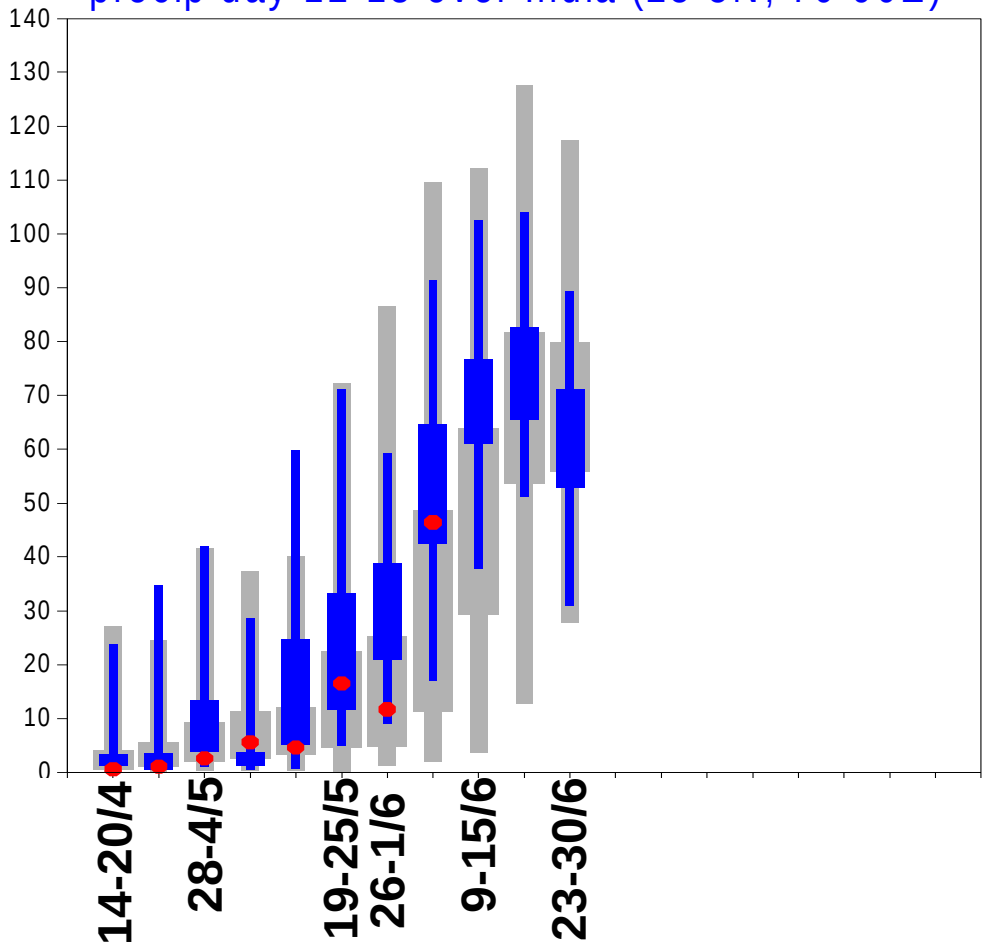


Indian Monsoon 2007



2008 Monsoon

precip day 12-18 over India (25-5N, 70-90E)



Evaluation of the skill the monthly forecasting system to predict Indian rainfall

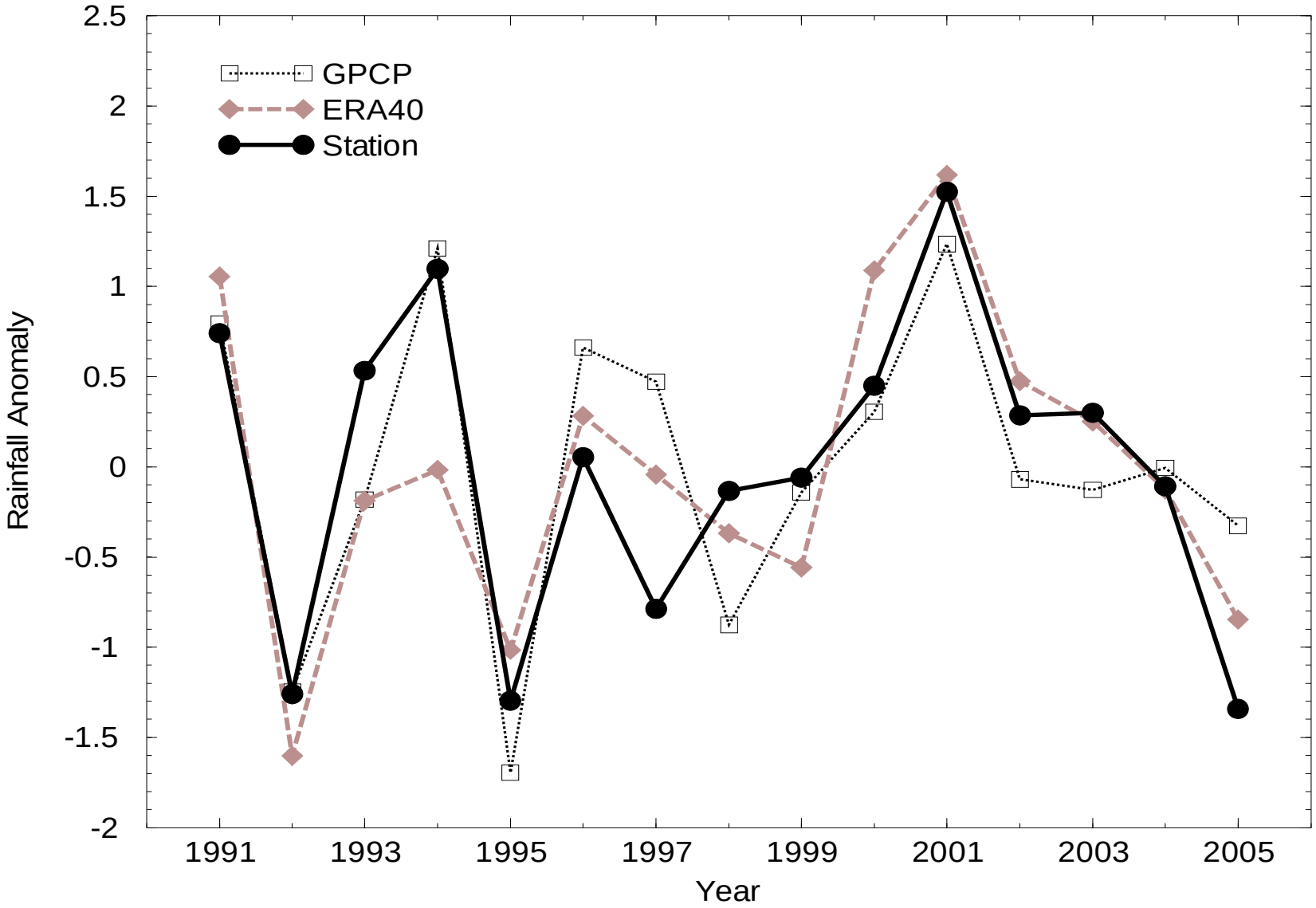
Experiment's setting:

- 46 day forecasts (60 km resolution from day 0 to 10, 80 km from day 10 to day 45)
- 15 ensemble members
- Starting dates: 15 May 1991-2007
- Model Cycle 31R2 (operational cycle from 12/06 to 06/07)

Experiments

Experiment Name	Day 0-10	Day 10-46
VEPS	TL399L62 Uncoupled	TL255L62 Coupled
PERS	TL399L62 Uncoupled	TL255L62 Uncoupled
MOFC	TL159L62 coupled	
ML	TL159L62 coupled to an ocean-mixed layer model	

June Rainfall

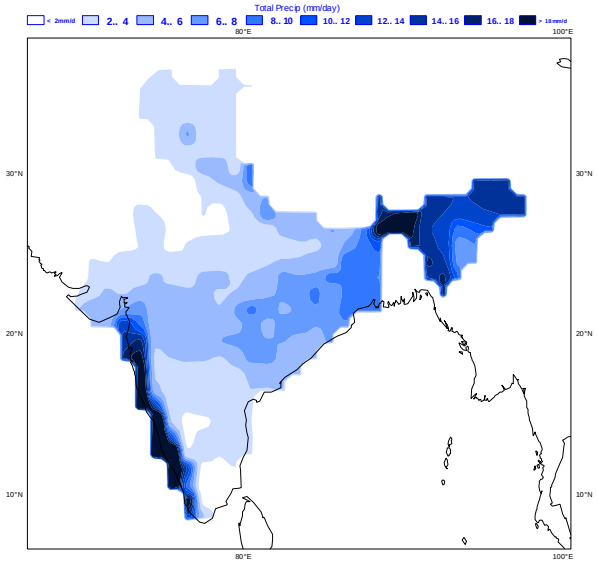


June Rainfall 1991-2007

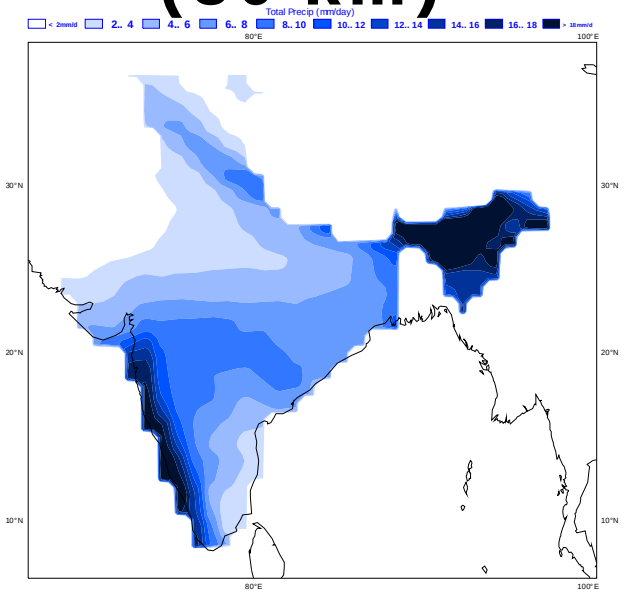
Total Precip (mm/day)

< 2mm/d | 2.. 4 | 4.. 6 | 6.. 8 | 8.. 10 | 10.. 12 | 12.. 14 | 14.. 16 | 16.. 18 | > 18mm/d

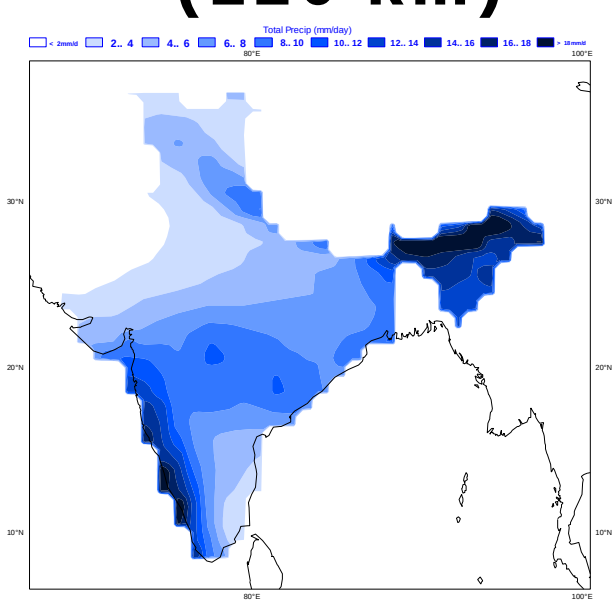
Observations



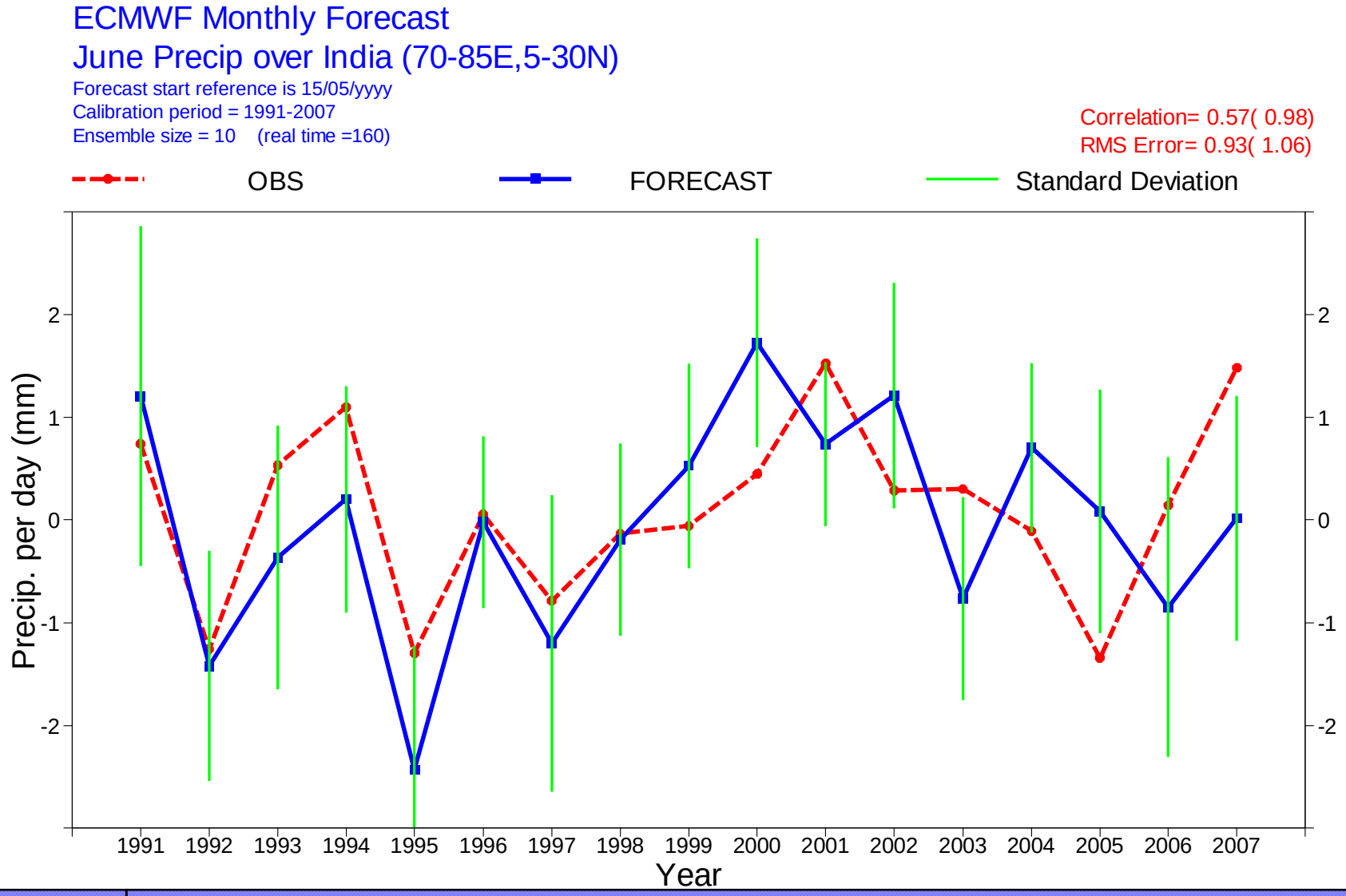
VarEPS (80 km)



MOFC (120 km)



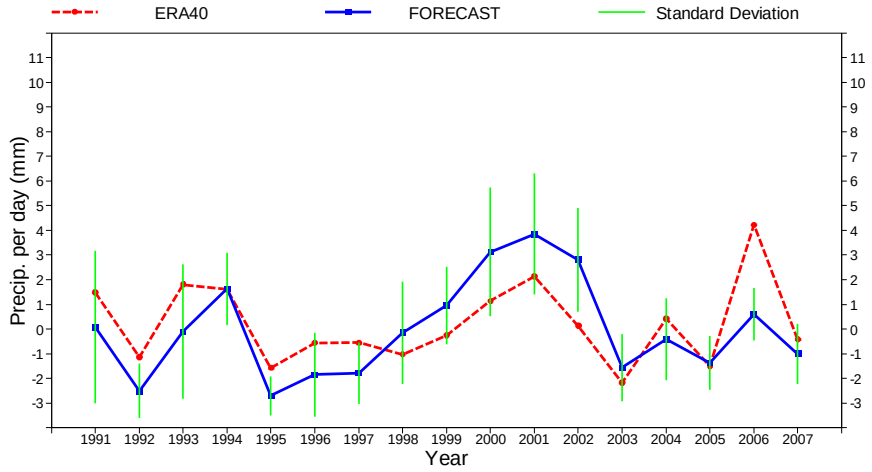
June Precipitation over India



June Precipitation over India

	VEPS	PERS	MOFC	ML
Correlation	**0.57 (+/- 0.05)**	**0.59 (+/- 0.06)**	**0.43 (+/- 0.07)**	**0.62 (+/- 0.04)**
RMS error	**0.92**	**1.6**	**0.98**	**0.84**

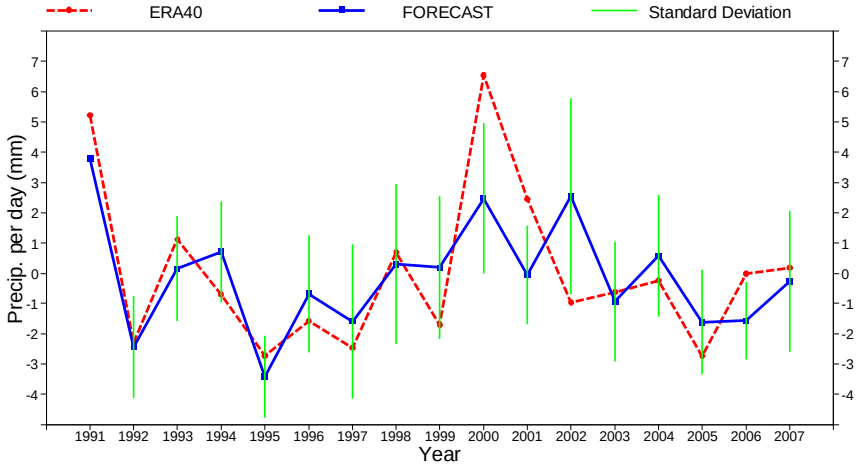
June pentads



1-5 June

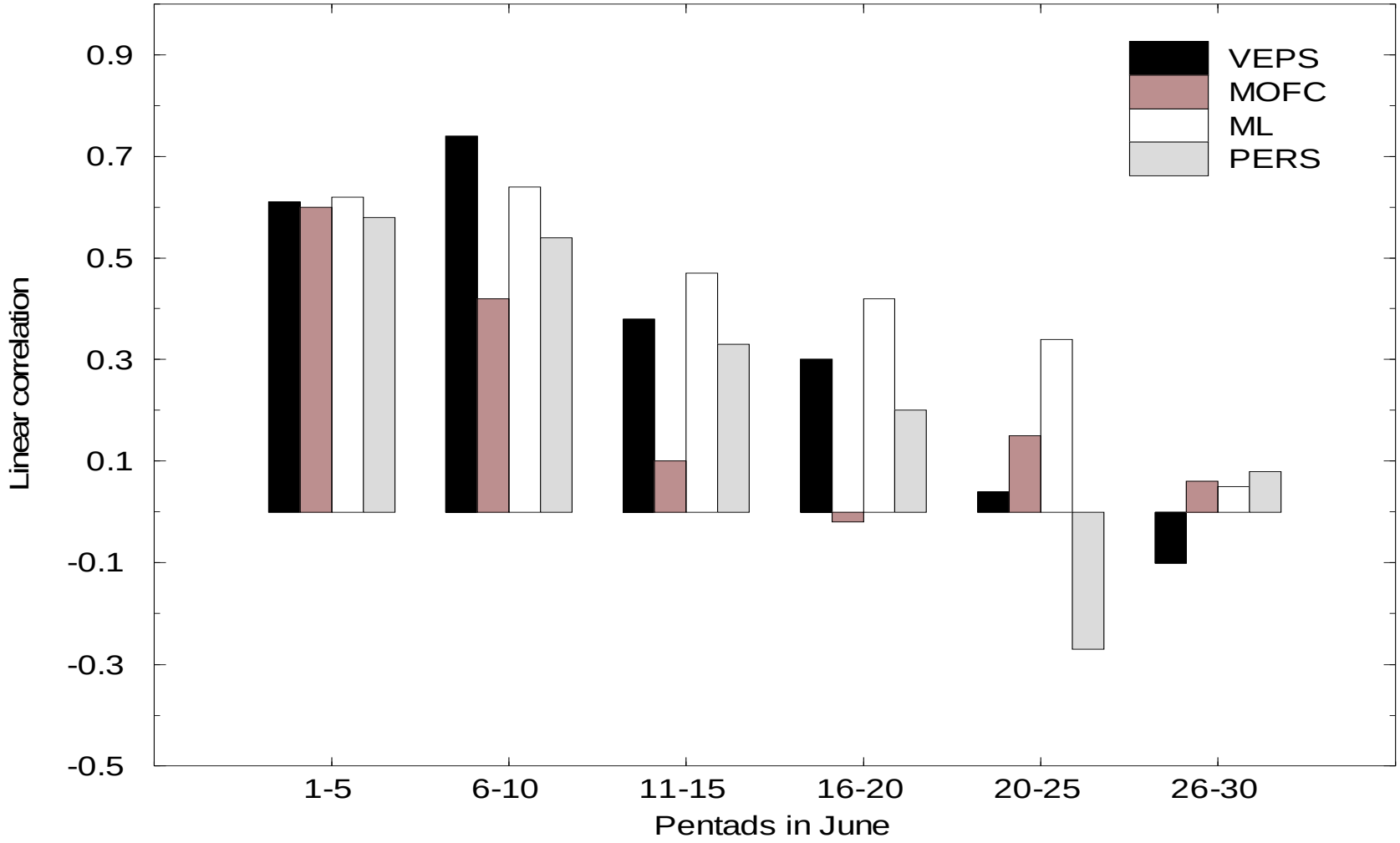
Forecast range:

Day 16-20



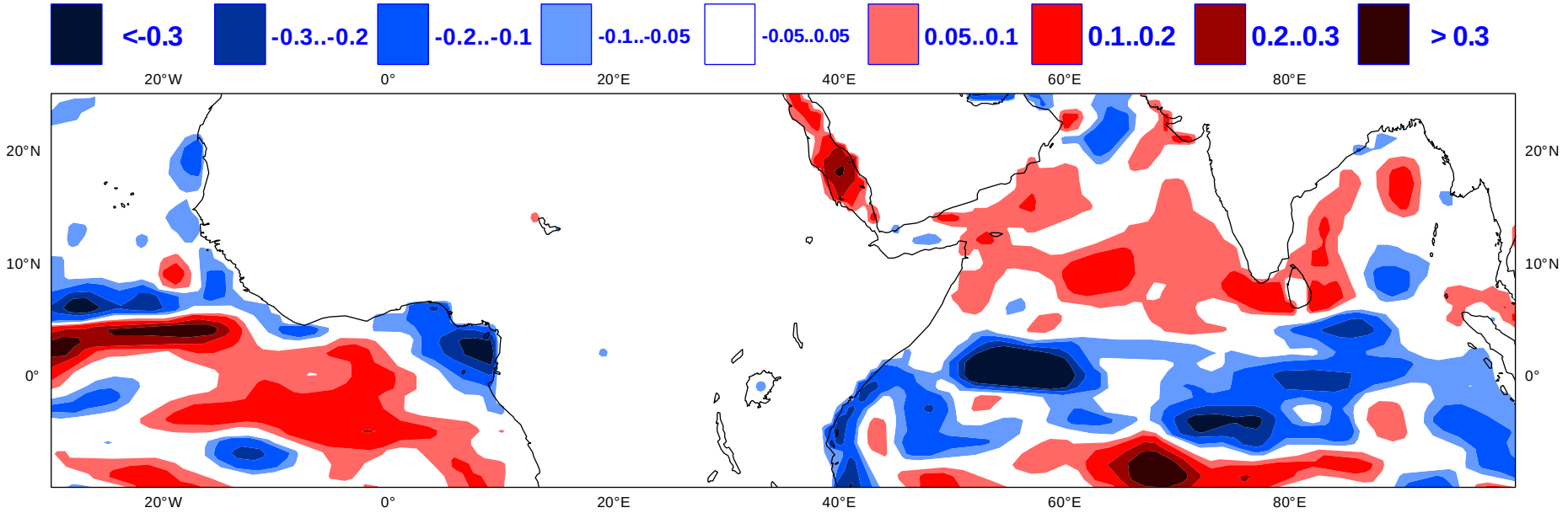
6-10 June

Forecast range:
Day 21-25

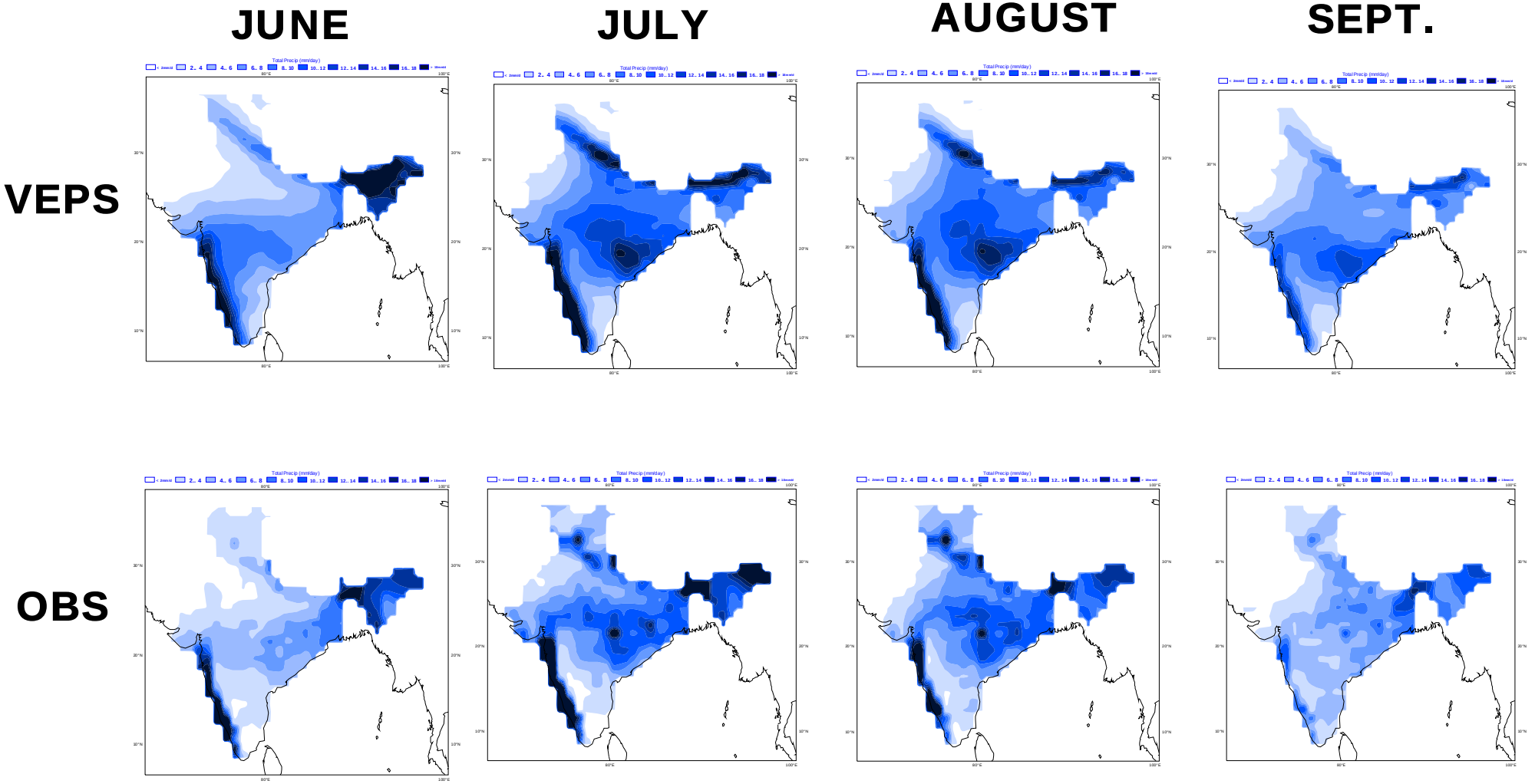

VEPS
MOFC
ML
PERS
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
-0.5
Linear correlation
1-5
6-10
11-15
16-20
20-25
26-30
Pentads in June

June SST prediction

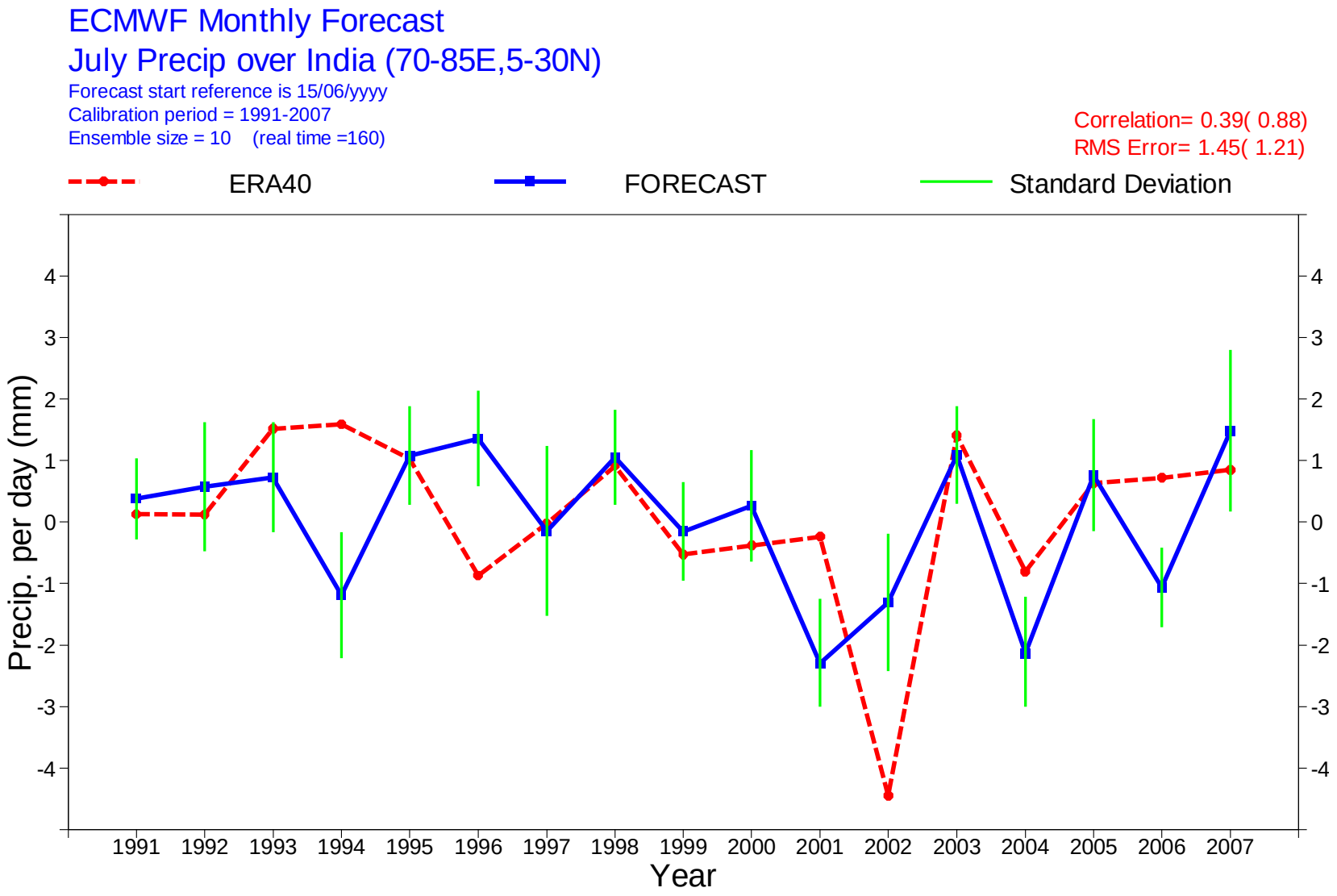
Difference of skill to predict SSTs(linear correlation with analysis) between mixed-layer model and coupled model.



Rainfall Climatology

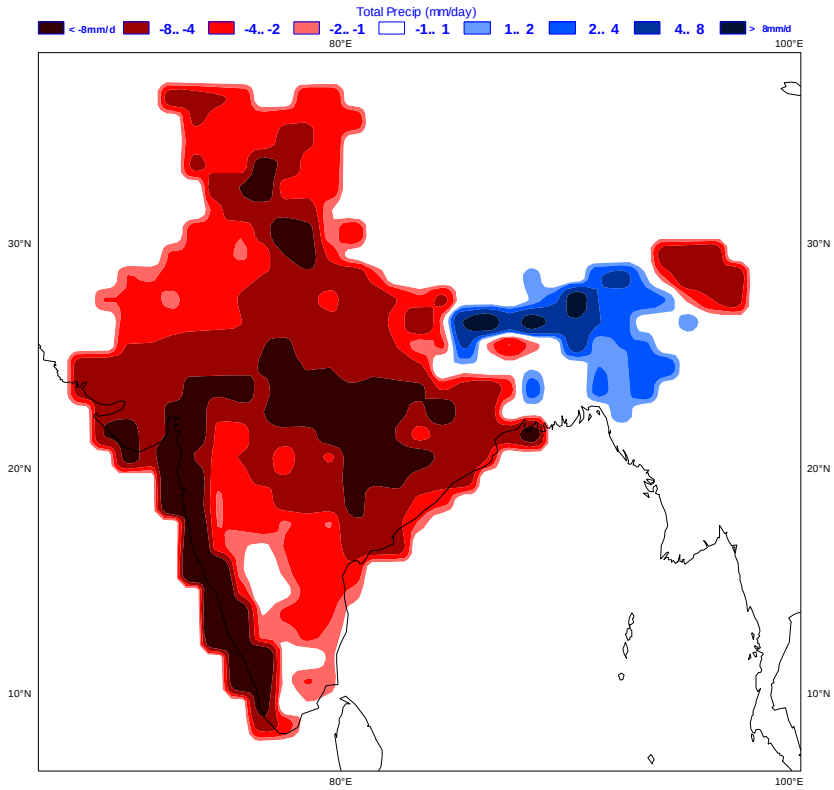


July Precipitation over India (VEPS-CY32R3)



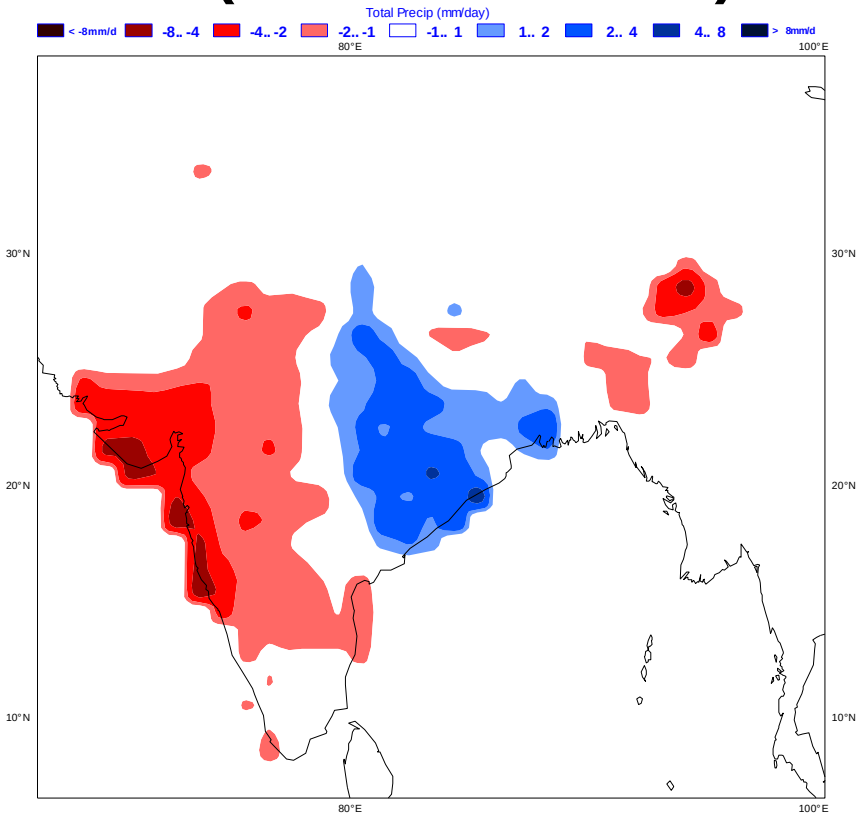
Precipitation over Indian: July 2002

Observations

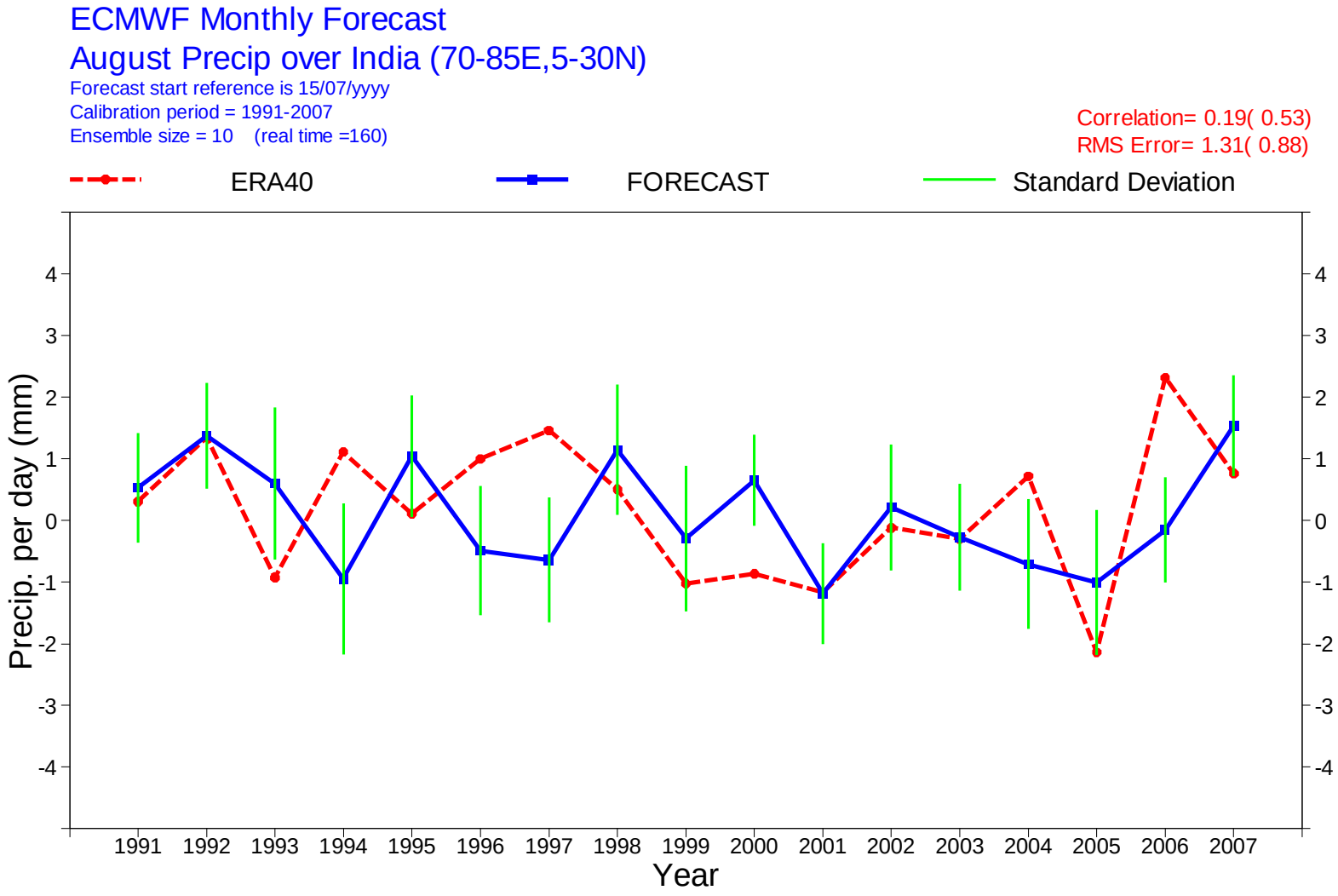


VarEPS

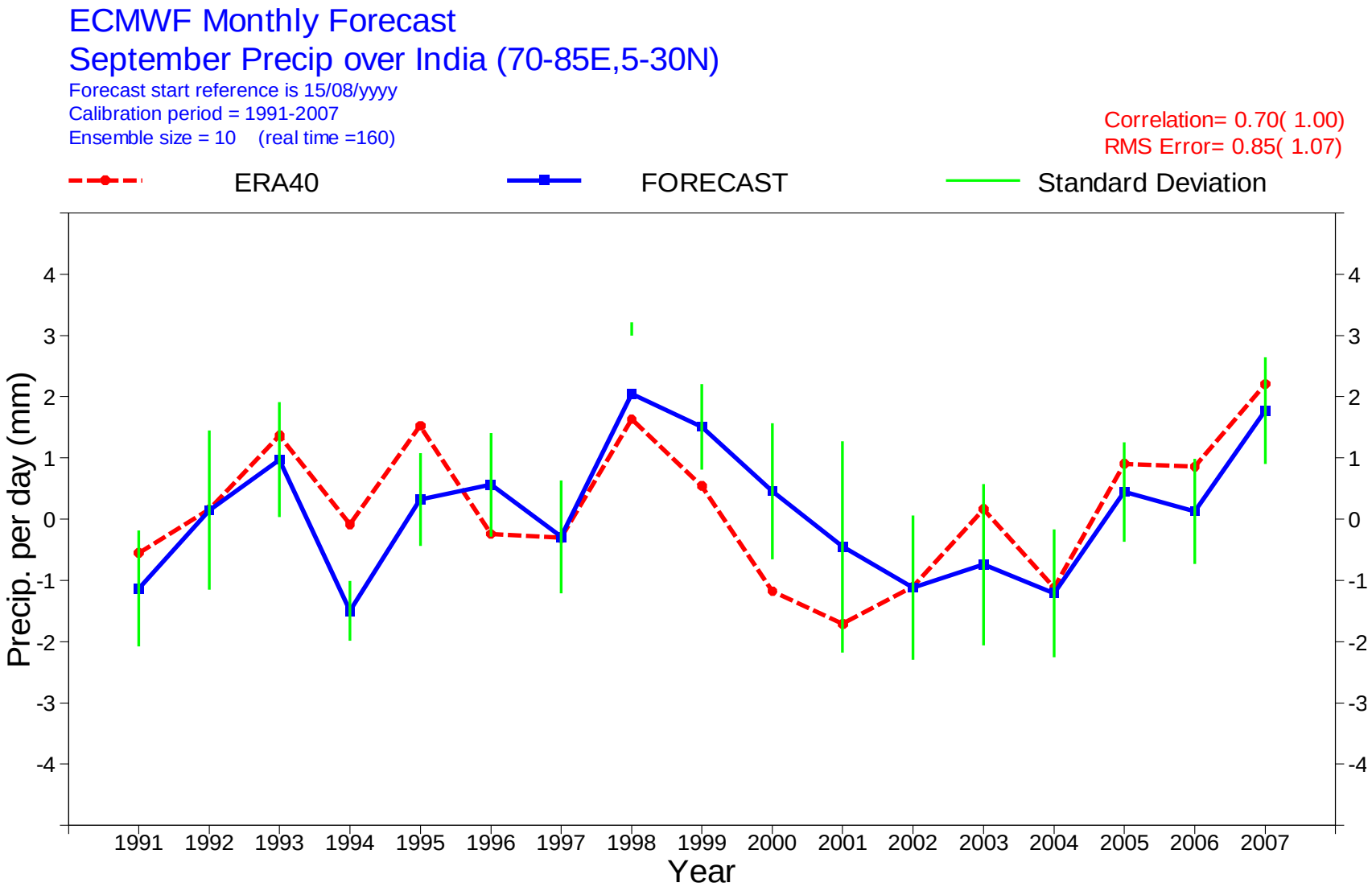
(ensemble mean)



August Precipitation over India

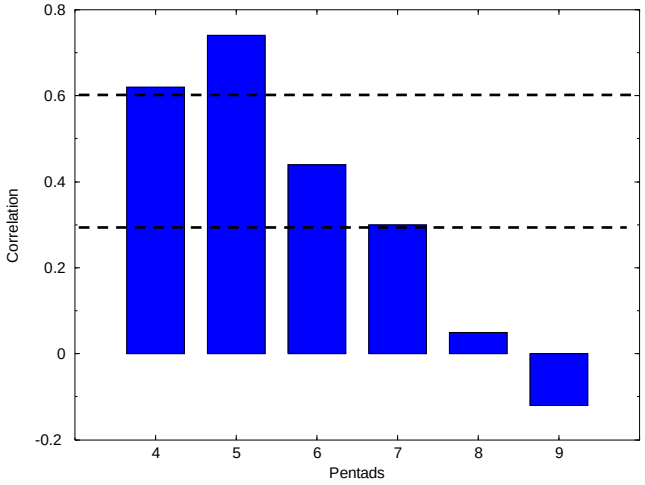


September Precipitation over India

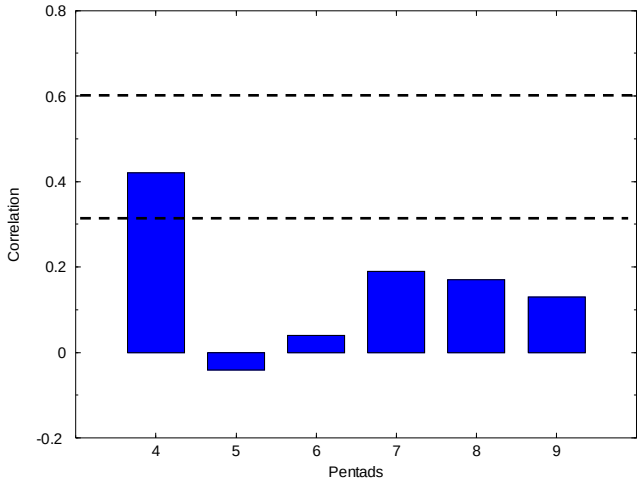


Skill to Predict Pentads

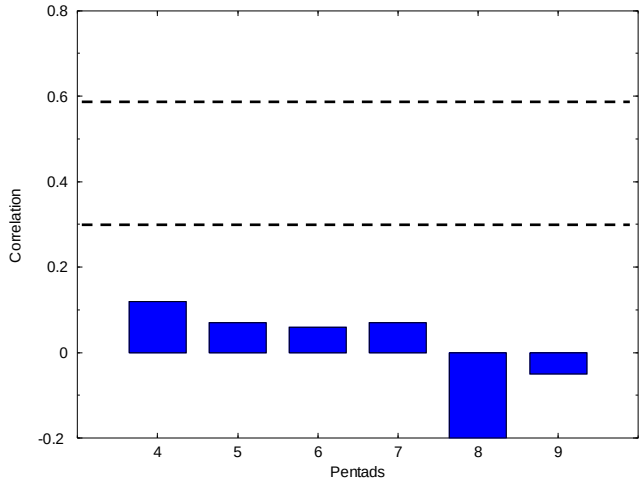
June



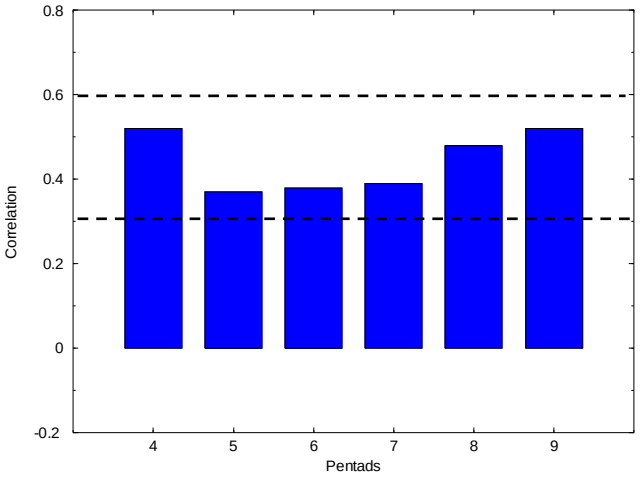
July



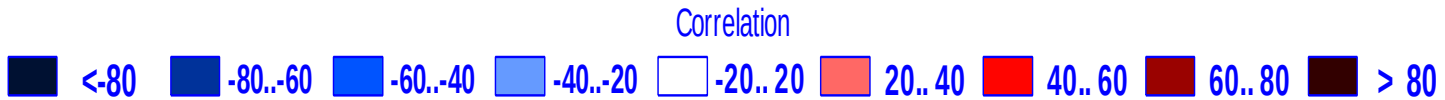
August



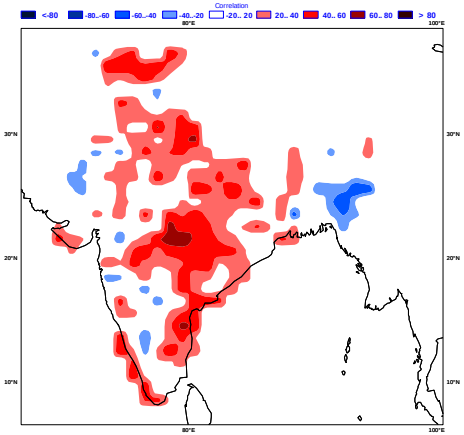
September



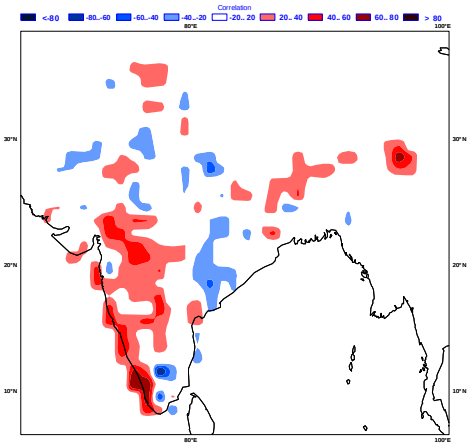
Monthly Mean Precipitation Correlation: 1991-2007



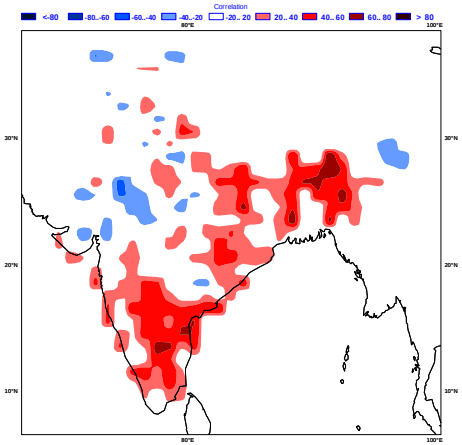
June



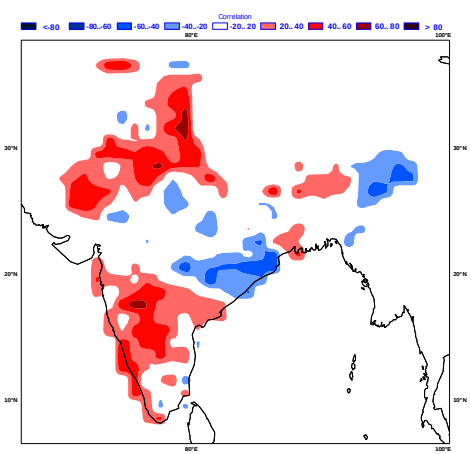
July



August



September



Conclusion

- The VarEPS-Monthly system is skilful to predict Indian rainfall in June and September. The skill is very low is August.

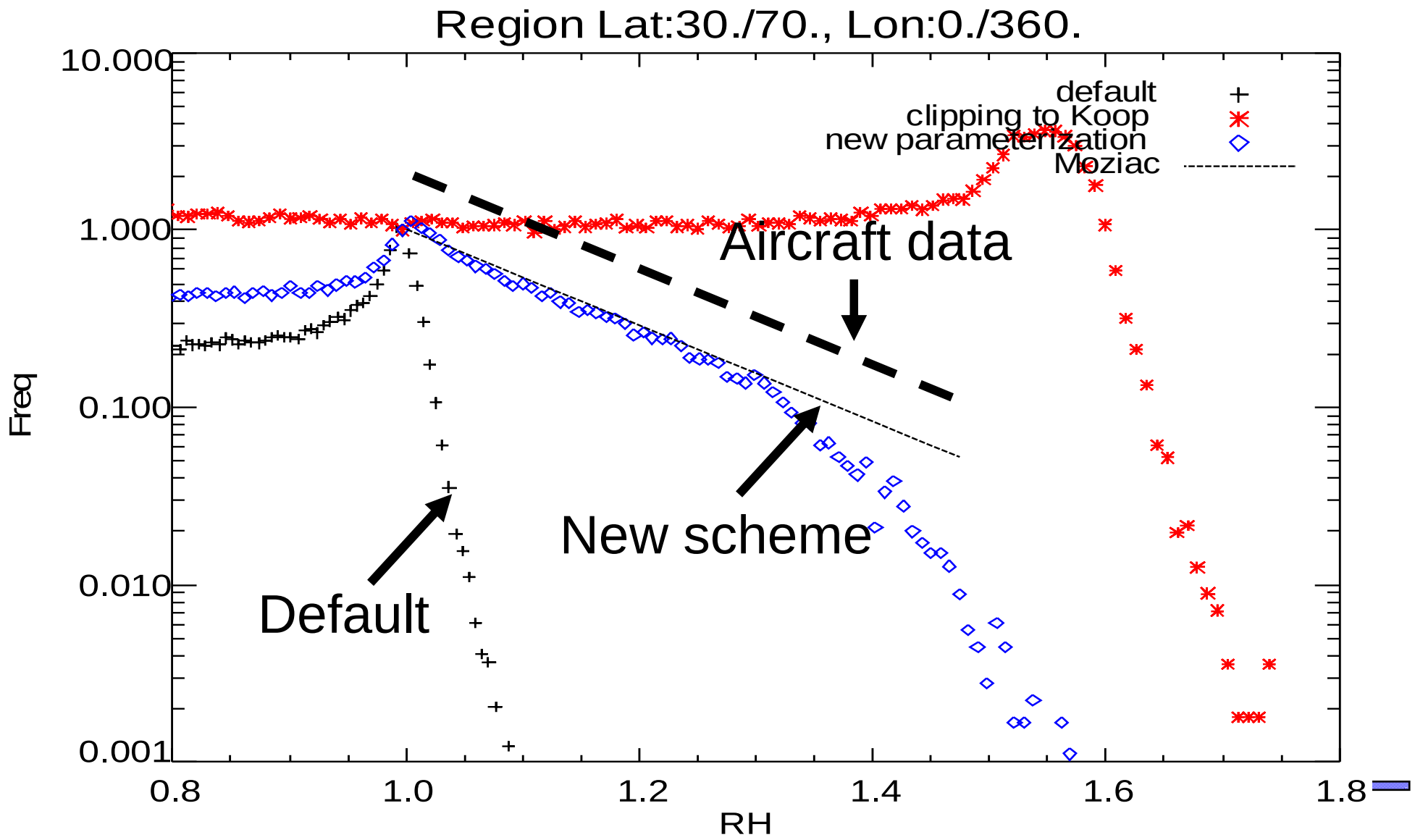
- Increasing horizontal resolution or using an ocean mixed layer model lead to better prediction of June Indian rainfall.

Recent or planned changes to the ECMWF physical parametrizations

- **Improved treatment of ice sedimentation, auto-conversion to snow in cloud scheme and super-saturation with respect to ice (CY31R1)**
- **RRTM-SW + McICA**
- **MODIS albedo + revised cloud optical properties (CY32R2)**
- **New formulation of convective entrainment**
- **Variable relaxation timescale for closure**
- **Reduction in background free atmosphere vertical diffusion**

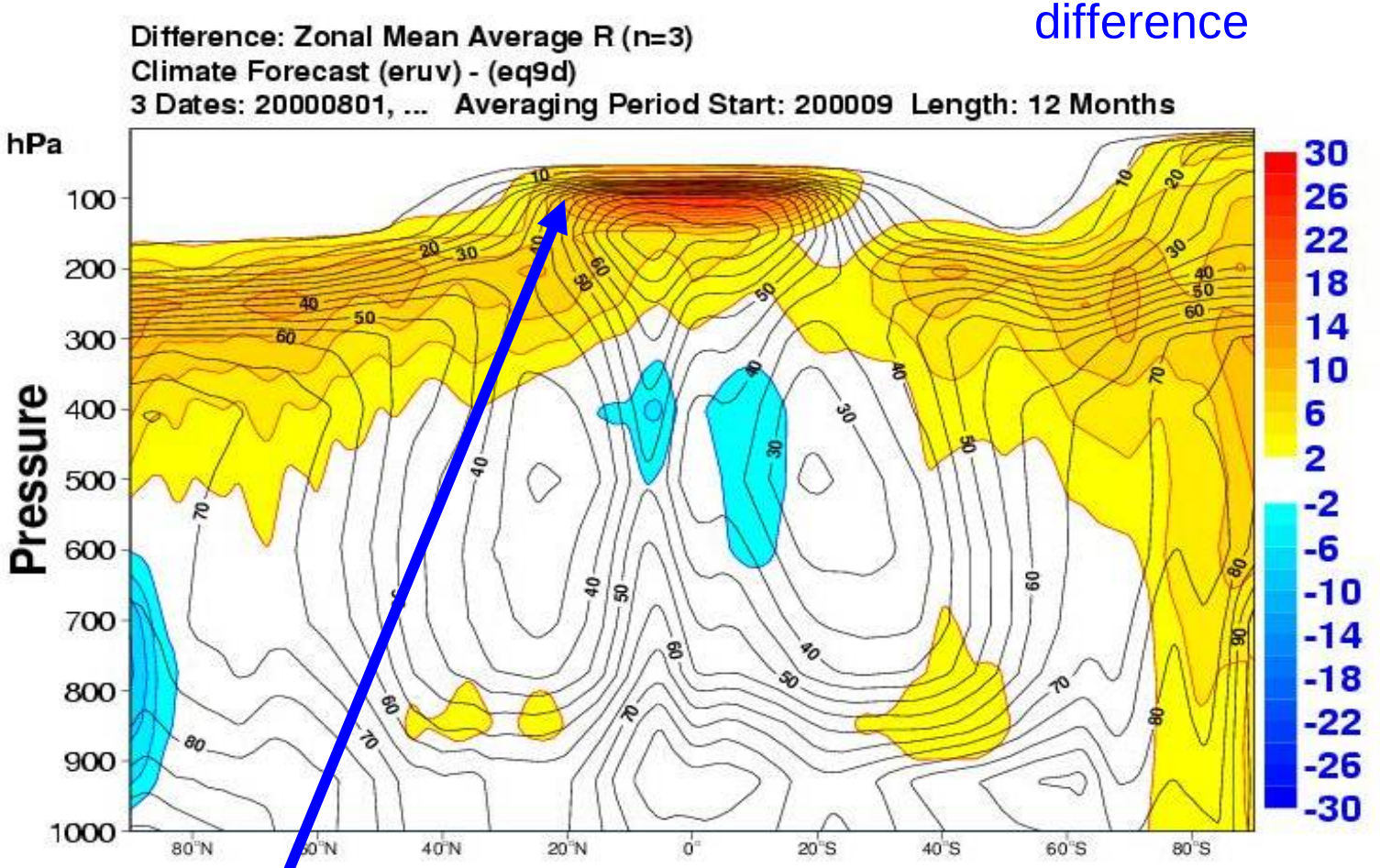
(CY32R3)

Simple ECMWF scheme: comparison to Mozaic aircraft data (from Gierens et al.)



Impact on relative humidity (RH) climatology

31r1 – 30r1 annual mean difference



Largest changes in the tropical upper troposphere

Convection changes to operational massflux scheme

New formulation of convective entrainment:

Previously linked to moisture convergence

– Now more dependent on the relative dryness of the environment

New formulation of relaxation timescale used in massflux closure:

Previously only varied with horizontal resolution – Now a variable that is dependent on the convective turnover timescale i.e. variable in both space and time also

Impact of these changes is large including a major increase in tropical variability

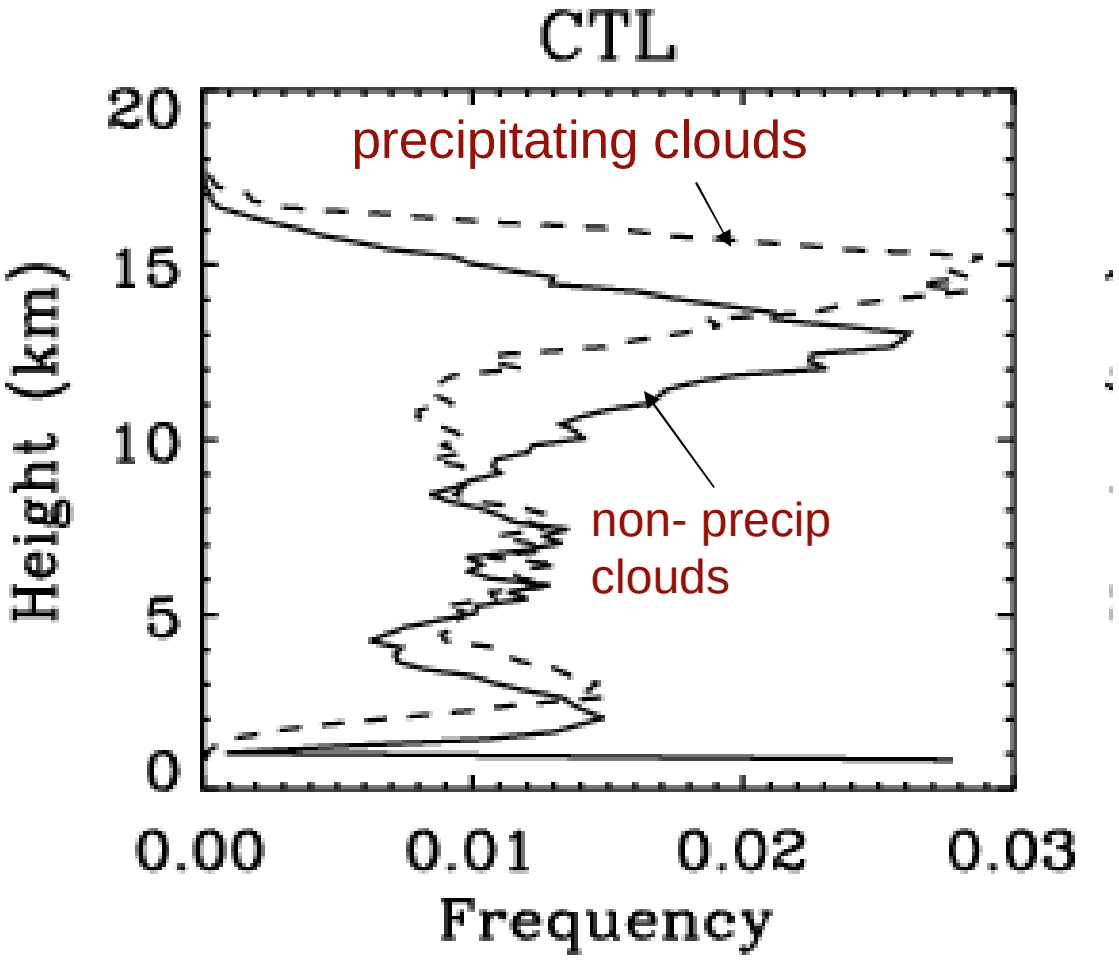
Composite vertical profile for west pac, JJA

Minimum cloud top heights distributions (CloudSat)

Of note:

•Trimodality (quadra-modal) heights

• precipitating clouds are deeper than non precipitating clouds



Average tropical cloud profiles

In the Tropics now a tri-modal cloud distribution becomes apparent, with a strong increase in mid-level clouds. CloudSat data will be used to verify these results.