Active-Break Cycles and Monsoon Intraseasonal Oscillation

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Part-I Topics

1. Definition
2. Monsoon Annual Cycle
3. Active-Break Cycles
4. Monsoon ISO and Active Break Cycles
5. Statistical Properties of ISO
6. Techniques of Extended Range Forecast of active-break cycles.

Part-II Topics

1. Identification of Active Break Spells
2. Composite method
3. Lag Regression/Lag Correlation based Method
4. Filtering Based Method
5. EOF based Method
6. Self Organizing Map Based Method

7. Real-Time monitoring of MISO (EOF method)

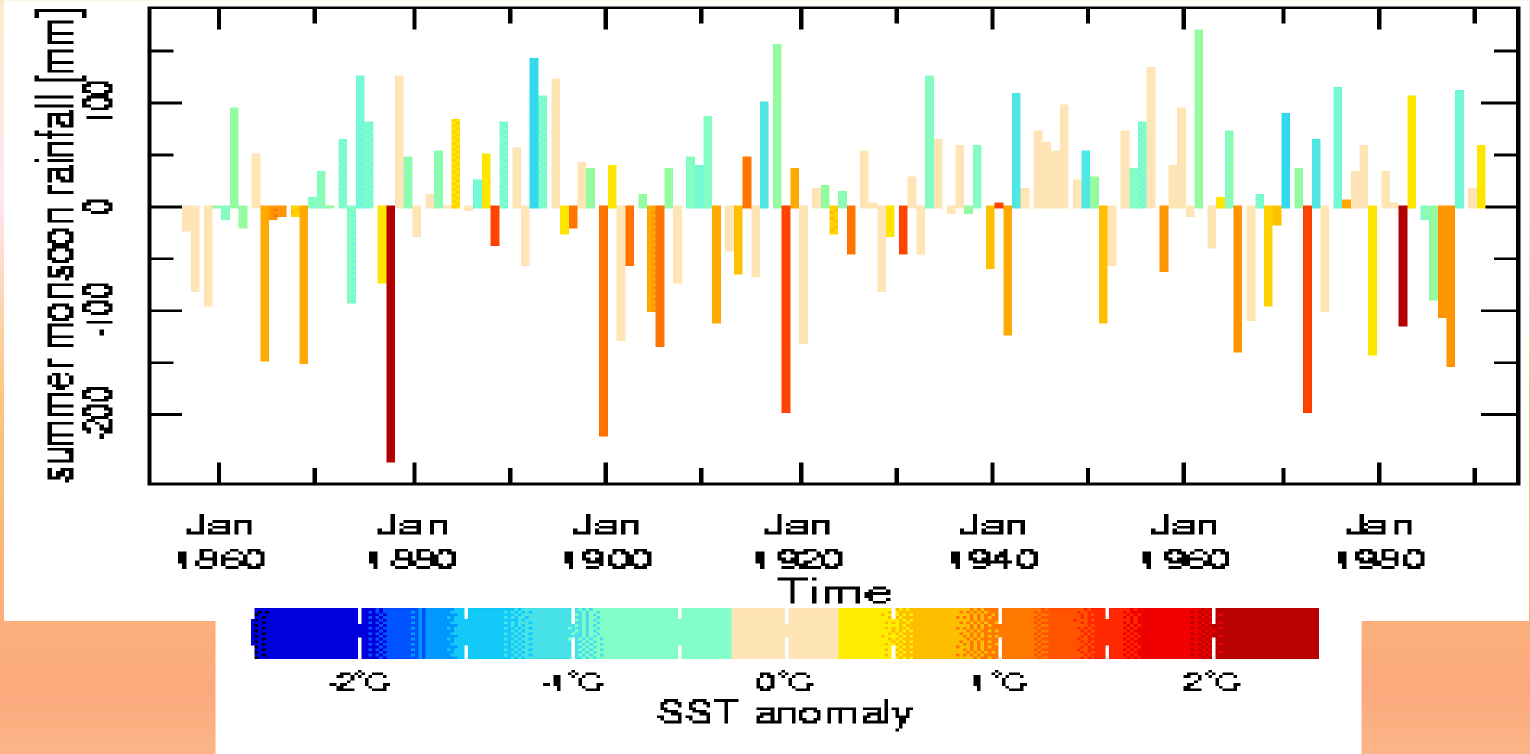
1/6 Definition

- **Active Break Spells, their durations, amplitude and phase.**
- **Intraseasonal Variability**
- **Monsoon Season**
- **Homogeneous Region**
- **Filtering Techniques**

2/6 Monsoon Annual Cycle

- **Monsoon Annual Cycle is the seasonal appearance of rainfall activity over the Indian subcontinent. June-September is the monsoon month**
- **Characterized by Vigorous onset, gradual (sometimes super-fast*) spreading of rainfall over Indian Subcontinent.**
- **MISOs are superimposed over the Annual Cycle**

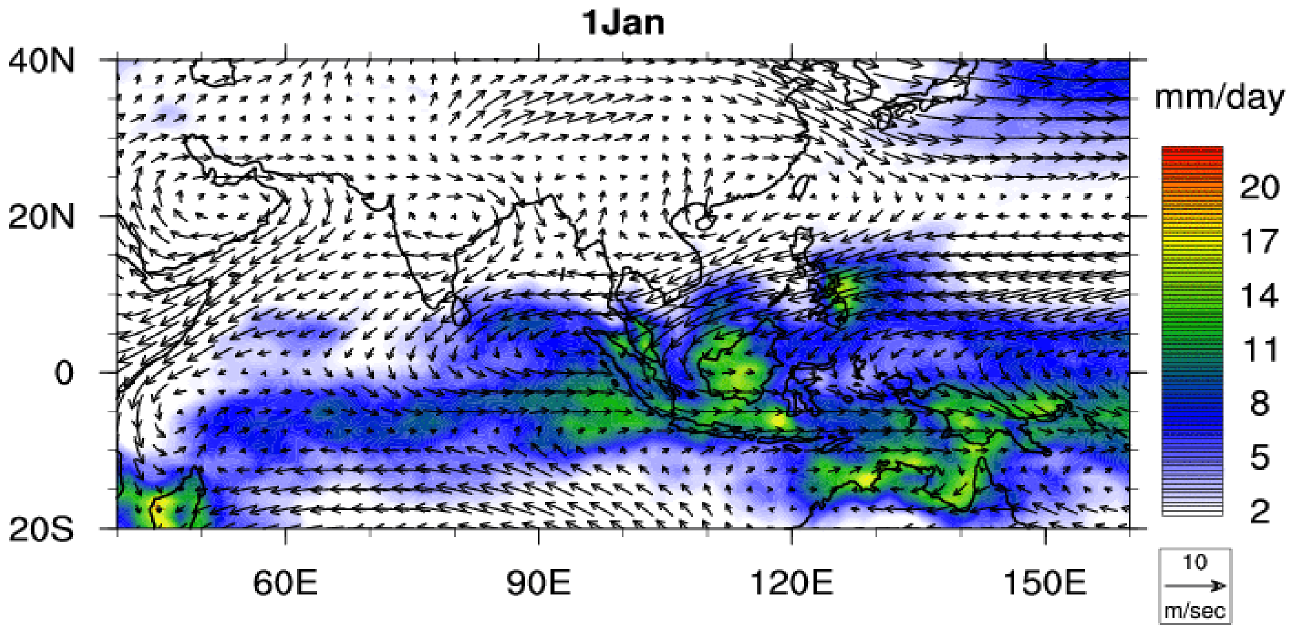
Seasonal Monsoon Rainfall Inter Annual Variability



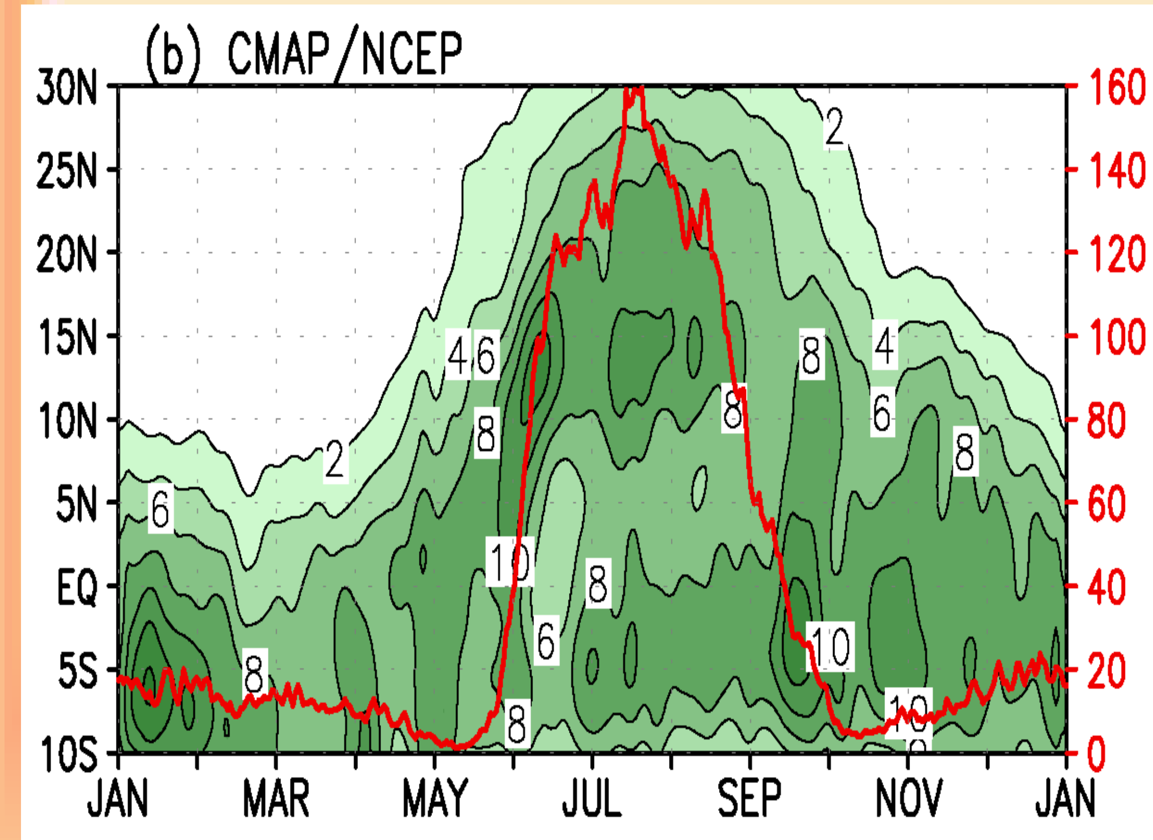
Years

India has long records of rainfall over the country. Here departure from long term mean of seasonal mean rainfall over the whole country for about 130 years is shown. All India seasonal mean rainfall is about 90 cm. The departures are shown in units of 9 cm (about 10% of the mean). Large positive departures means flood while large negative departures means drought. It may be noted that monsoon rainfall is not monotonically increasing with global warming, but has a decadal variation.

Seasonal Migration

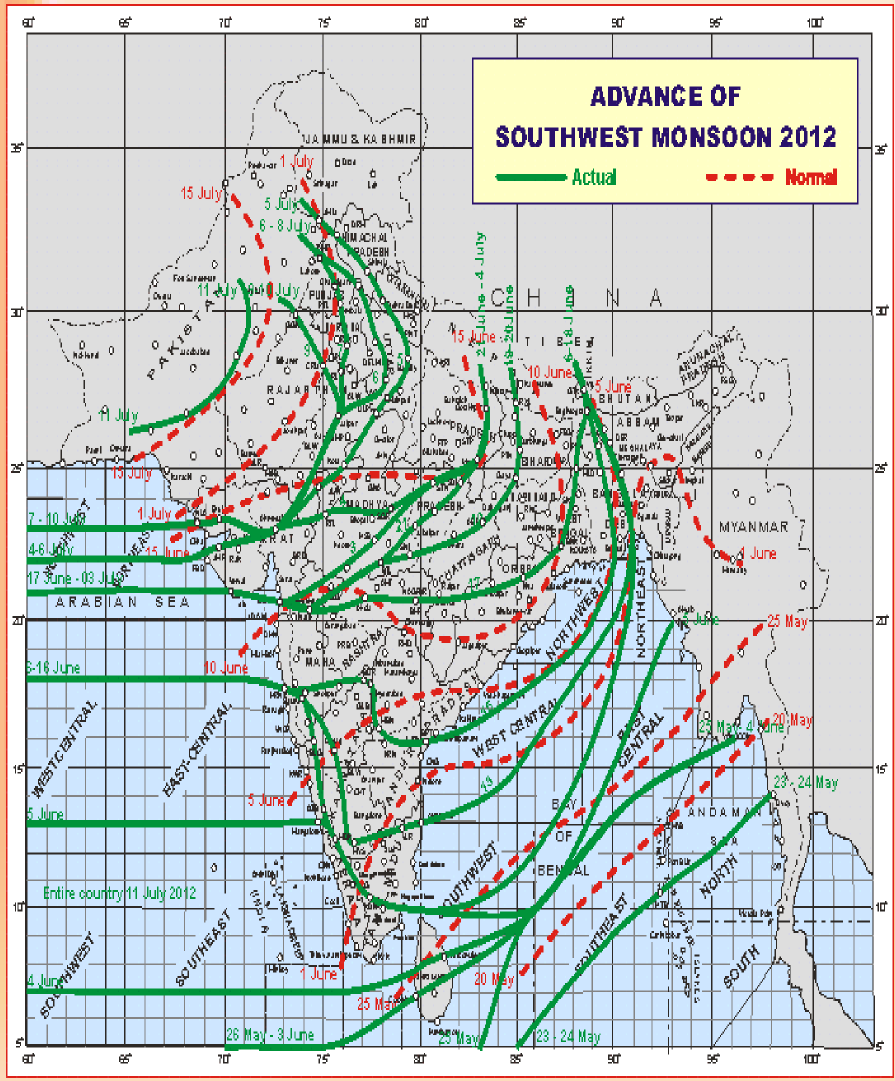


Seasonal Migration (Contd.)



Annual Evolution of the Indian monsoon. Precip. Averaged over 70-90E (shaded) and Kinetic Energy of the Low-Level Jet from observations.

Monsoon Onset



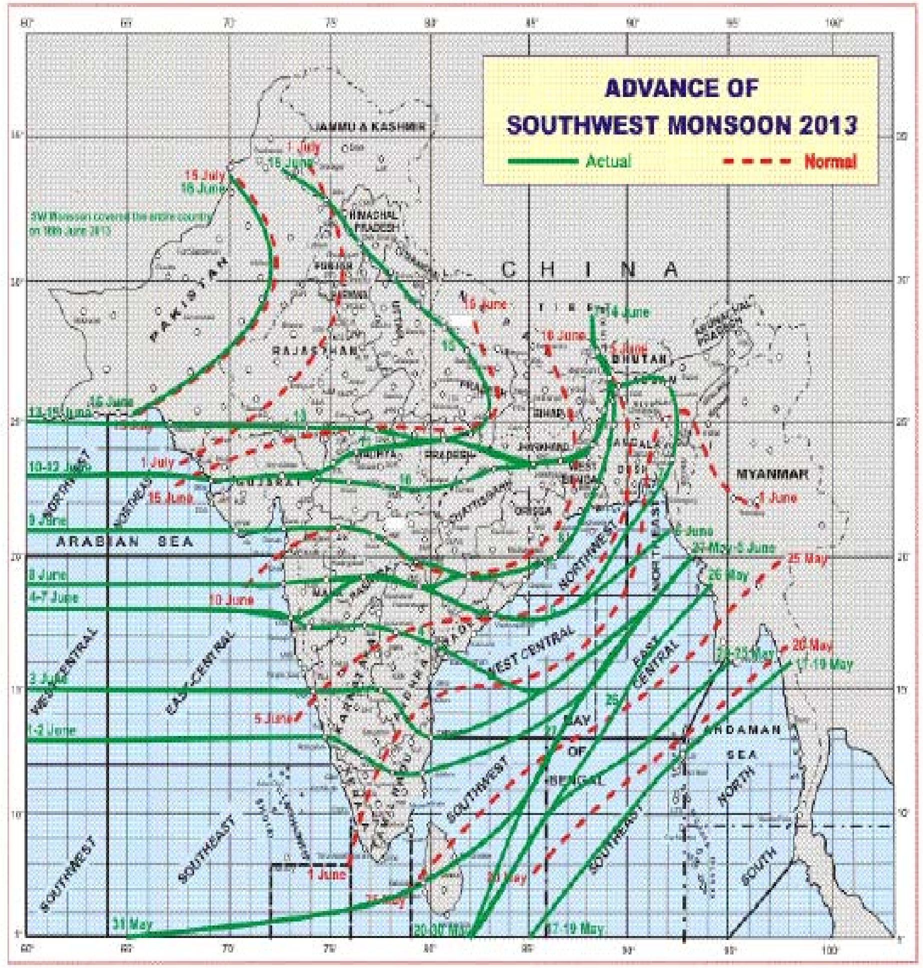
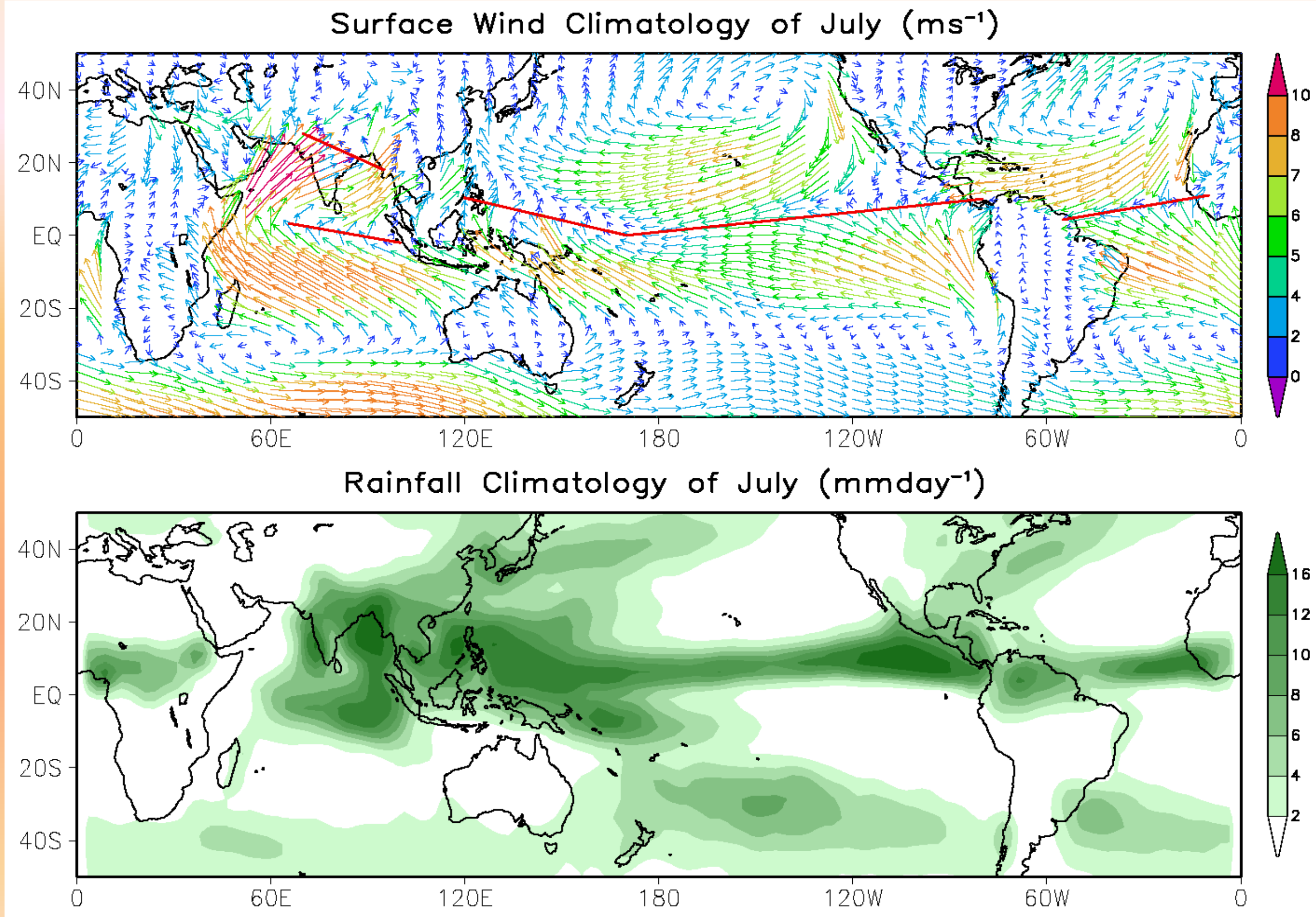
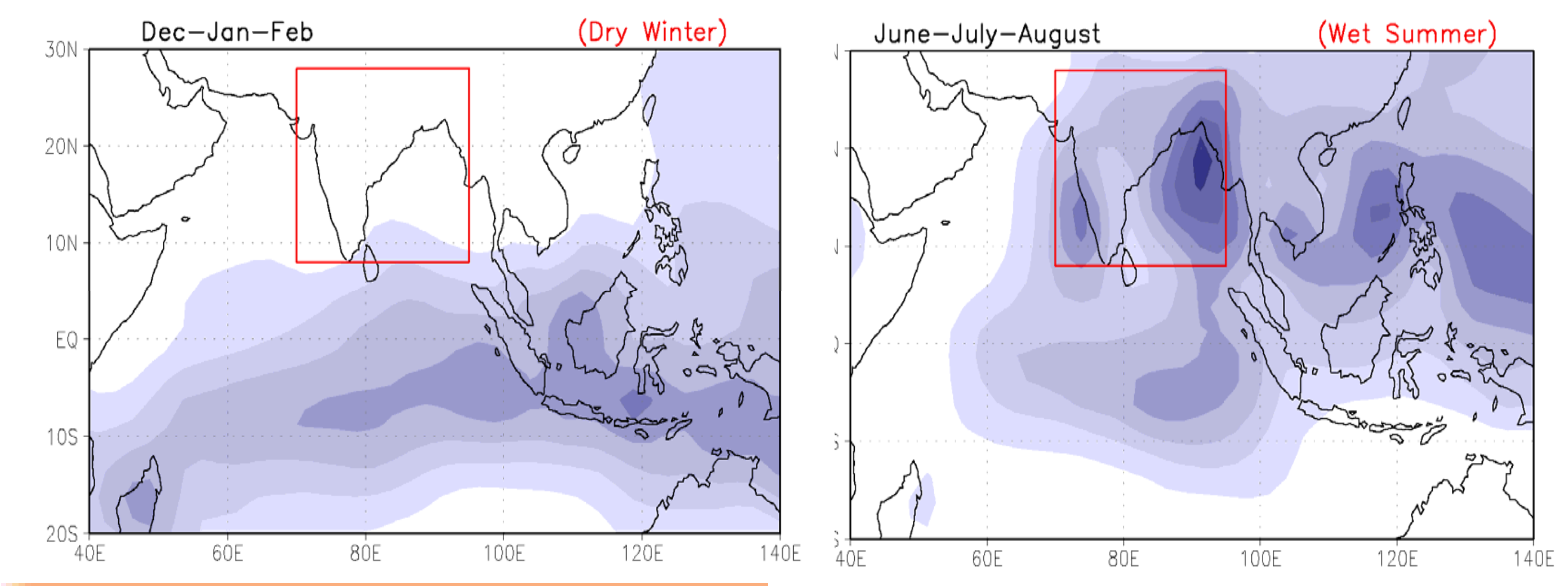


Figure 1: Advance of Southwest monsoon 2013 (courtesy: http://www.imdpune.gov.in/mons_monitor/mm_index.html)

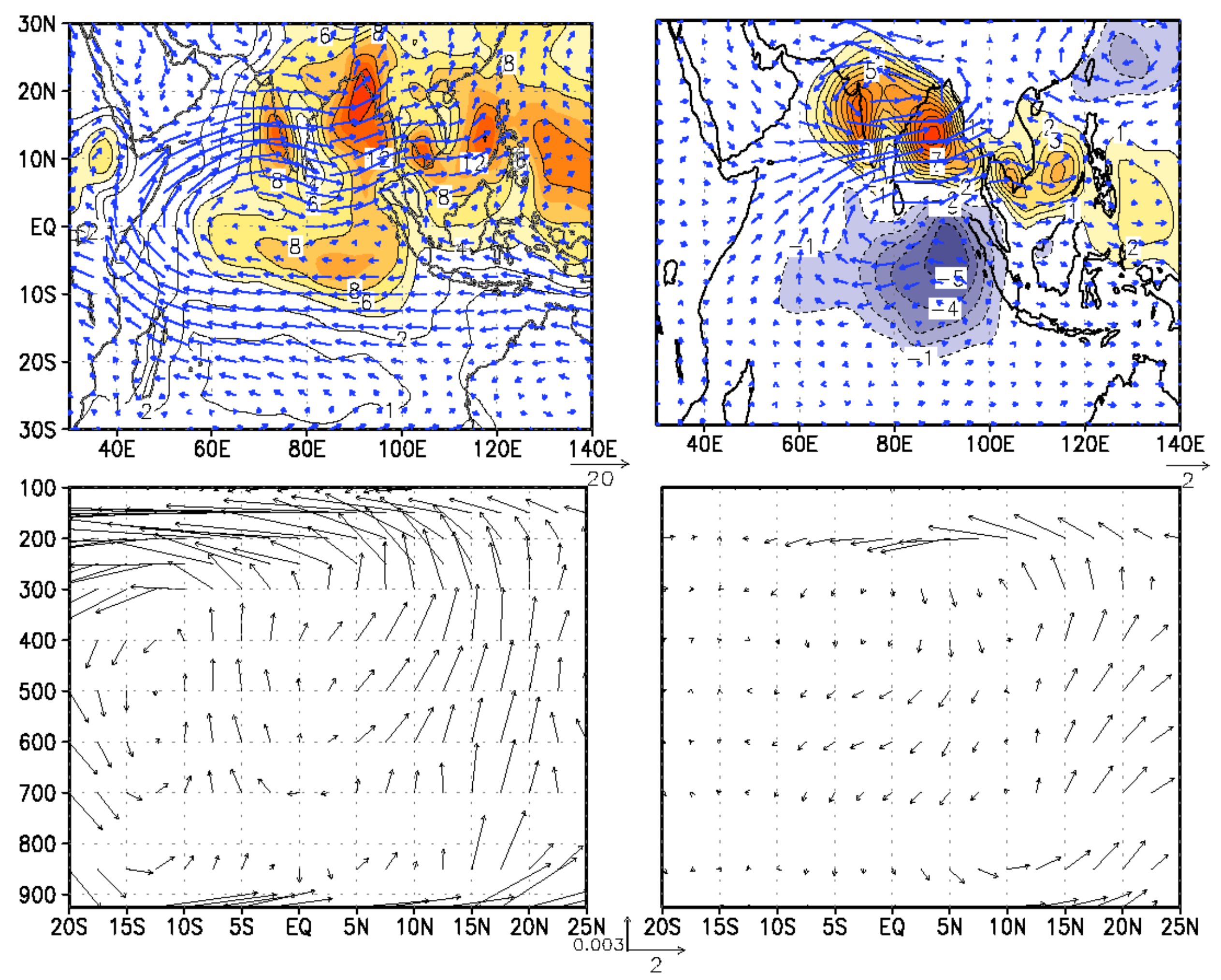
Mean July rainfall and surface wind convergence



Long Term Mean



Some More Features of Seasonal Mean



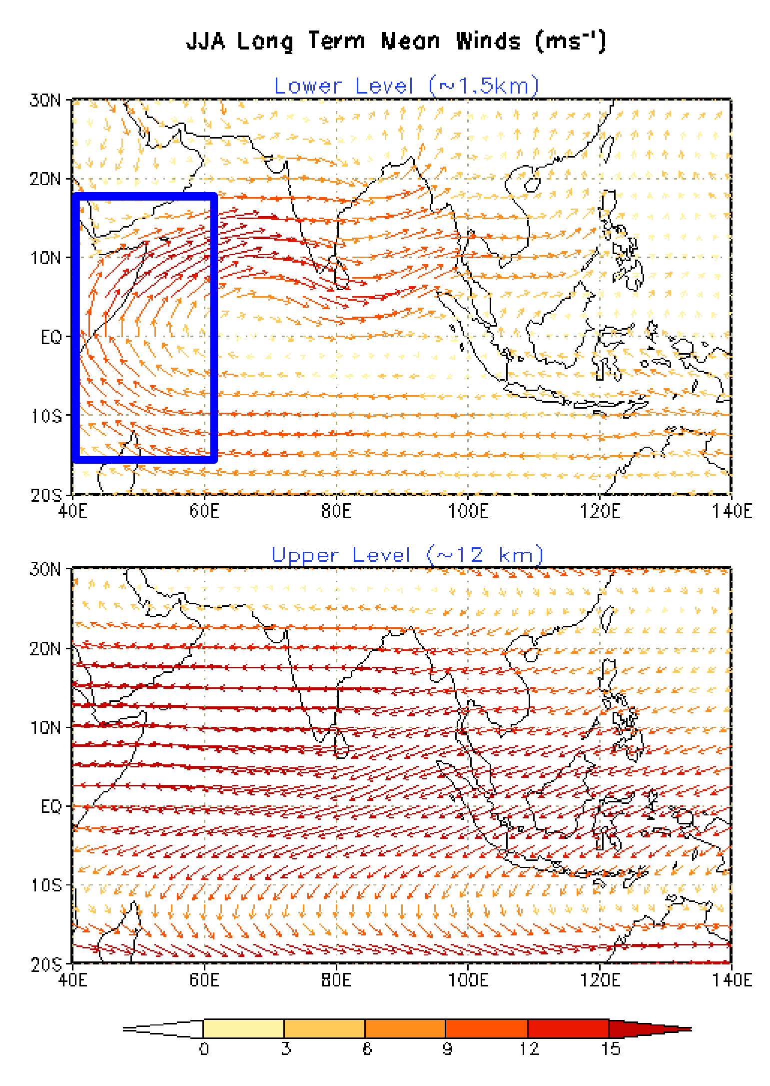
Mean monsoon Hadley circul.

70E-90E

Anom. Hadley circul. In an 'active' phase,

70E-90E

Features (contd.)

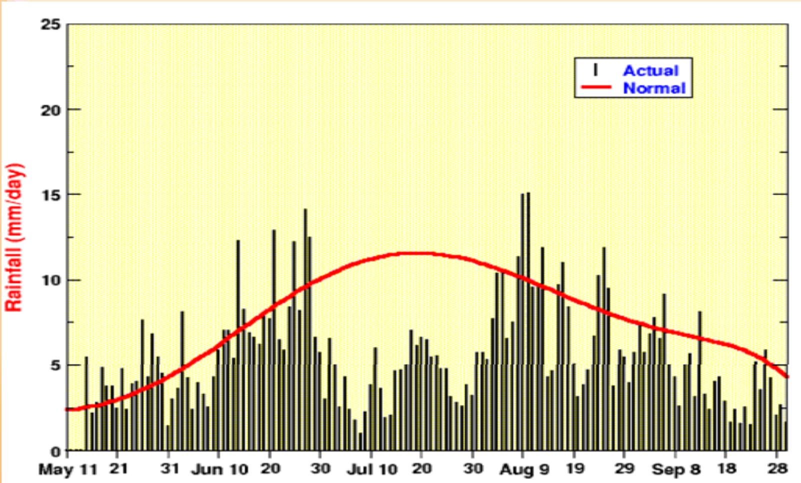


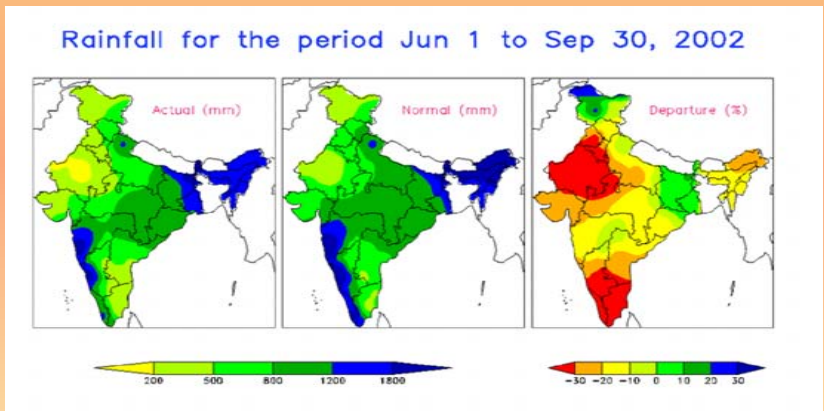
Characteristic features of summer monsoon circulation

Low level, cross-equatorial flow, south-westerlies, westerly jet in Arabian sea

Upper level easterlies, Monsoon Easterly Jet

3/6. Active Break Cycle





The active/break cycles are superimposed over the seasonal mean .

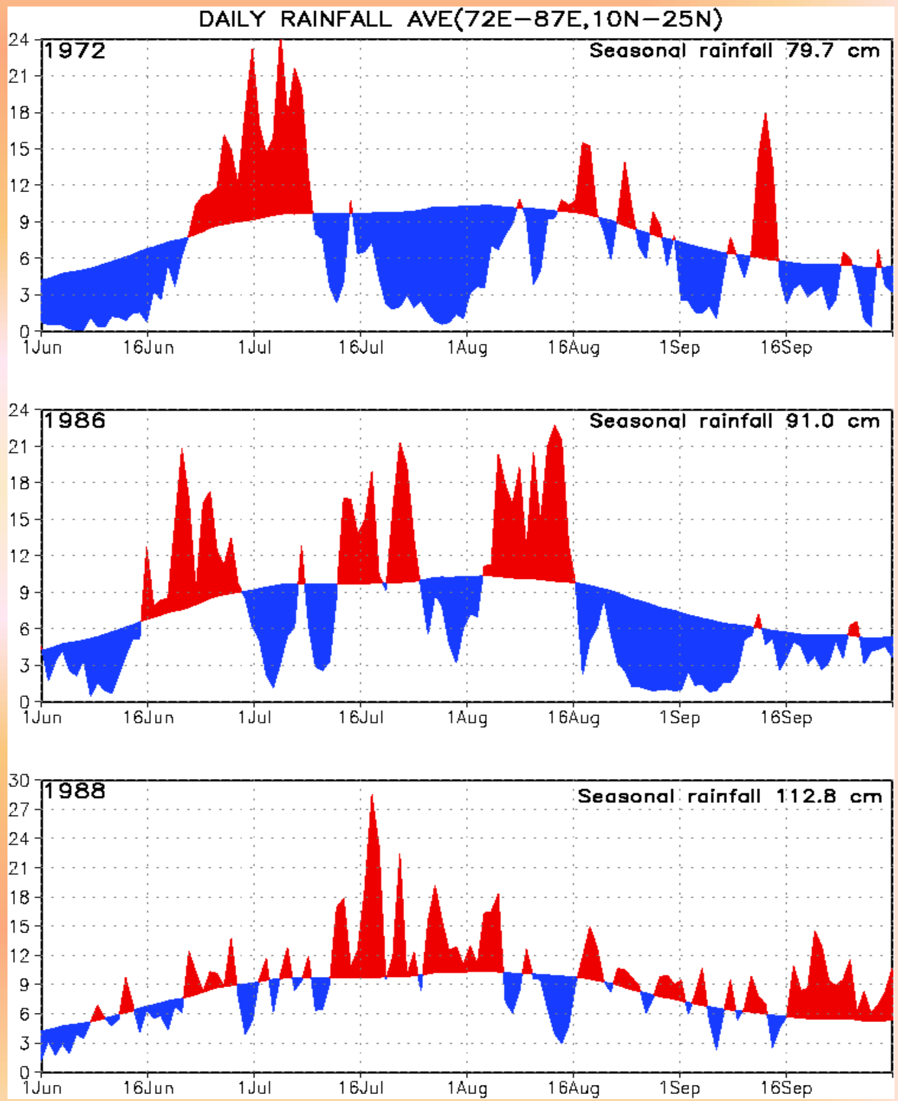
Active Break cycles are normally defined over a Homogeneous Region over India.

Active-break spells (cycles)

Daily rainfall (mm/day) over central India for three years, 1972, 1986 and 1988

The smooth curve shows long term mean.

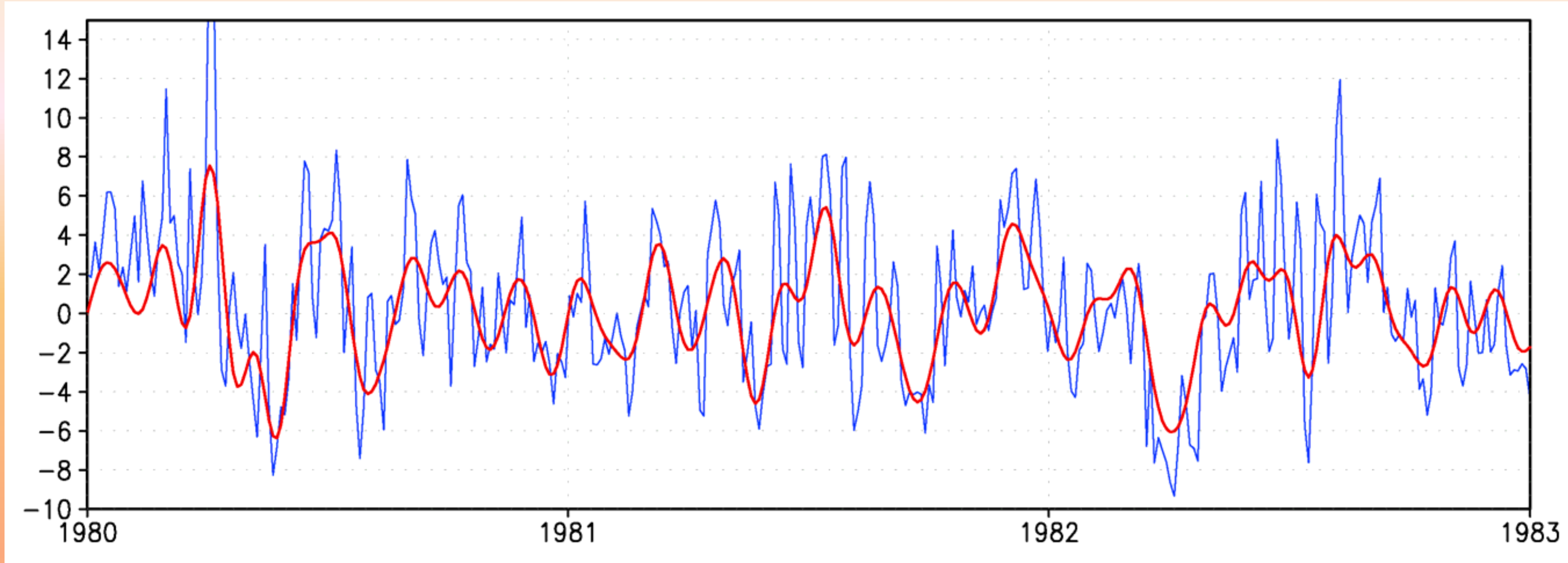
Red shows above normal or wet spells while blue shows below normal or dry spells



- **Question: Can you say anything about the duration of the Intraseasonal Active-Spells from the last slide?**

4/6. Monsoon Intraseasonal Oscillation

Active Break Spells With Northward Propagation of ITCZ



Time series of daily rainfall anomaly (mm/day) over central India (blue) during 1 June – 30 Sept. for three years and 10-90 day filtered (red) rainfall.

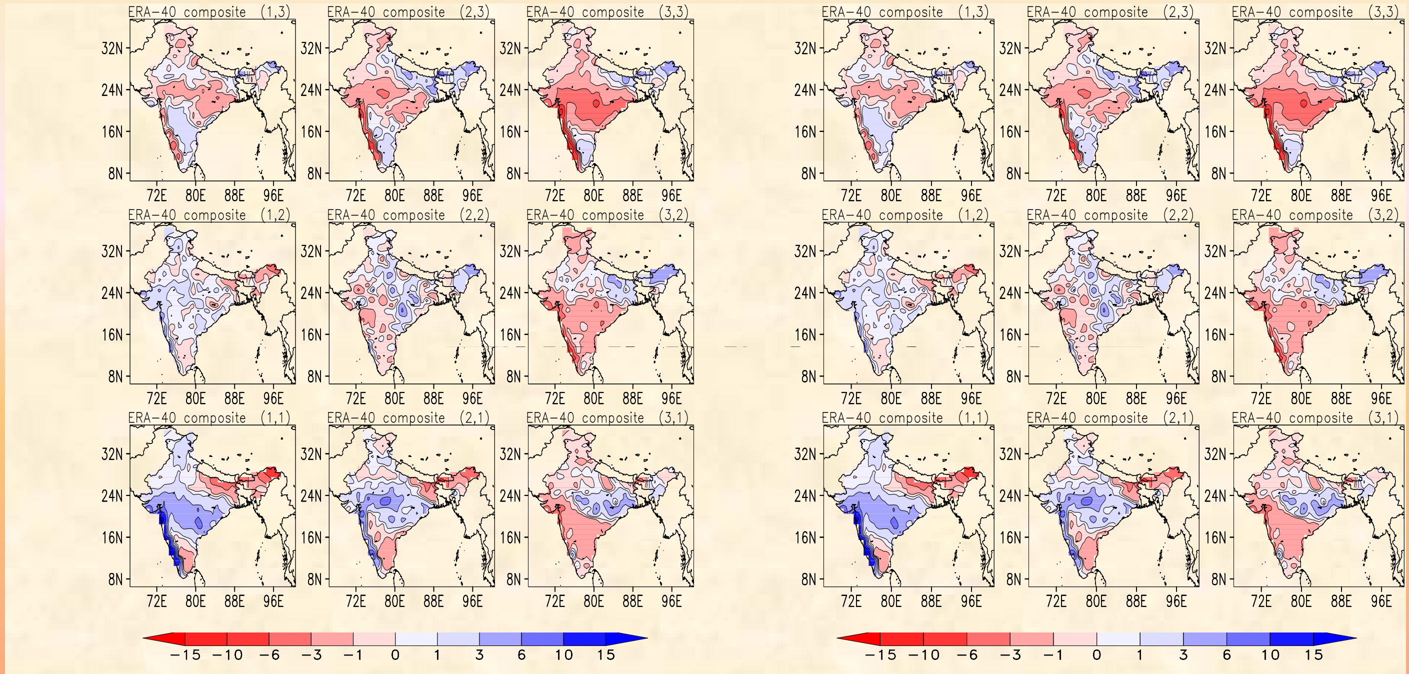
Compositing Techniques

- **Simple Lag Composite**
- **Lag-Regression/Lag Correlation**
- **EOF based composite**
- **Self Organizing Map based composite**

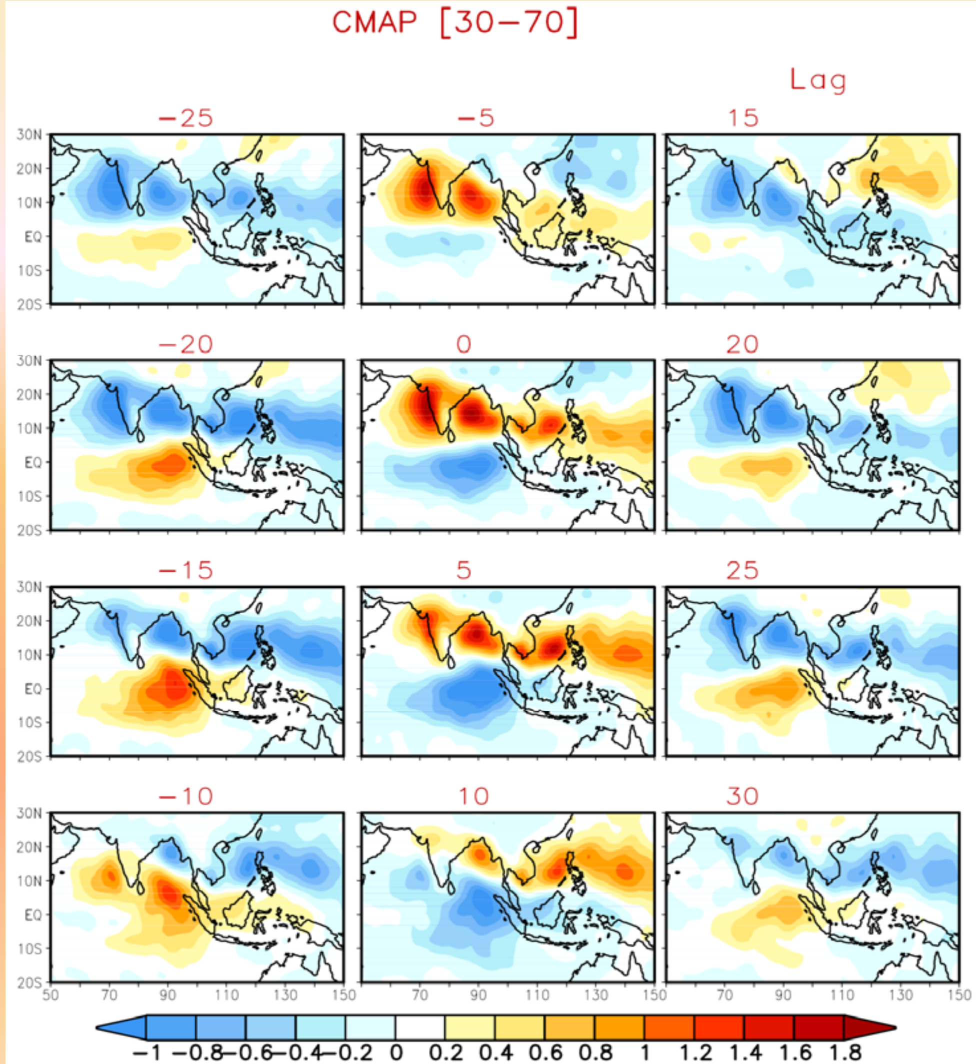
Need For Different Methods

- The space-time structures of ISO are not theoretically derived. The structure we know are results of exploratory data analysis in the last 50 years specifically after the identification of MJO.
- Each method has their own domain of applications.

Active-Break Composite of Rainfall using SOM



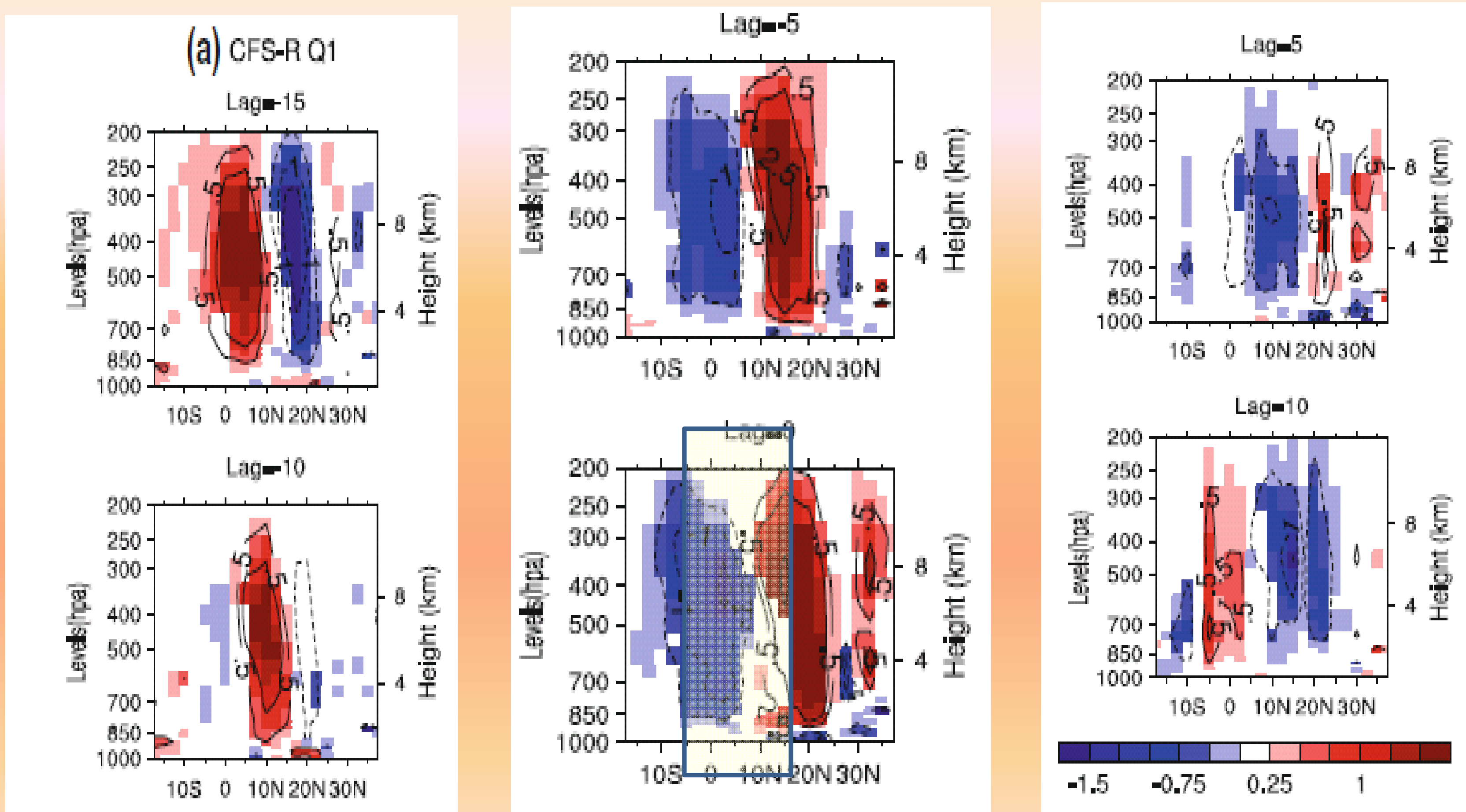
Propagation Characteristics of MISO



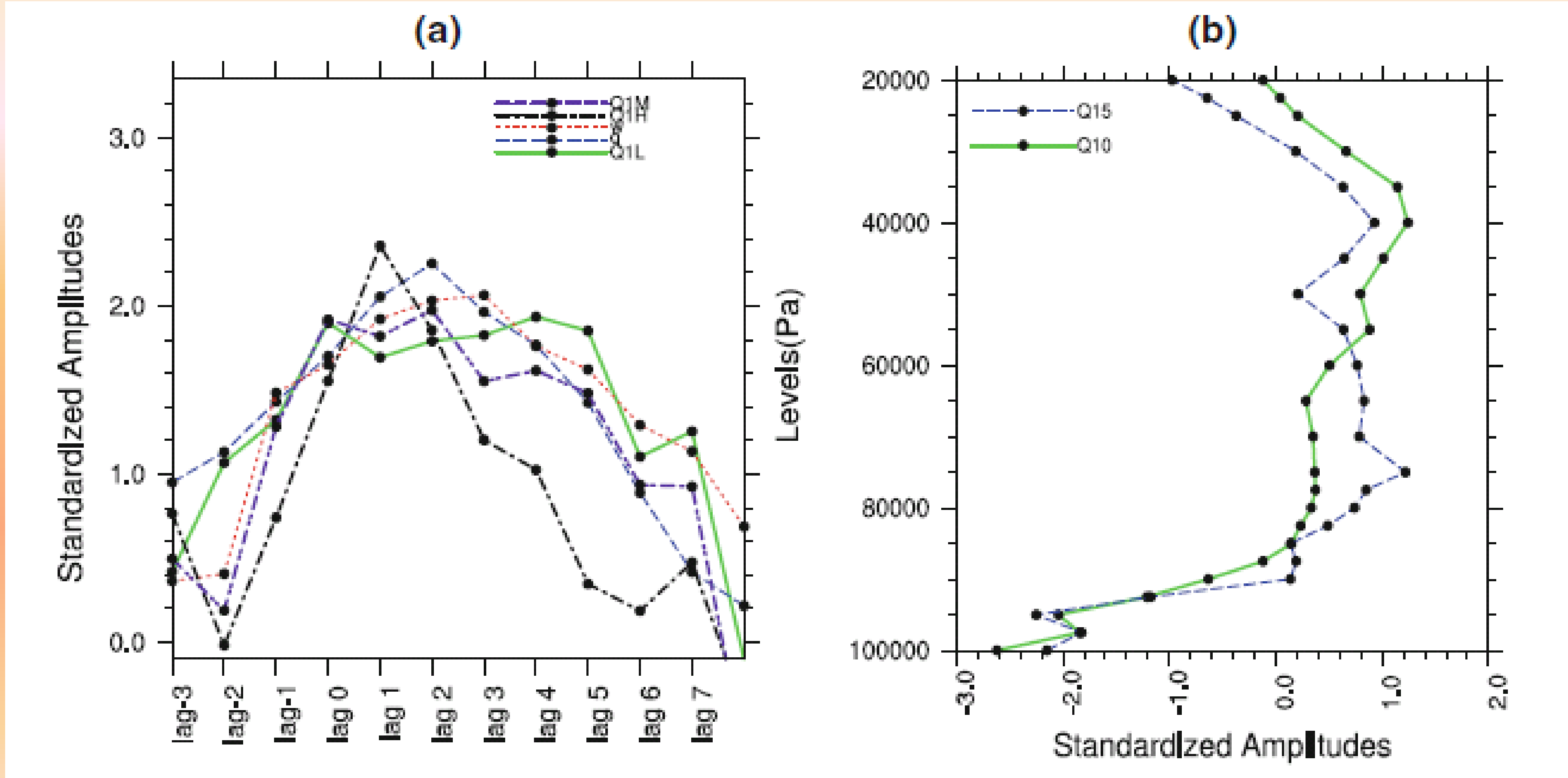
Observed evolution of the precipitation anomaly patterns over a full cycle of the 30-70 day mode.

Lag regressions of the 30-70 day filtered CMAP anomalies with respect to a reference time series over the monsoon region.

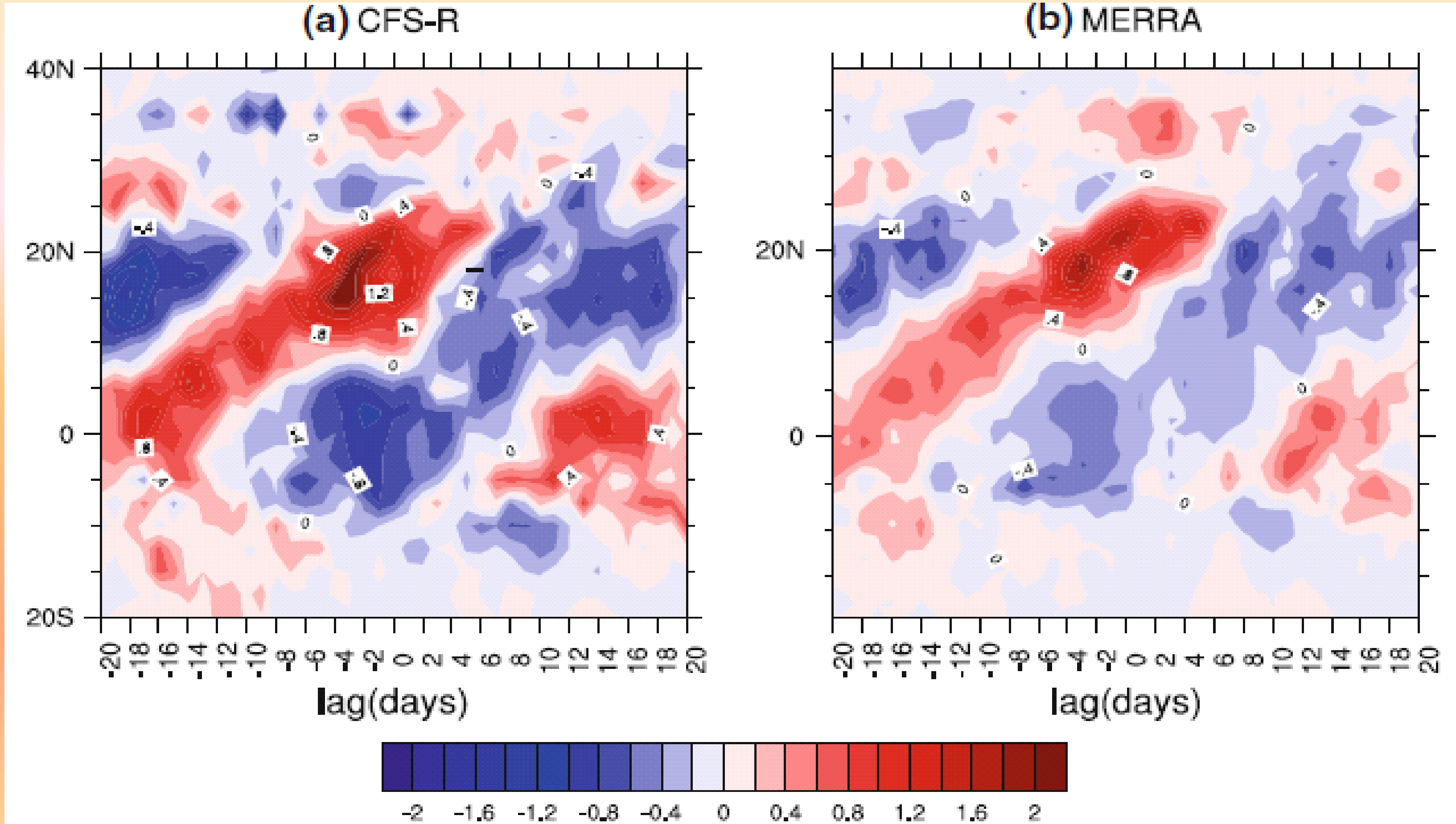
Vertical Structures of Propagation



Stratiform Heating/ Convective Heating/ Shallow versus deep heating structures of MISO



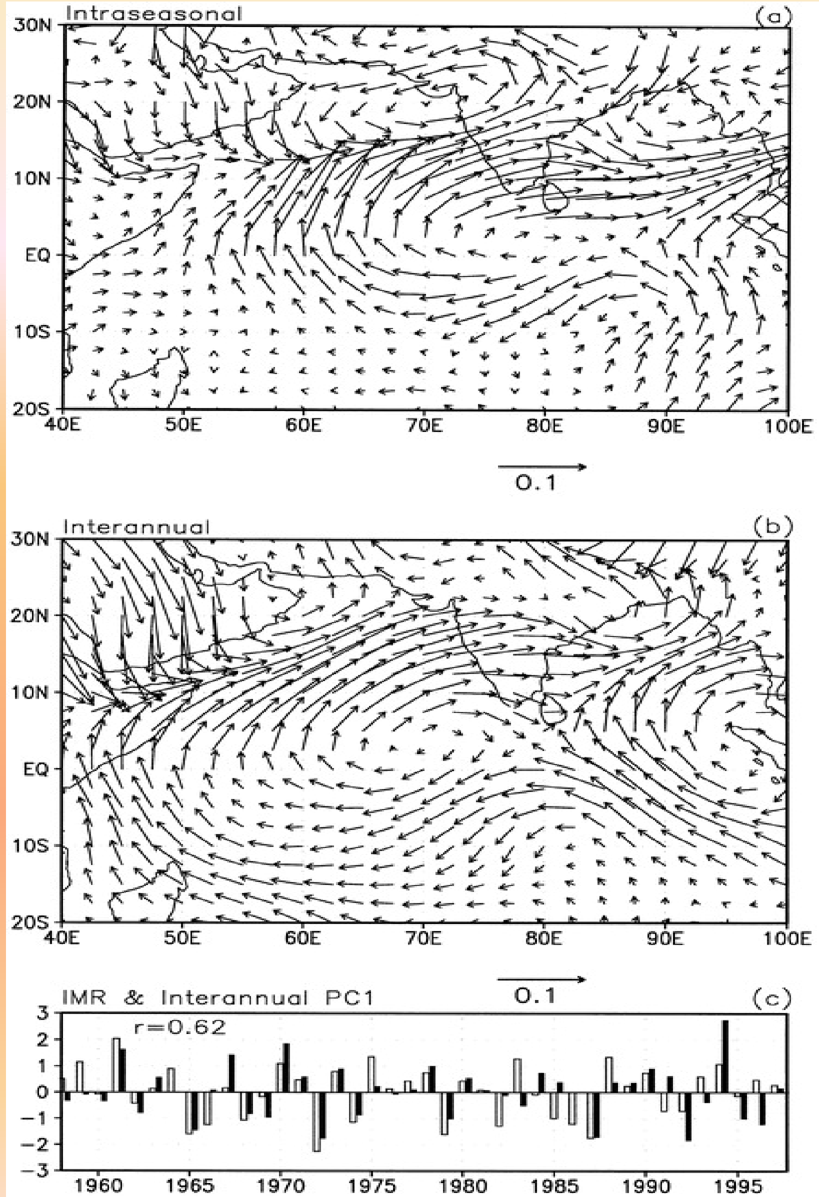
Hovmuller Diagram of Propagation



Common Mode of Variability

- MISO and **M**onsoon Iinterannual **V**ariability shown to have common spatial structure.
- Commonality in spatial structure indicate that both are related in terms of spatial coherence.

Common Mode (contd.)



First EOF of the intraseasonal and interannual 850-hPa winds.

(a) Intraseasonal EOFs are calculated with ISO-filtered winds for the summer months (1 Jun–30 Sep) for a period of 20 yr (1978–97).

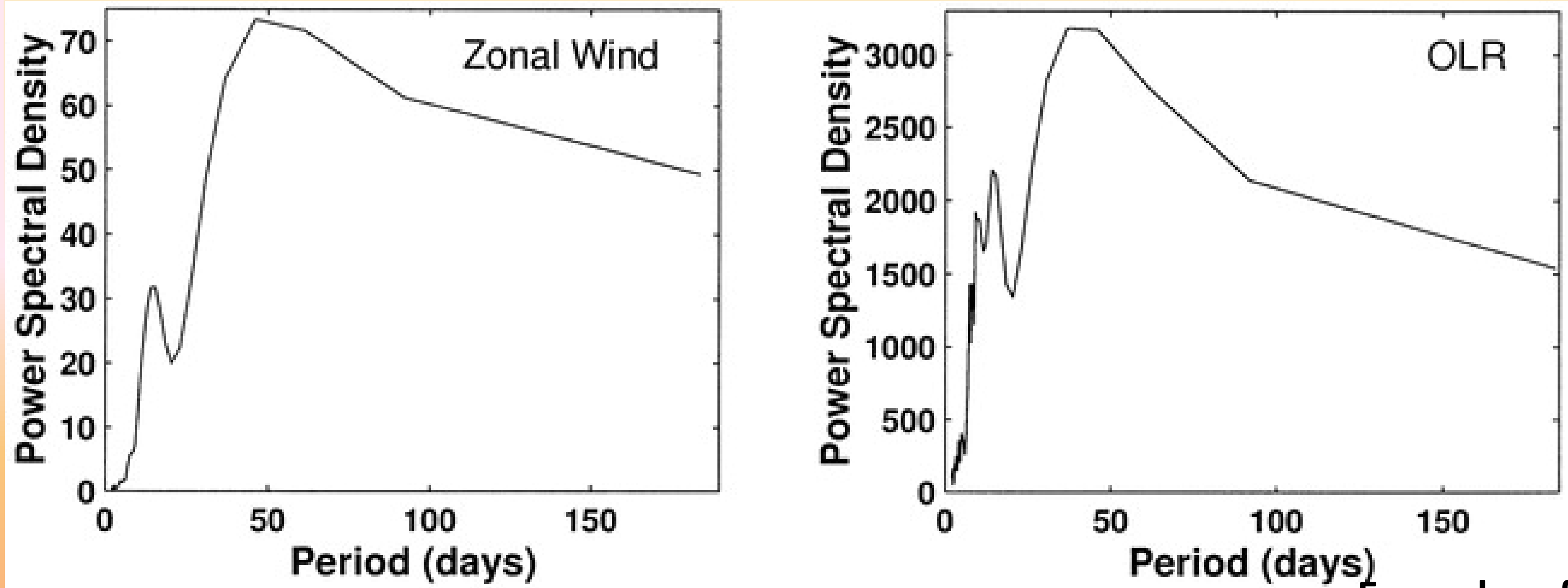
(b) Interannual EOFs are calculated with the seasonal mean (JJAS) winds for 40-yr period (1958–97). Units of vector loading are arbitrary.

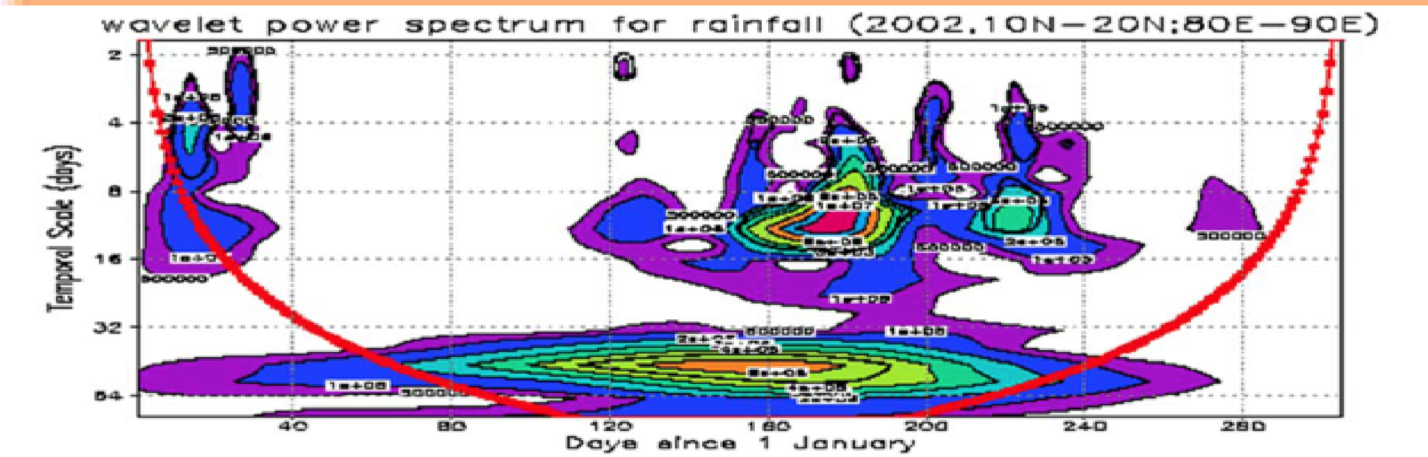
(c) Relation between IMR and interannual PC1. Filled bars indicate interannual PC1, and the unfilled bars represent IMR. Both time series are normalized by their own standard deviation. Correlation between the two time series is shown

MISO and summer MJO

- Are they related or Independent?

5/6 Statistical Properties of MISO



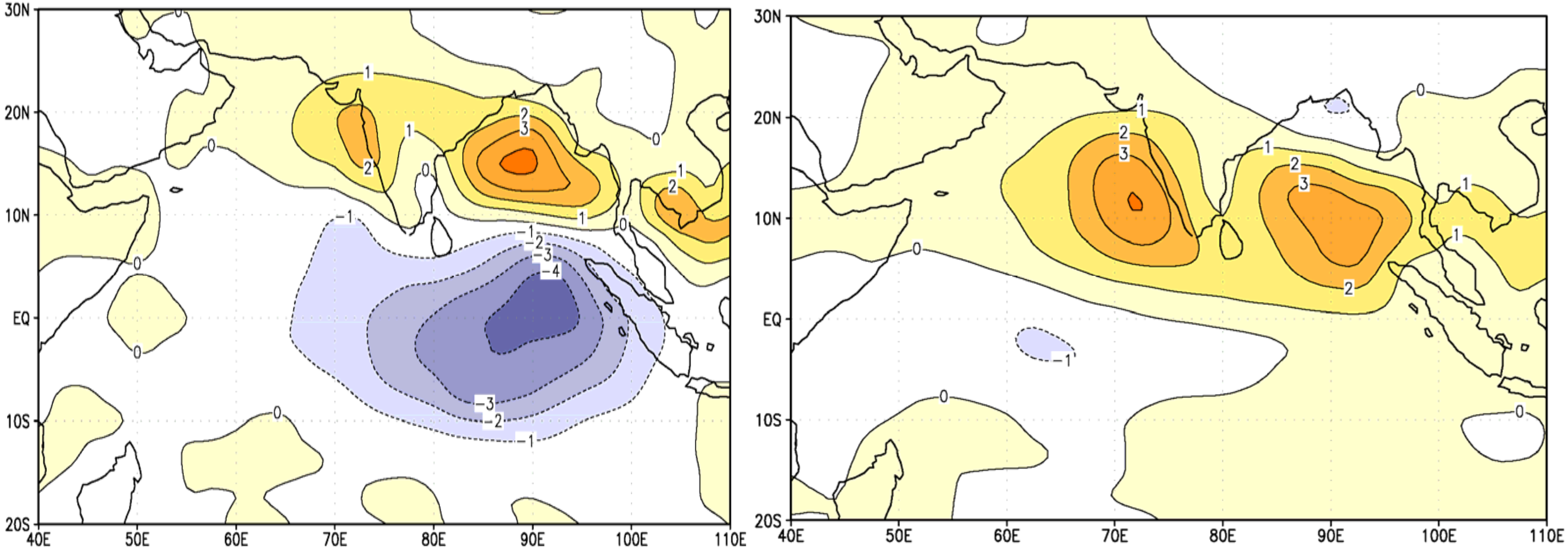


- Examples of spectra of zonal winds and OLR for a typical year (1984) at a typical point (90°E, 10°N). (Goswami and AjayaMohan, JAS,2010

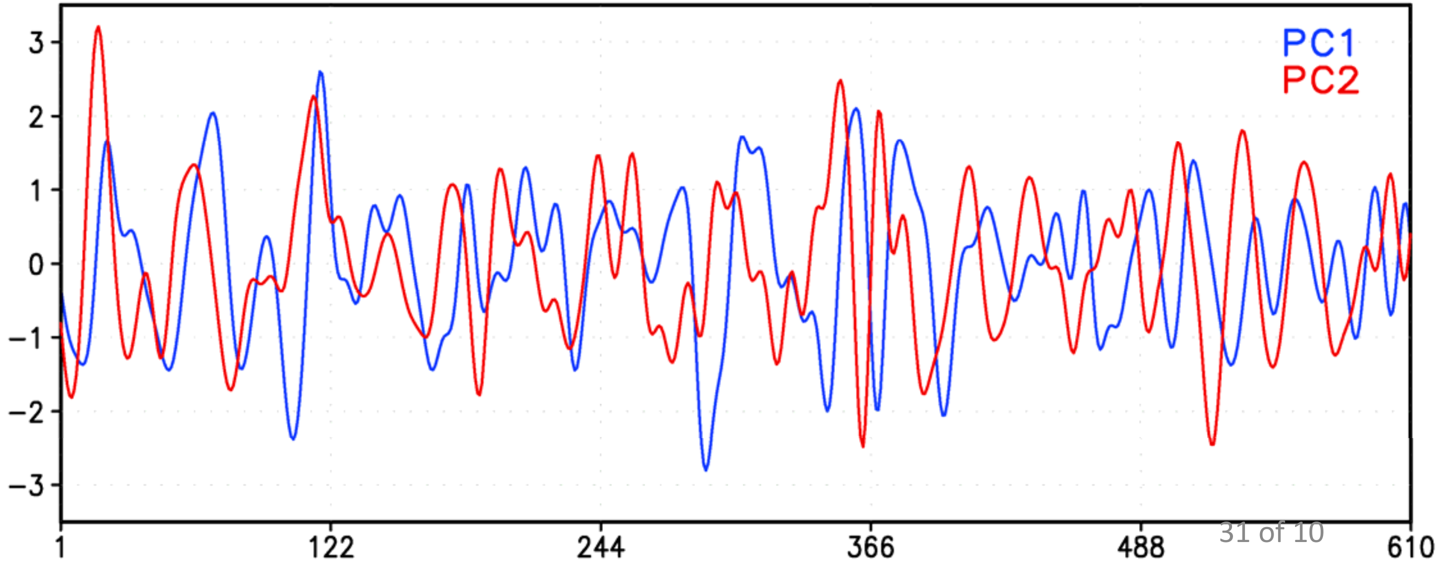
6/6 Extended Range Forecast of ISO

- ***Forecast outlook*** in the range of **15-20** days
- Not attempting to predict weather systems and cyclones

Empirical Extended Range
***Prediction* of Monsoon ISOs**



First two EOFs of CMAP pentad (interpolated to daily) rainfall for JJAS (1979-2001)



Predictors

PC1-4 of 10-90 day filtered CMAP

PC1-2 of Surface Pressure

$$PC^*(t+\tau) = \sum_{i=1}^{N} \beta_i(\tau) PC_i(t)$$

Predictants

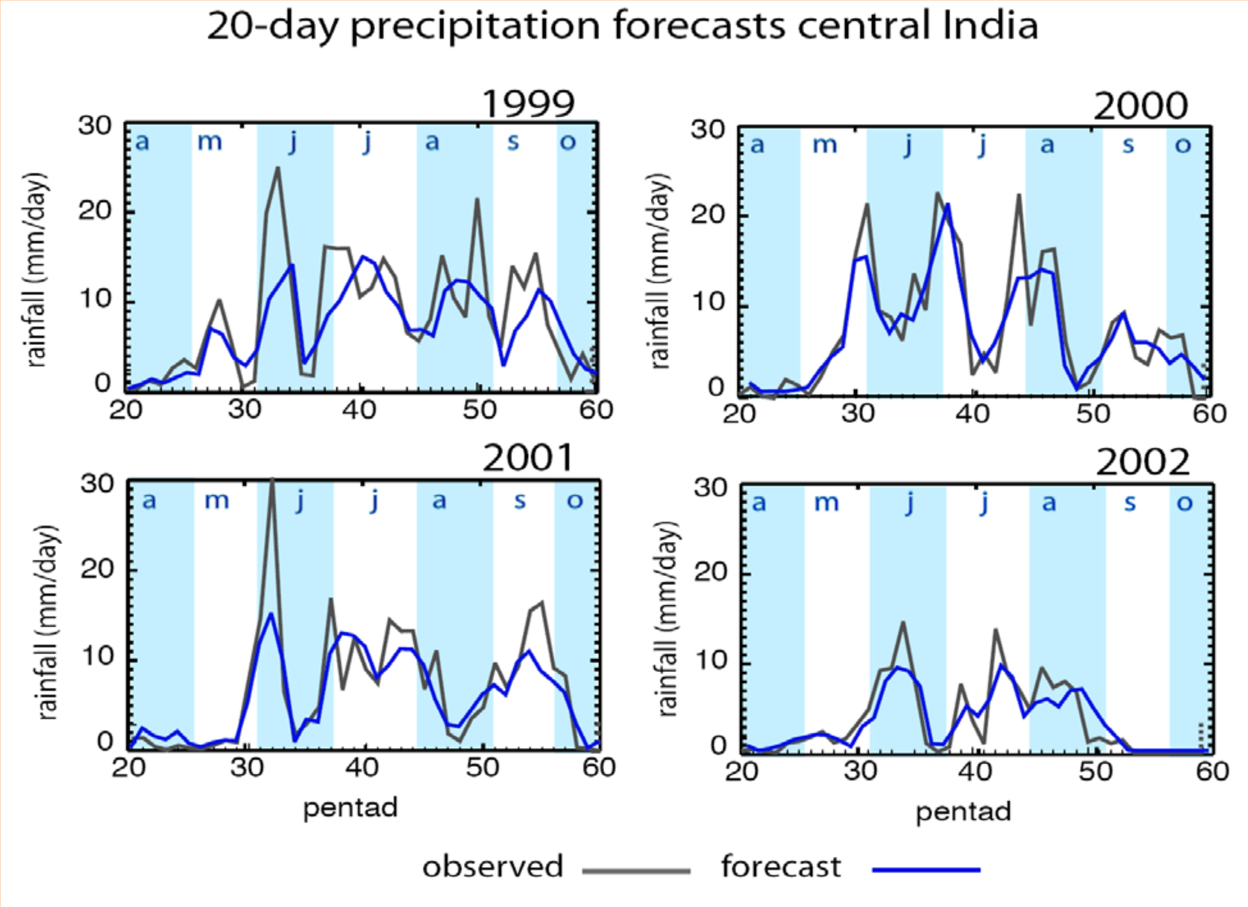
PC1-4 of filtered rainfall

Predicted rainfall at lead time τ

$$P(x,y,t+\tau) = \sum_{i=1}^{4} PC_i^p(t+\tau) E_i^p(x,y)$$

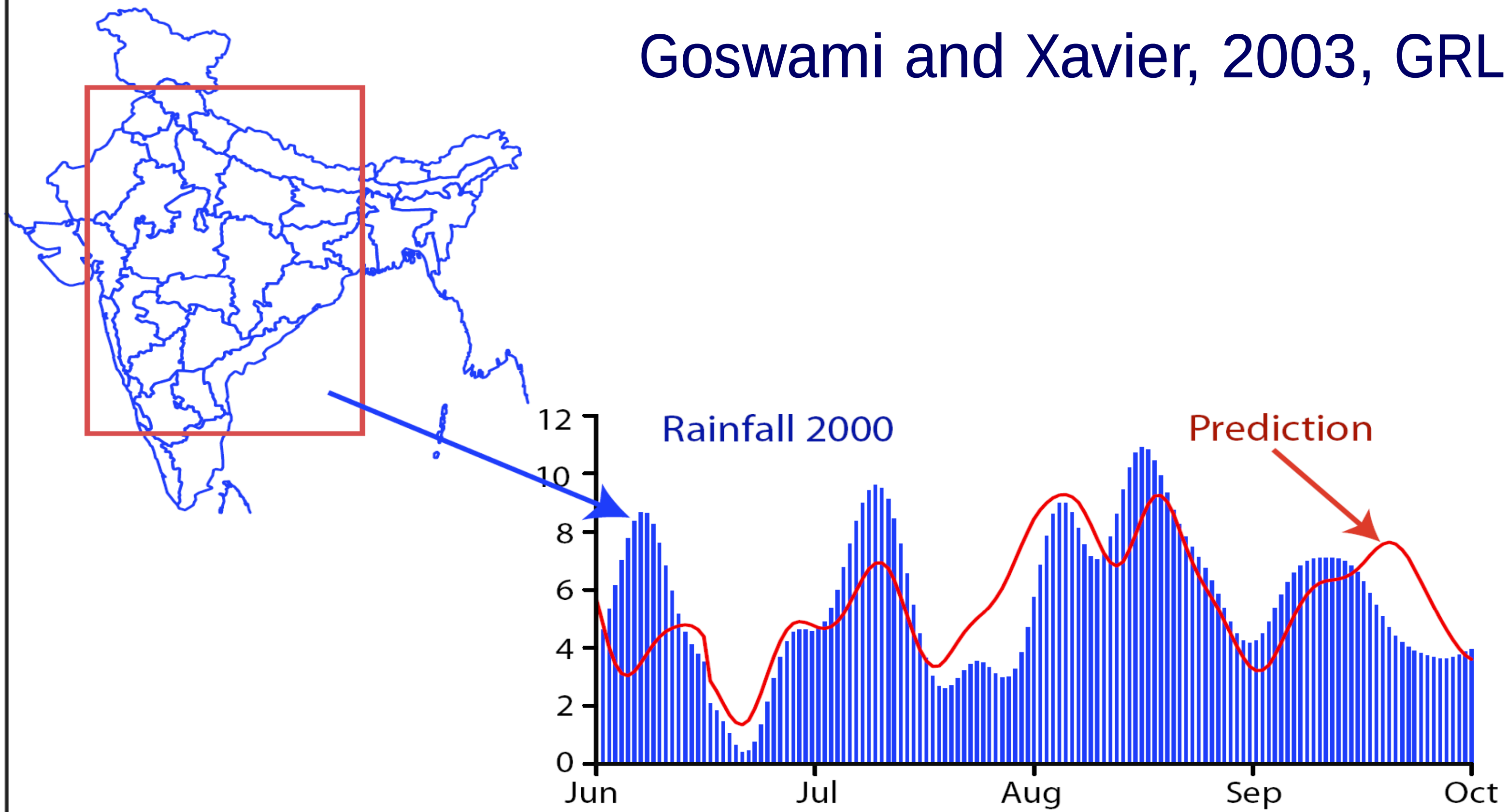
- **EXAMPLE of SOME ISO prediction using linear methods. These methods predict the rainfall ISO cycles**

Webster and Hoyos (2004, BAMS) also show very good skill for predicting ISO phases using a slightly different empirical technique (wavelet banding)



20-day forecast of precipitation over central India for the summers of 1999-2000. Blue lines indicate forecasts while the grey lines indicate verification obtained from area averaged GPI precipitation.

Goswami and Xavier, 2003, GRL



Time series of 18-day predictions (red line) and observations (blue bars) of the rainfall (mm/day) averaged over the monsoon trough region for June to September of (a) year 2000 and (b) year 2001 (Fig.4 of Goswami and Xavier 2003).

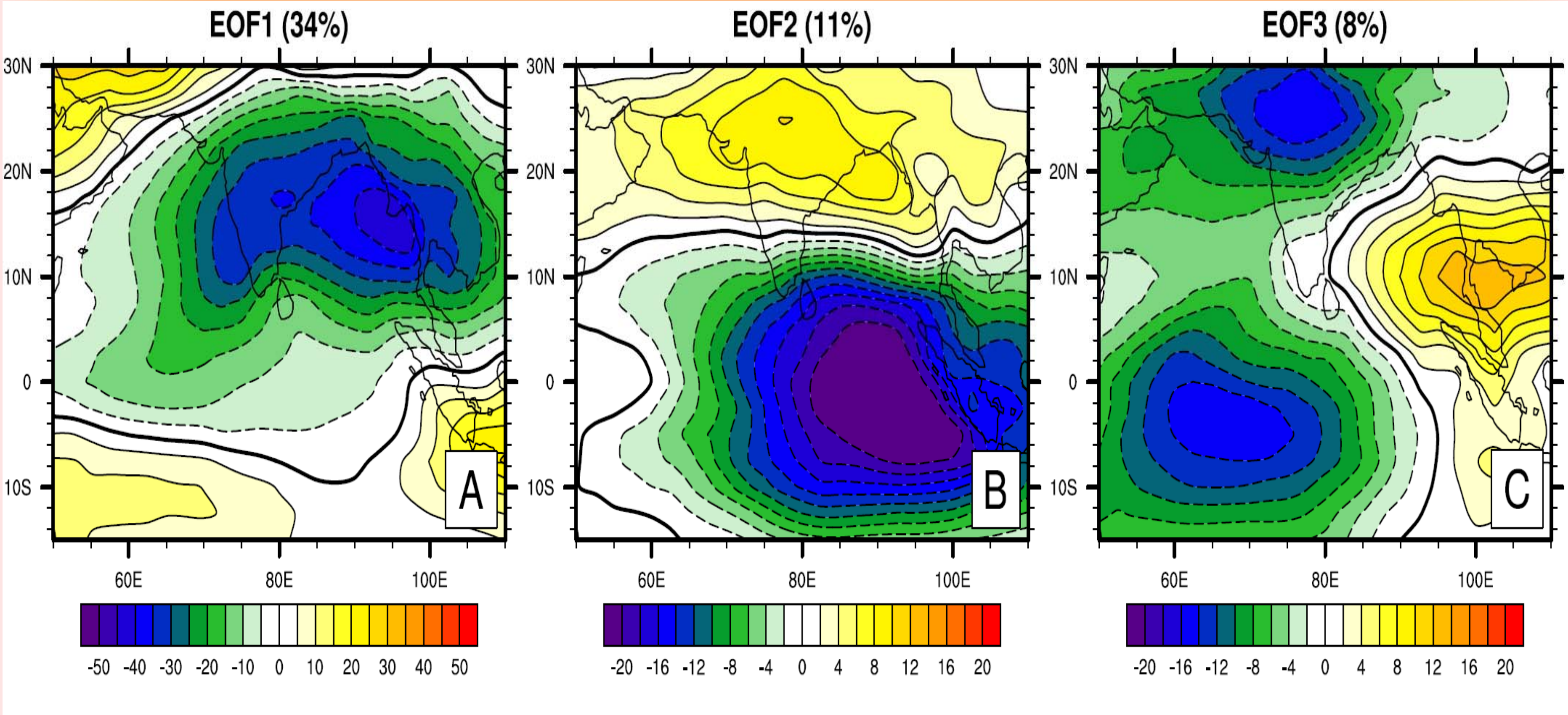
Example of some Non-linear Analogue based forecasting

Method 1. EOF based Analogue

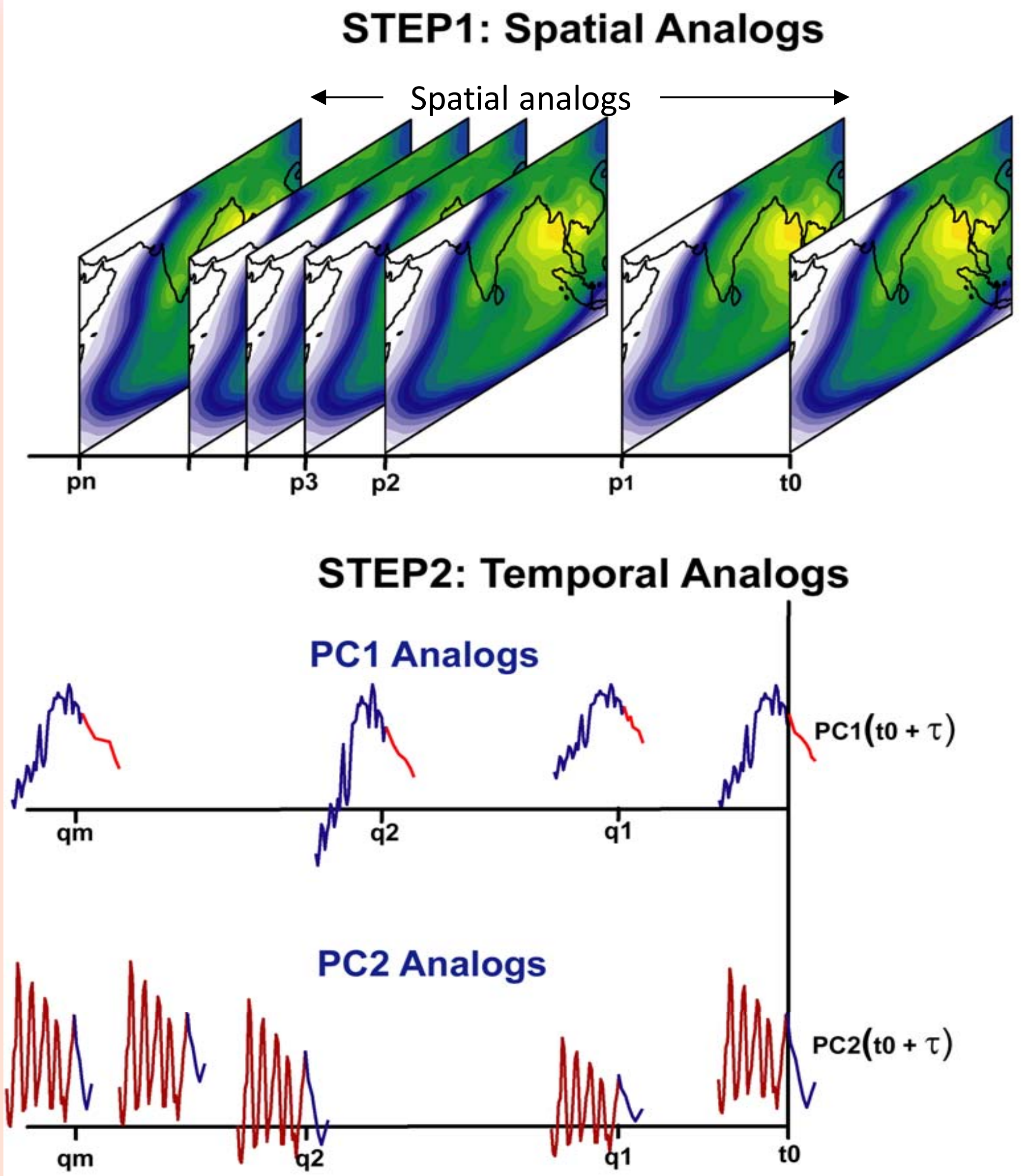
A new Analogue model for Extended Range prediction of the summer Monsoon ISOs useful for real time prediction

(Xavier and Goswami, 2007, MWR , 135, 4149-4160)

- **Data Used and methodology:**
- **Penrad OLR data from 1979 to 2004 are used. No filtering is involved.**
- **To isolate the ISO, OLR anomalies are reconstructed with the first 10 EOFs**
- **First, spatial analogues are identified and then temporal analogues for each PC are found from the cases selected for spatial analogues.**



First three EOFs of pentad OLR



Identify spatial analogues over the entire period (25 years) for the OLR field reconstructed with first 10 EOFs at to

Identify temporal analogues for all 10 PCs going 5 pentads backward from each of the spatial analogues

Prediction → average evolution of the identified temporal analogues

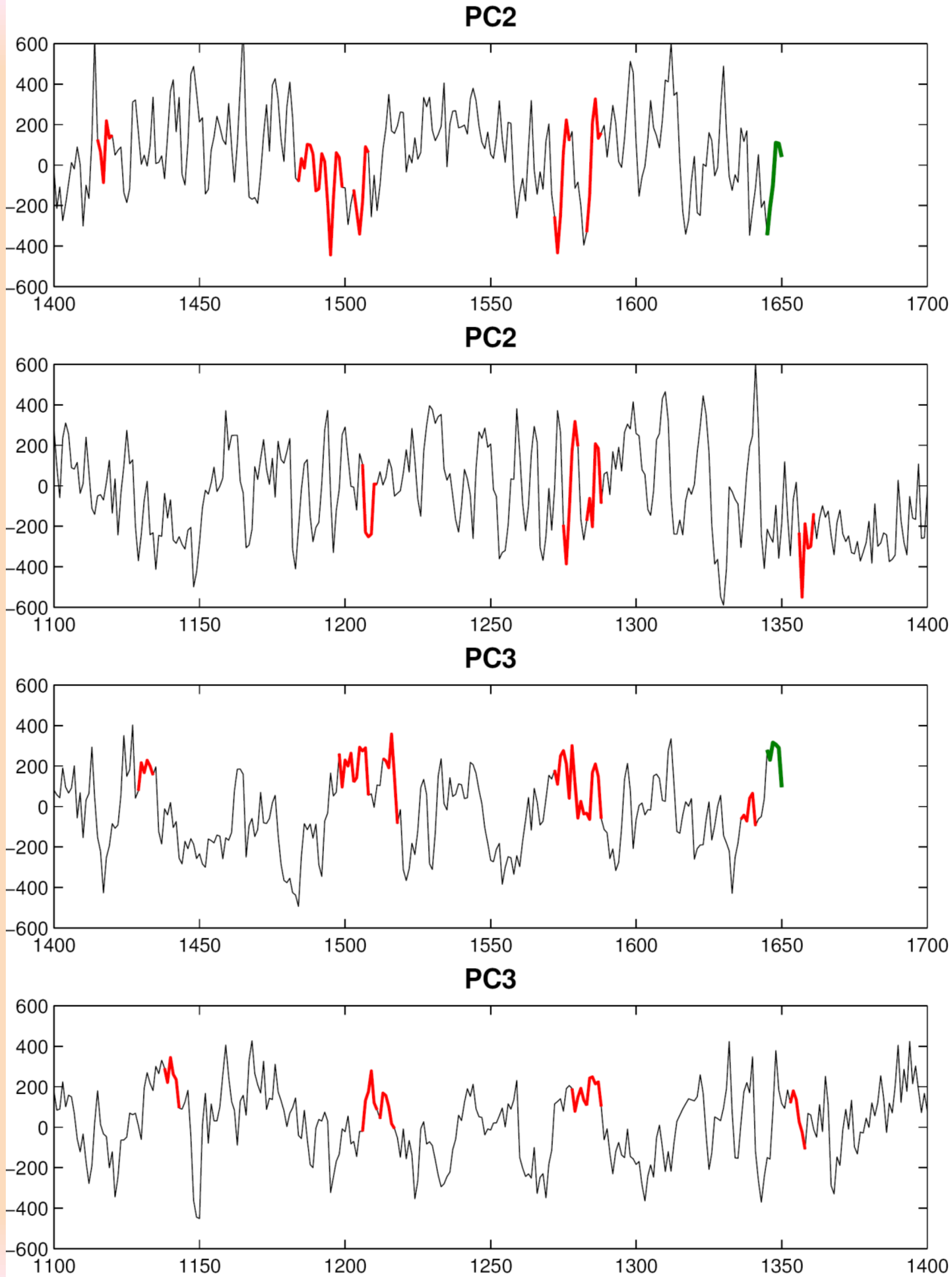


Illustration of a few temporal analogues of PC2 and PC3 for a particular initial condition.

Anomaly hindcasts

- Reconstruct the OLR data with 2-10 EOFs

  (removes the seasonal cycle)

- Look for spatial and temporal analogues as before

- Make predictions based on average evolution of these analogues

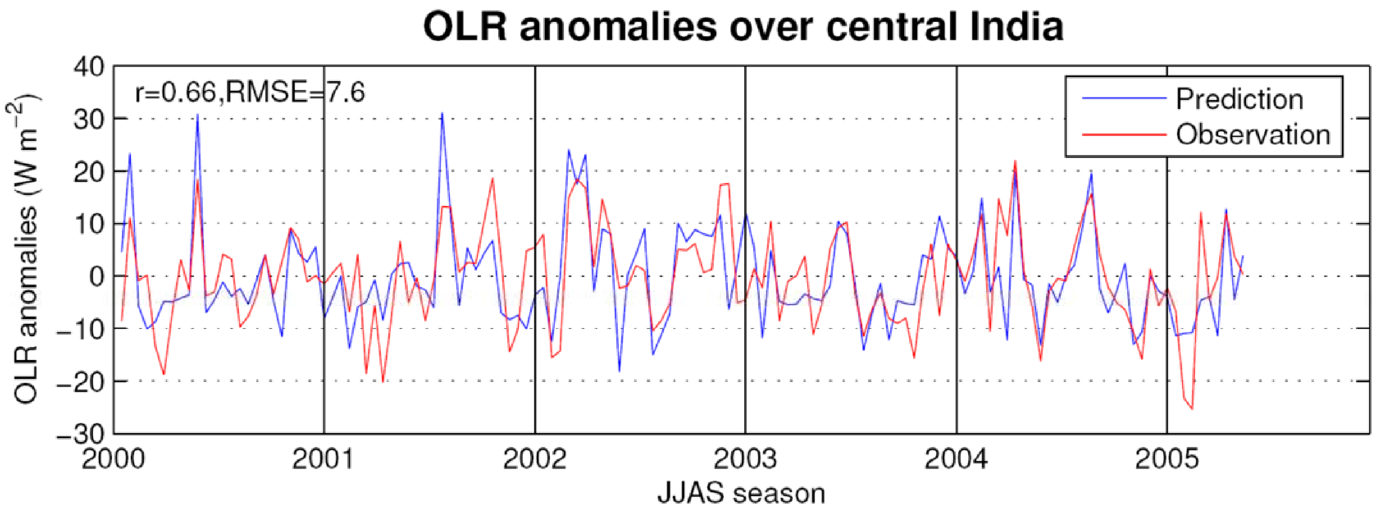


FIGURE 6.11: Prediction of OLR anomalies (W m^{-2}) at 4 pentad lead in comparison with observed values over the region 75°-95°E, 20°-25°N for the JJAS season of the hindcast period.

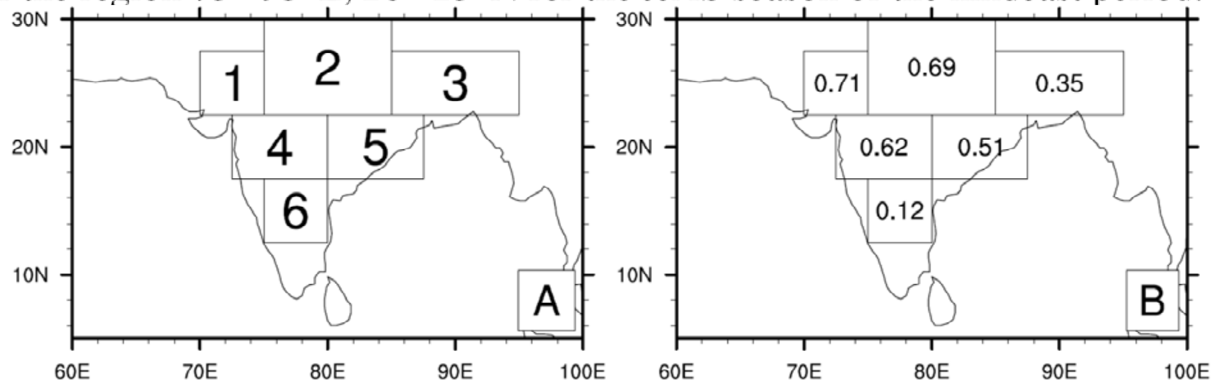


FIGURE 6.13: Regions chosen to evaluate the predictions with observations (A). The correlation coefficient between 4 pentad lead predictions and observations averaged over these regions for the May-October period (B).

Dependency of the forecasts on the state of initial condition

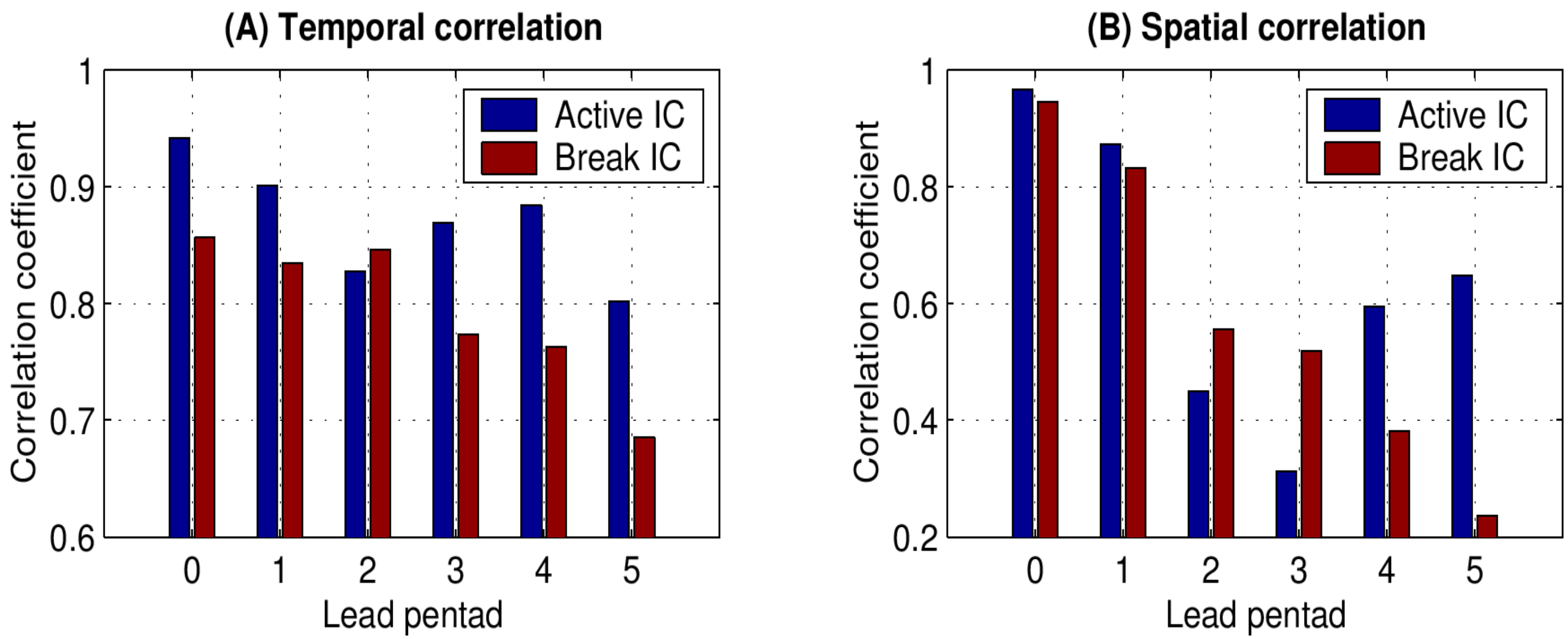


FIGURE 7.14: Temporal and spatial correlations between predictions and observations from active and break initial conditions at different lead times.

- **Method 2: A Non-linear Analogue**

The Intraseasonal Prediction of Monsoon using Self Organizing Map

(based on following Hypothesis:)

Monsoon Intraseasonal oscillations are convectively coupled Oscillations with complex (but fixed) phase relationship of rainfall with circulation (large scale) parameters.

Such Complex phase relationship leads to the event to event variability of monsoon ISO phases

- **In order to bring out such phase relationship of rainfall with circulation, teleconnections of rainfall ISO to the large scale dynamics is to be known (or established) a priori.**
- **However, many such teleconnections has been already been established on seasonal scale as depicted through large scale indices.**

Some examples are:

Webster Yang index, Wang and Fan index, Goswami et al., defined index

- If the convectively coupled hypothesis is valid, and there is a standard active and break pattern, the commonality among the teleconnection will be reflected in these rainfall patterns.
- Spatio-temporal evolution of these patterns of rainfall will be reflected in the spatio temporal evolution of the circulation indices which basically depicts the teleconnection…
- To get an idea of the commonality amongst a large number of dynamical parameters and whether such commonality is reflected in the rainfall we will use a pattern recognition technique known as Self Organizing Map

The SOM Algorithm

- The SOM consists of a (usually) one or two dimensional array of identical neurons. The input vector is broadcast in parallel to all these neurons.

- For each input vector, the most responsive neuron is located. The weights of this neuron and those within a neighborhood around it are adapted to reduce the distance between its weight vector and the current input vector.

THE SOM NETWORK

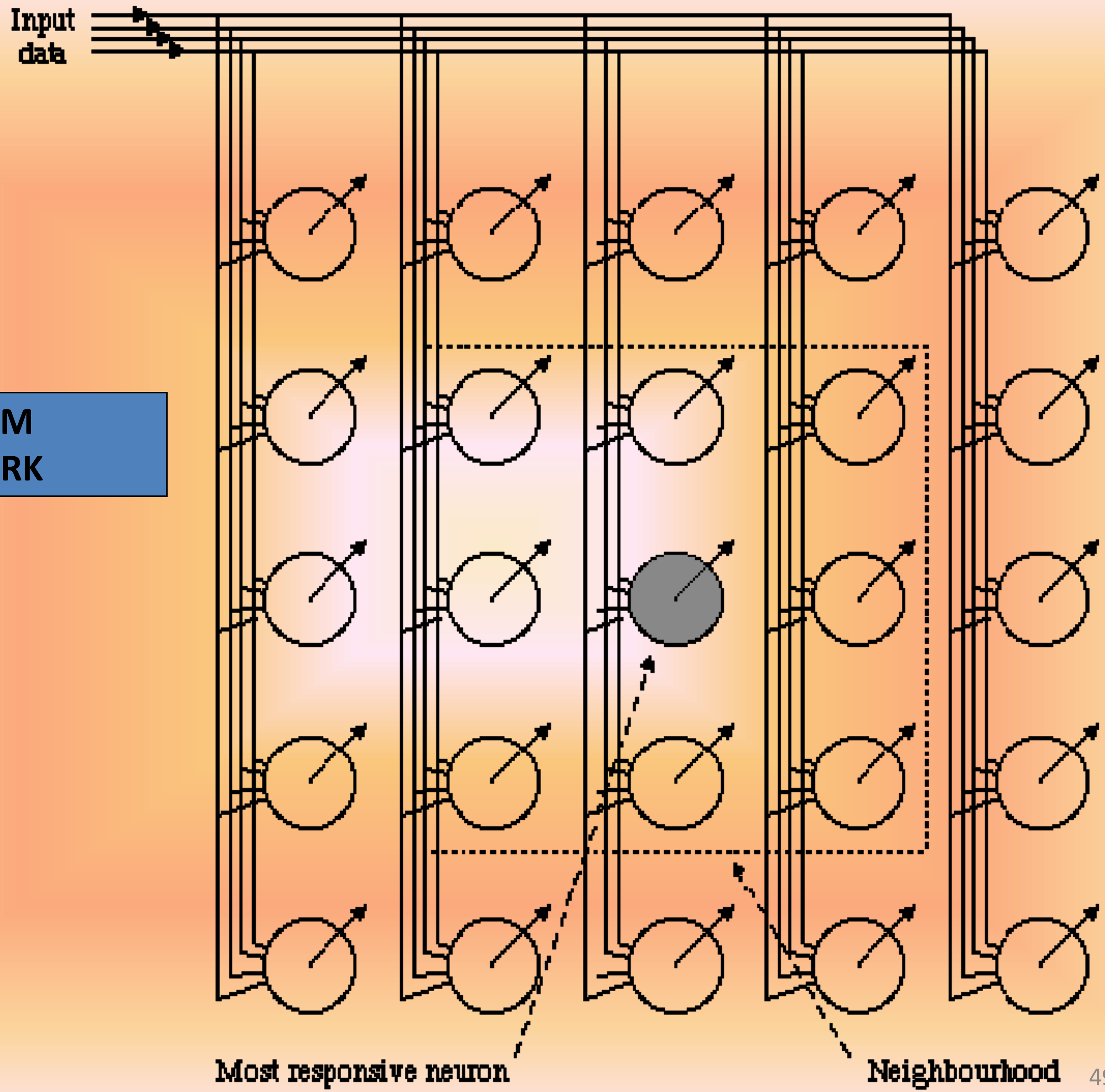


Table showing the indices used in this study.

DATA source:
NCEP, ERA and IMD

The last 3 indices used for creating another SOM model

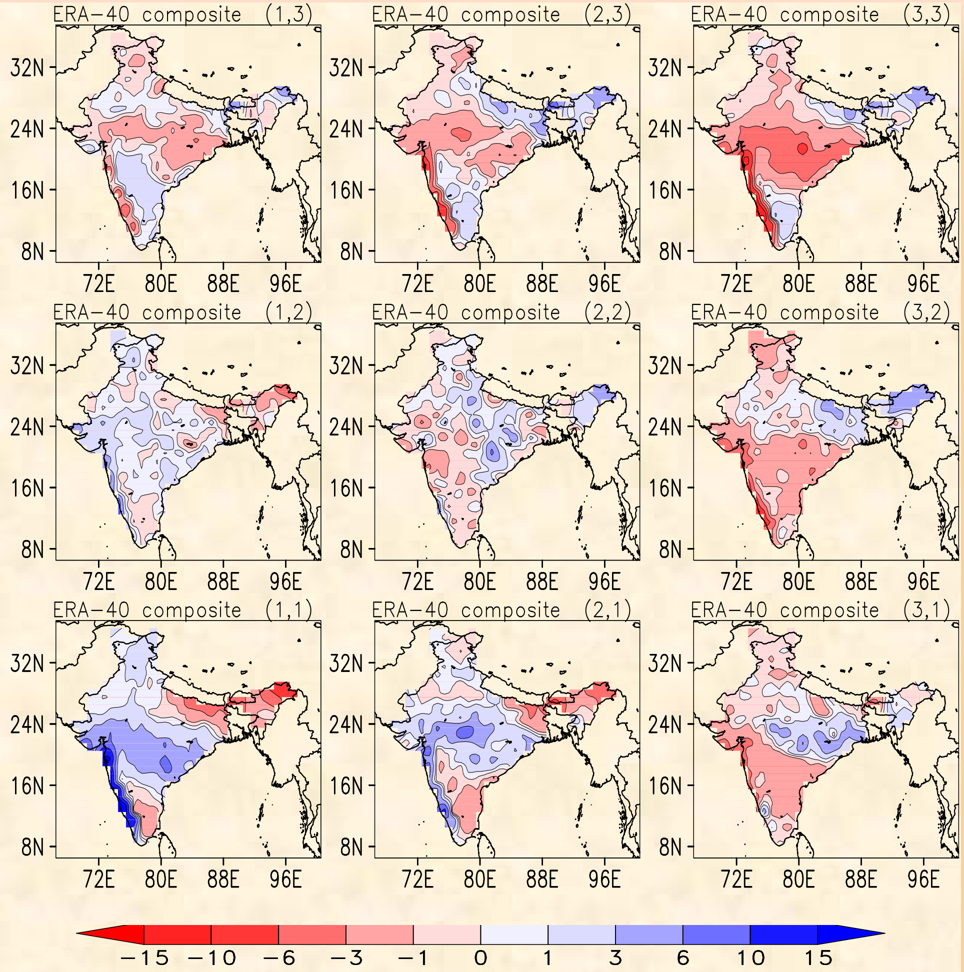
1	**Precipitation Index (PR index):** (70^0E-85^0E, 15^0N-25^0N)
2	**Goswami et al. Index (GO index):** **[V850(70^0E-110^0E,10^0S-30^0N) – V200(70^0-110^0E,10^0S-30^0N)]**
3	**Wang and Fang Index (WF index):** **[U850(40^0 E -80^0E,5^0N-15^0N) - U850(60^0-90^0E,20^0-30^0N)]**
4	**Webster and Yang Index (WY index):** **[U850(40^0E-110^0E,0^0-20^0N) – U200(40^0-110^0E,0^0-20^0N)]** **[U850(40^0-110^0E,0^0-20^0N) – U200(40^0-110^0E,0^0-20^0N)]**
5	**Mean sea level pressure index (MS index):** **msl(65^0E-95^0E,15^0N-25^0N)**
6	**Specific humidity (850mb) index (SH index):** **Sph850(65^0E-95^0E,15^0N-25^0N)**
7	**Geopotential Height (500mb) index (GP index):** **Gph500(65^0E-95^0E,10^0N-20^0N)**
8	**U-shear index:** **[U850(100^0E-140^0E,15^0S-5^0N)-U200(100E-140E,15s-5N)]**
9	**Omega (vertical velocity at 500 mb) index:** **w500(50^0E-115^0E,0^0N-7.5^0N)-w500(80^0E-150^0E,10^0N-20^0N)**
10	**Mean Sea level Pressure shear Index:** **msl(110^0E-150^0E,10^0N-20^0N)-msl(40^0E-60^0E,15^0S-5^0N)**

The SOM Classification of Rainfall using ERA-40 data.

Plotted are the IMD rainfall anomalies.

Anticlockwise direction From any node will show North-Prop

Break Node



Active Node

- The Above Figure shows that SOM algorithm can effectively isolate out the ISO phase propagation and its spatial structure based on large scale information
- This information may be used to predict the ISO

Prediction using the Self Organizing Map:

Basically this is an analog method of prediction

Here we present a scheme for prediction of rainfall over central India (15°N-25°N, 70°E-85°E) 4 pentads in advance.

a. Prediction using SOM model-1 (6 dynamical parameters and past 9day information):

Principle:

The SOM classification on the training period extracts 15X15 patterns and their evolutionary history and stores them in the 'reference' vectors. Time histories of the patterns are saved in the dates clustered at each node. For prediction from a given date, a 'forecast' vector is created with current and past data for 9 days for all the large scale variables. This essentially contains the pattern and its evolutionary history at the initial time. If we could find an analogue of this pattern and its evolution in the past from the 'reference' vectors corresponding to different nodes, we could make a 4 pentad prediction from the evolutionary history of the analogue.

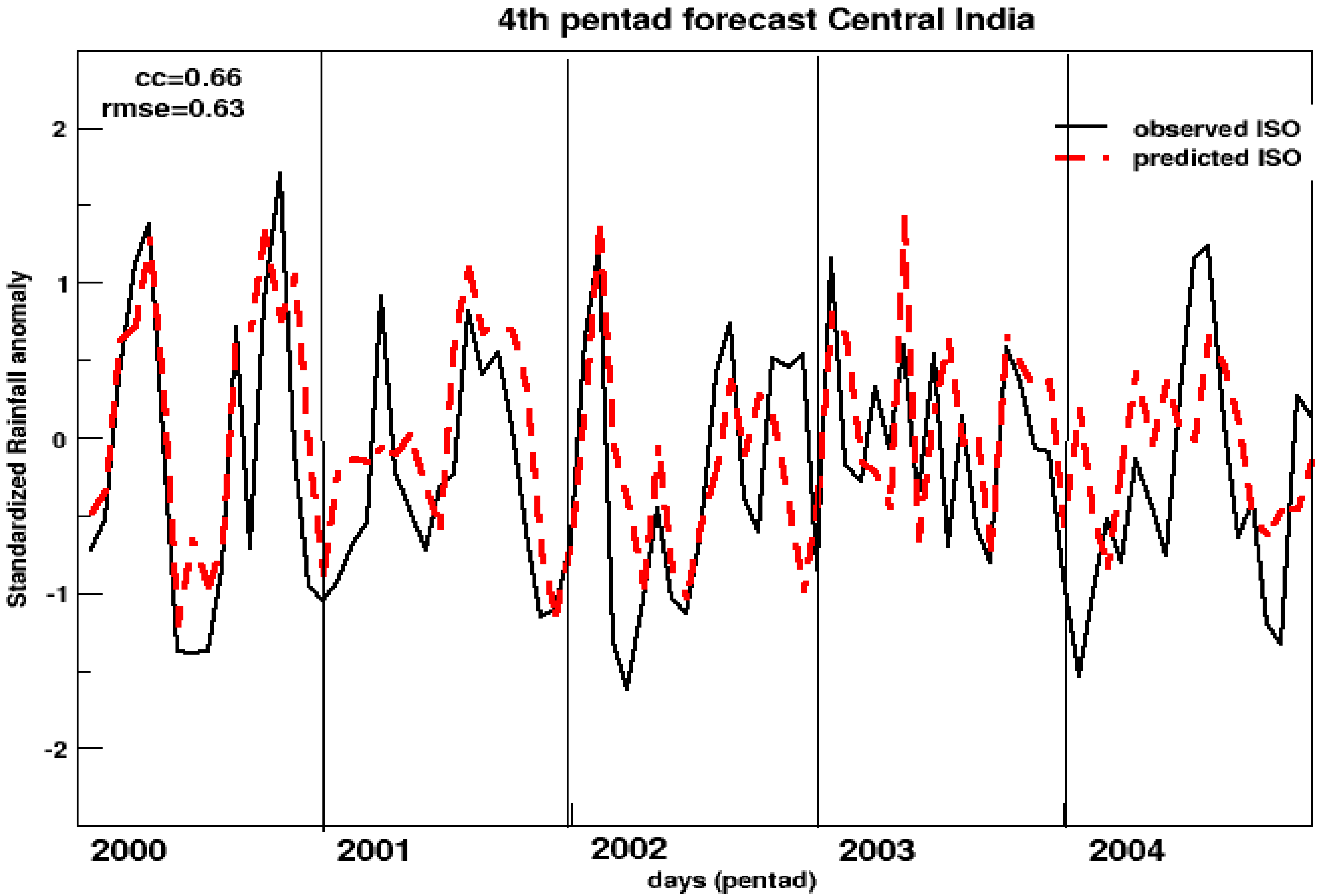
“forecast” vectors are constructed for the starting day of forecast and for the past 9 days using the same 6 large scale dynamical parameters. The Euclidian distance between the forecast vector and that of the reference vector attached to each of 15X15 nodes are calculated. The node for which this difference (distance) is least is considered as the true analogue of the forecast vector of that particular day.

Implementation:

1. **Identification of various shades: spatial shades and temporal shades**

2. **Deciding the order of classification i.e. no. of nodes. (used 15x15)**

3. **Calculating the reference vector.**


4th pentad forecast Central India
cc=0.66
rmse=0.63
observed ISO
predicted ISO
Standardized Rainfall anomaly
2
1
0
-1
-2
2000
2001
2002
2003
2004
days (pentad)

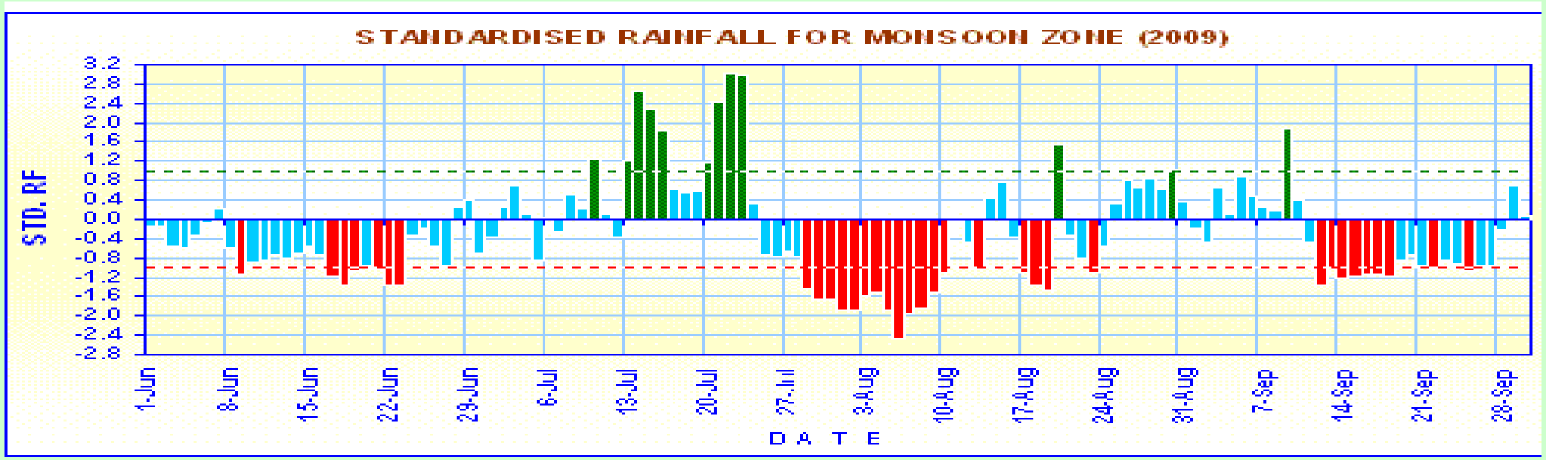
Probabilistic Forecasting Using SOM

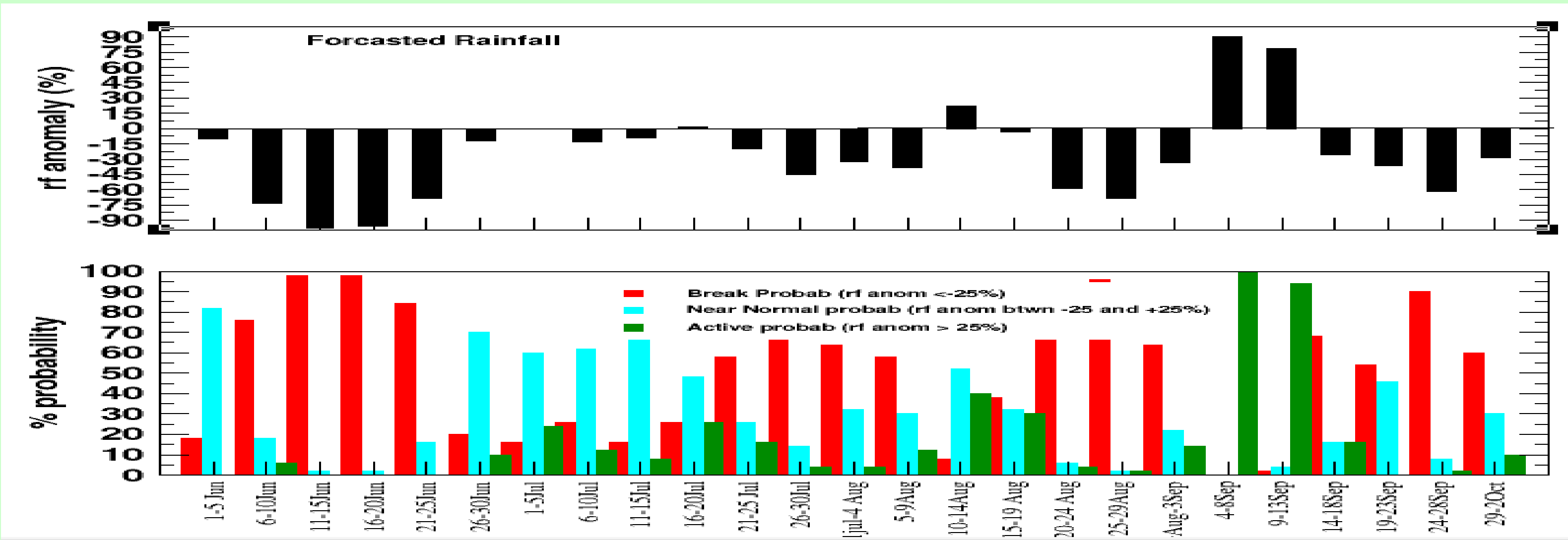
The SOM algorithm may be used to generate probabilistic ISO forecast through realization of Multi-Model ensemble

- **Some REAL time application for the year 2009**:

Predicted the June drought 4th Pentad in advance

Current IMD Probabilistic ISO prediction





From 2013 we have started giving extended range forecast outlook based on dynamical model (NCEP-CFSv2):

http://www.tropmet.res.in/erpas/

Sincere Thanks to

- **Prof. B.N. Goswami**
- **Dr A Suryachandra Rao**
- **Dr. A.K. Sahai**
- **Nabanita Borah**

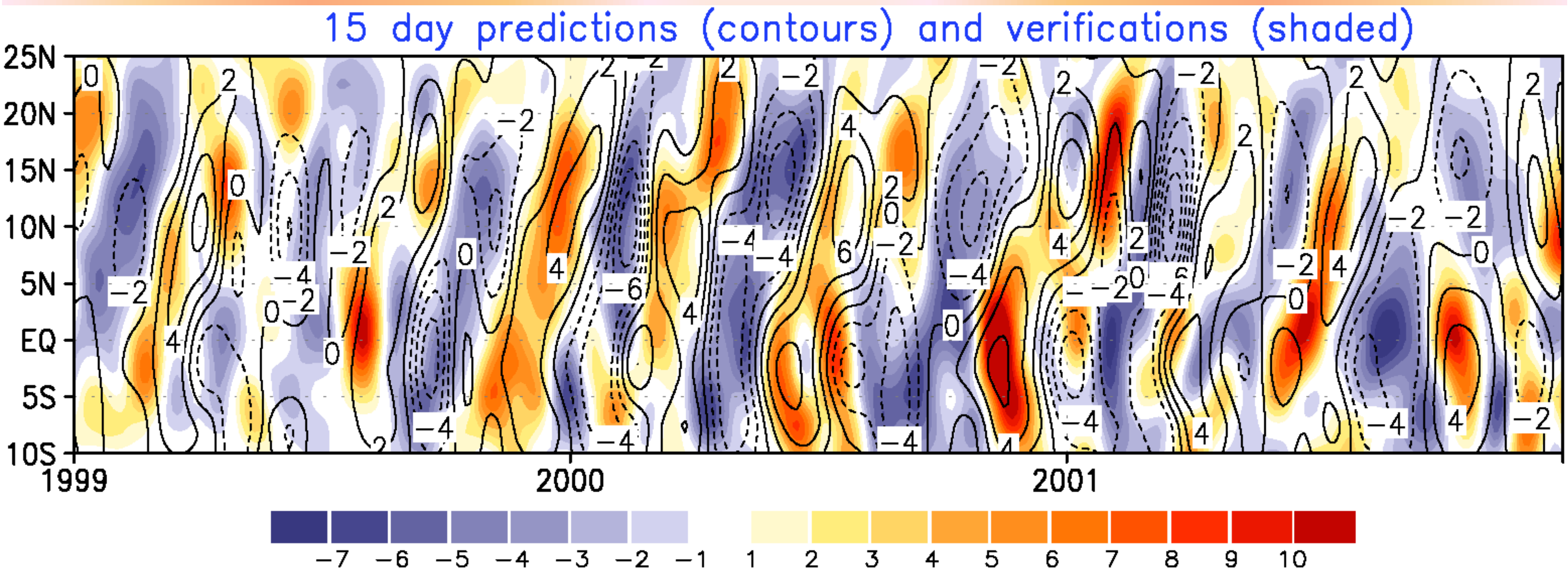
- **Organizers of this Conference**

Add On Slides

Model developed on 1 June-30 Sept. data for 1979-1995

Model is tested on independent data for 1996-2001

15-day predictions and verifications of rain anoms ave(70E-90E)



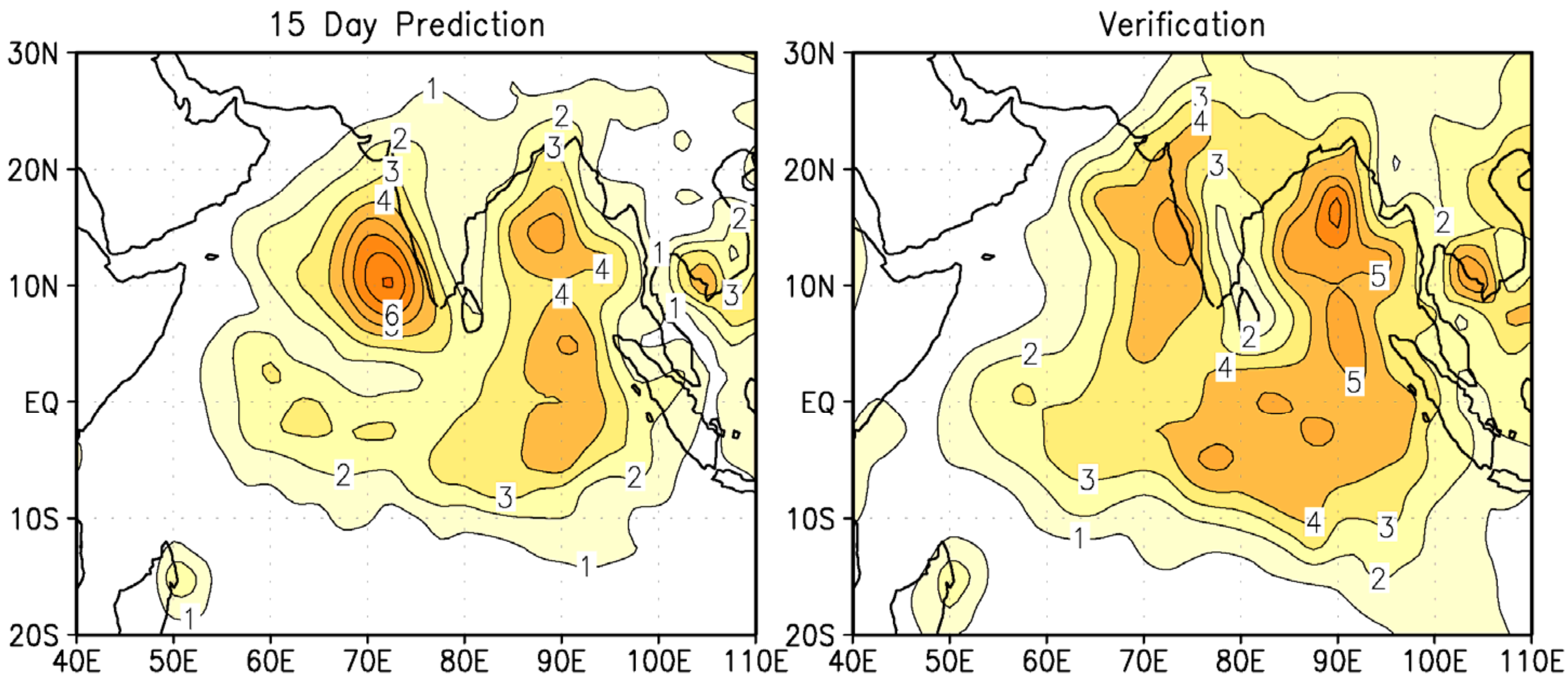
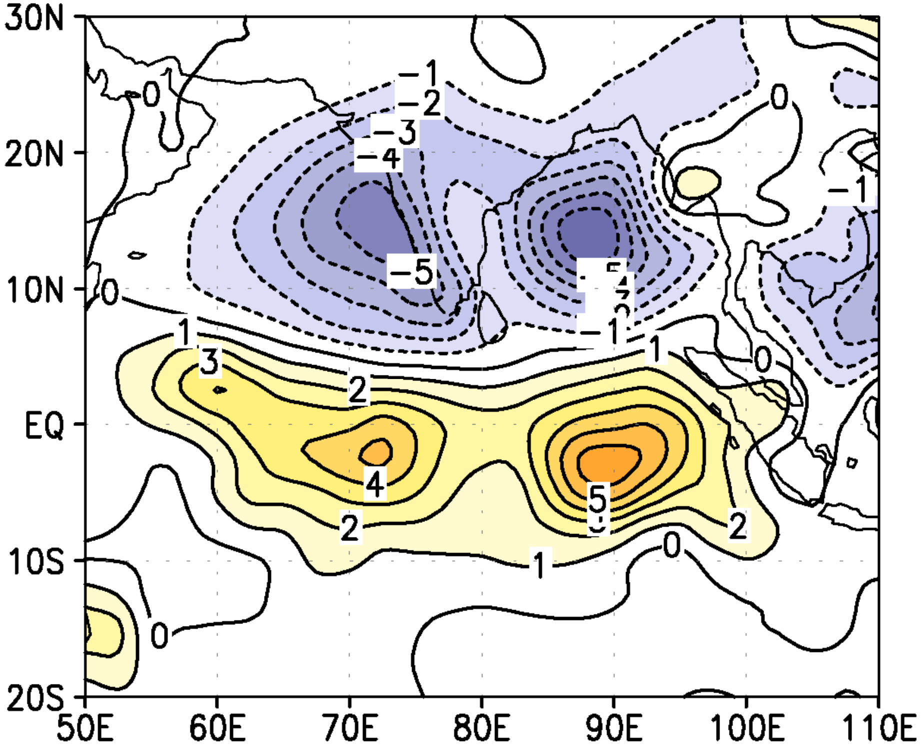
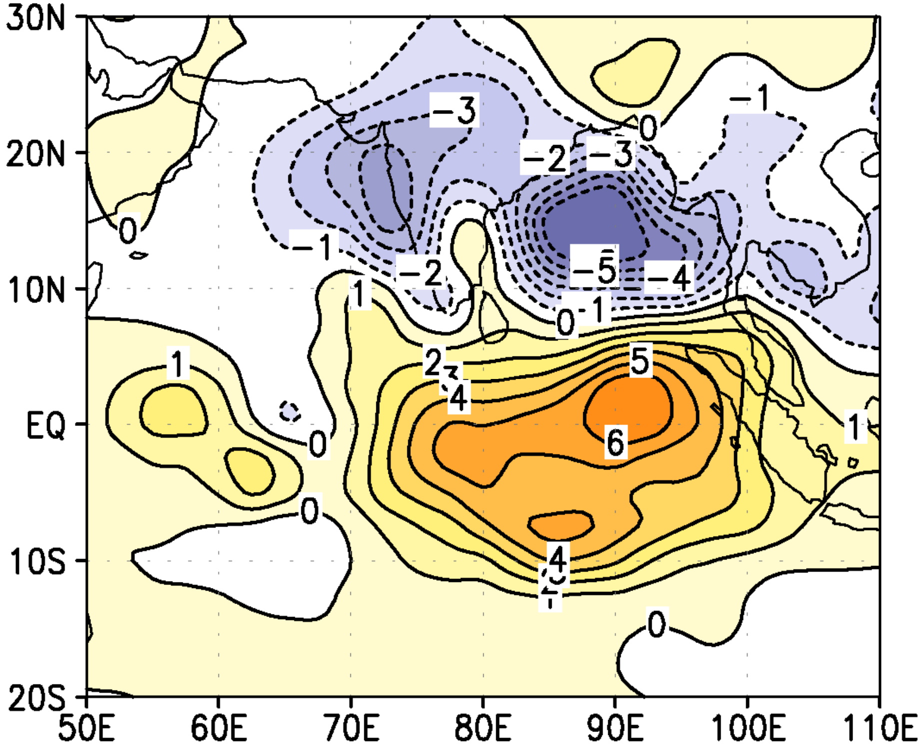


Figure 4.6: The Standard deviation of all 15 day predictions and verifications at all grid points.

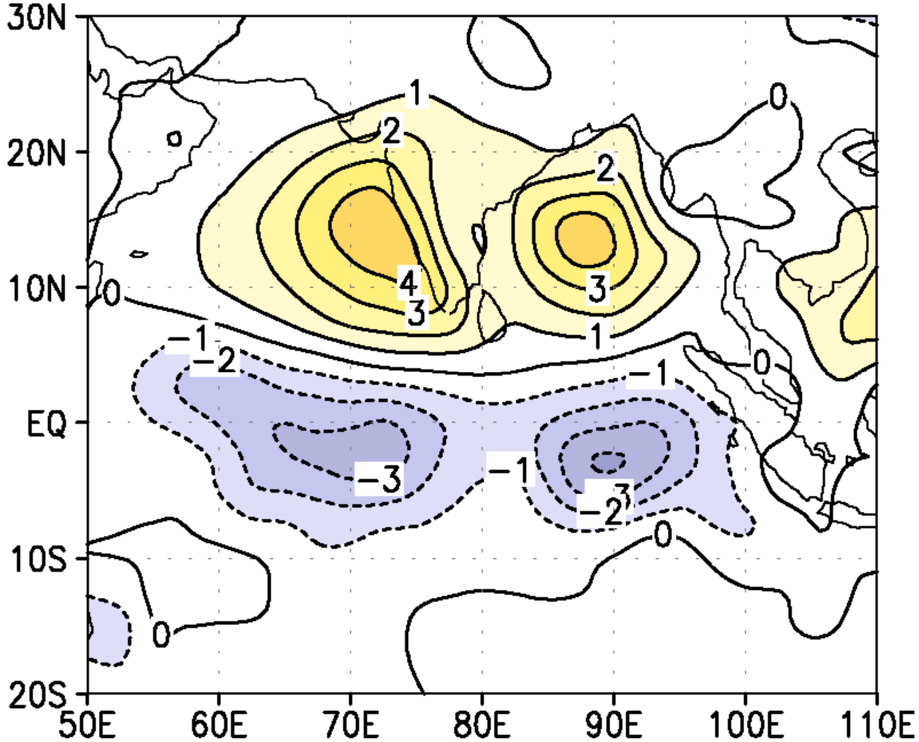


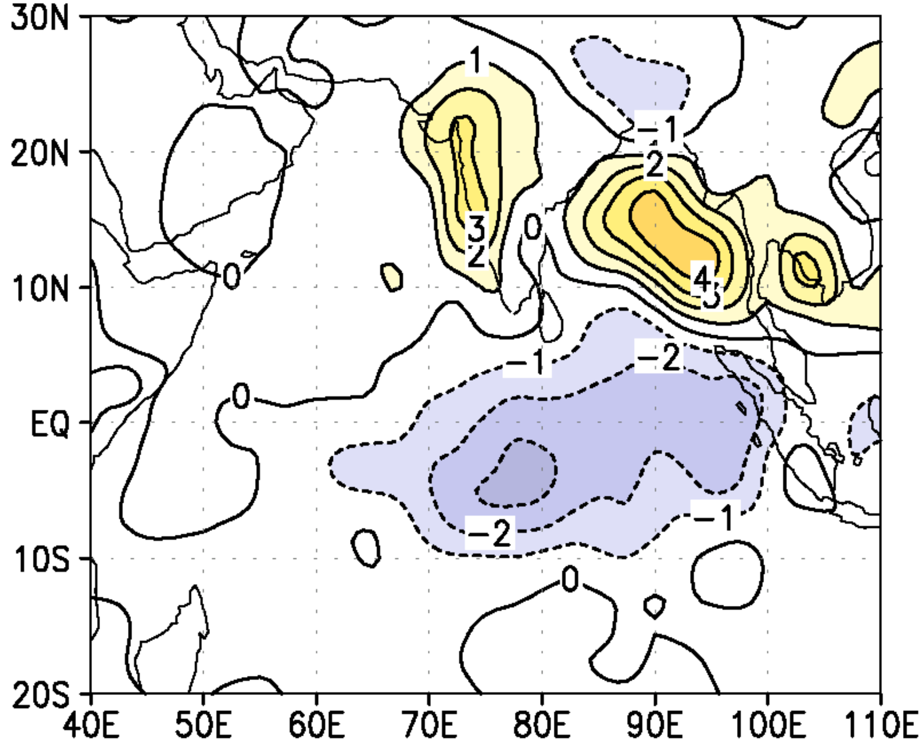
Mean of 18-day predictions of breaks (mm/day)



Mean of 57 verifications of the 18-day predictions from CMAP (mm/day)

(Mean of an ensemble of 57 such predictions starting from initial conditions around active conditions)

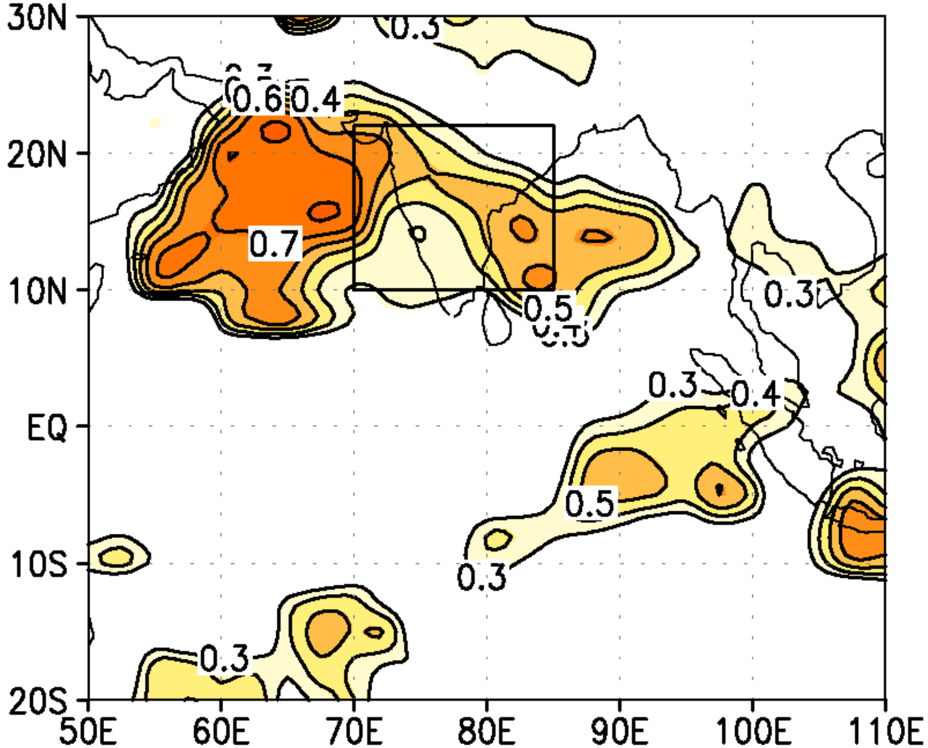


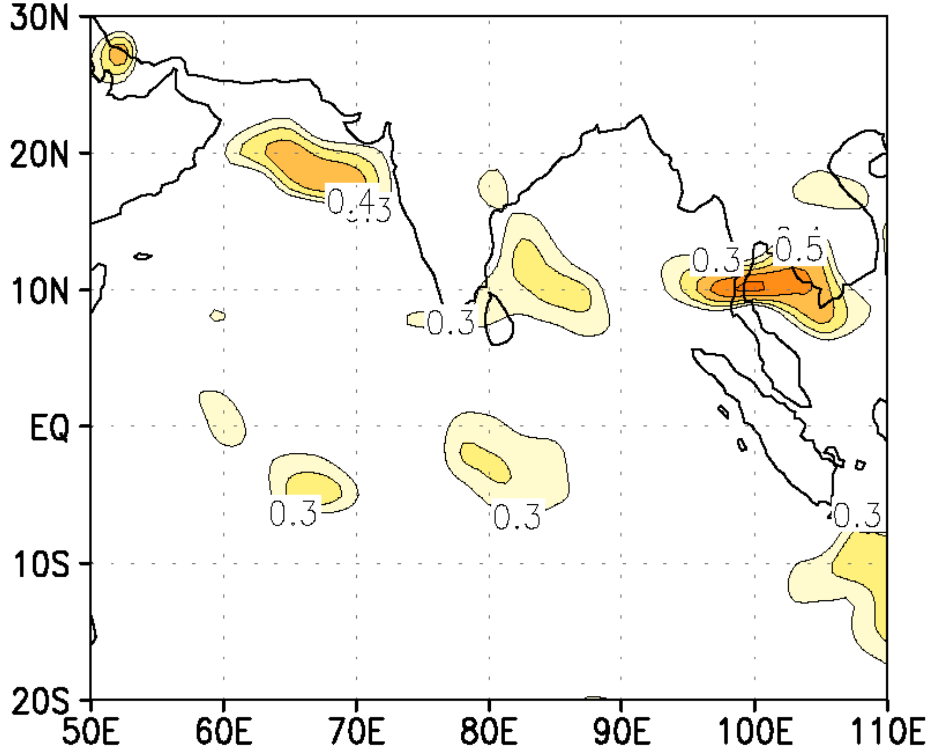


Mean of 18-day predictions of Active conditions (mm/day)

Mean of an ensemble of 54 such predictions starting from initial conditions around active conditions

Mean of 54 verifications of the 18-day predictions from CMAP (mm/day)



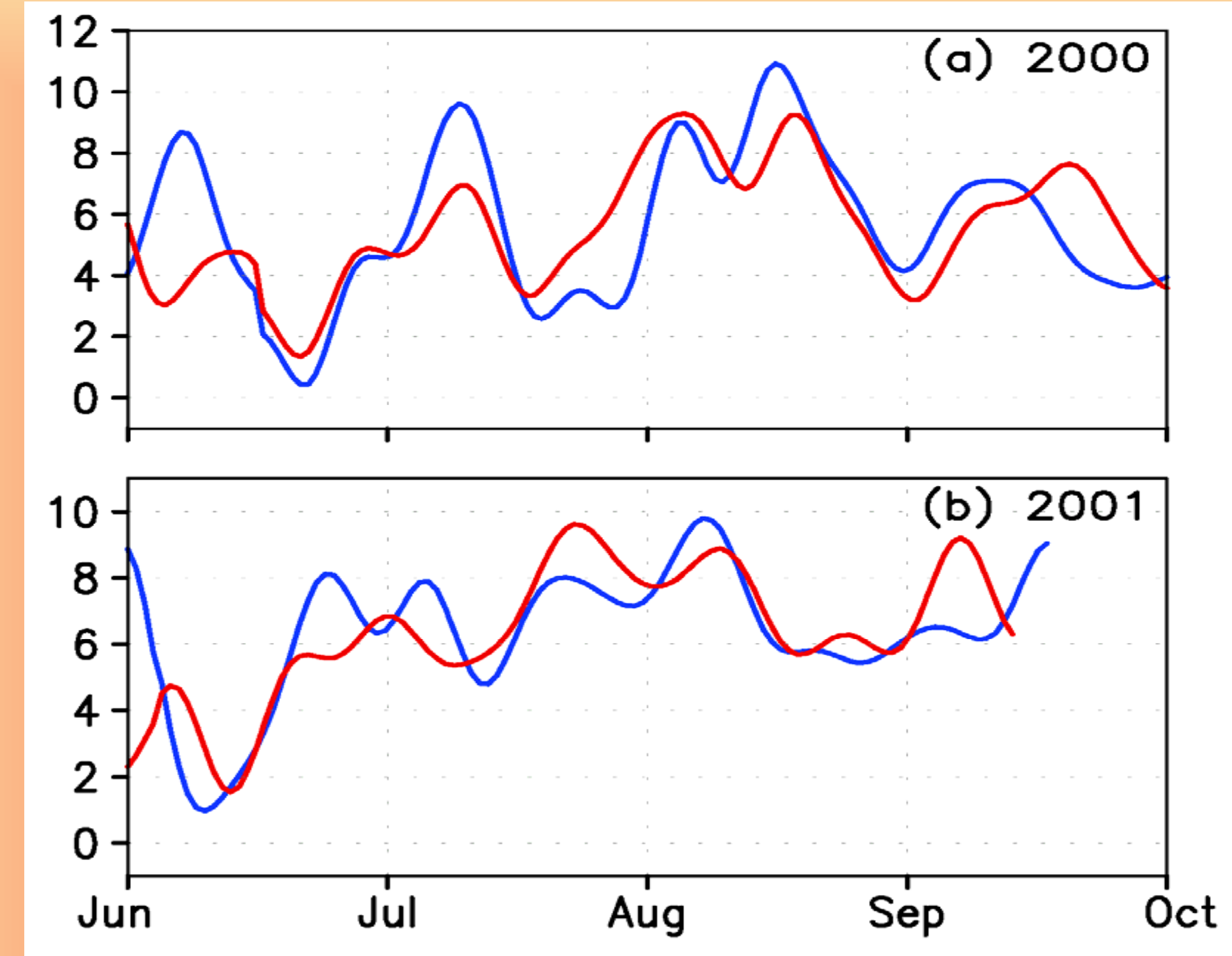


Correlation between 18-day predictions of breaks starting from active conditions with corresponding verifications (n=57).

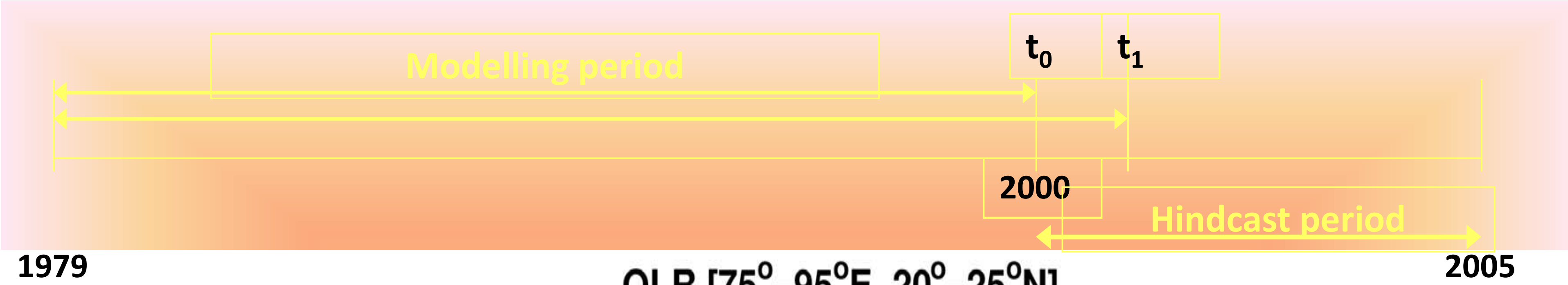
Correlation between 18-day predictions of active conditions starting from break conditions with corresponding verifications (n=54)

Lead Time	Prediction of Breaks	Prediction of Active
15 days	0.65**	0.38*
18 days	0.56**	0.43*

Correlations between predictions and observations of rainfall averaged over the monsoon trough region (70E-85E, 10N-22N)



18-day predictions of rainfall over the monsoon trough (red) together with actual observations (blue) for the period June 1-Sept. 30, of 2000 and 2001.



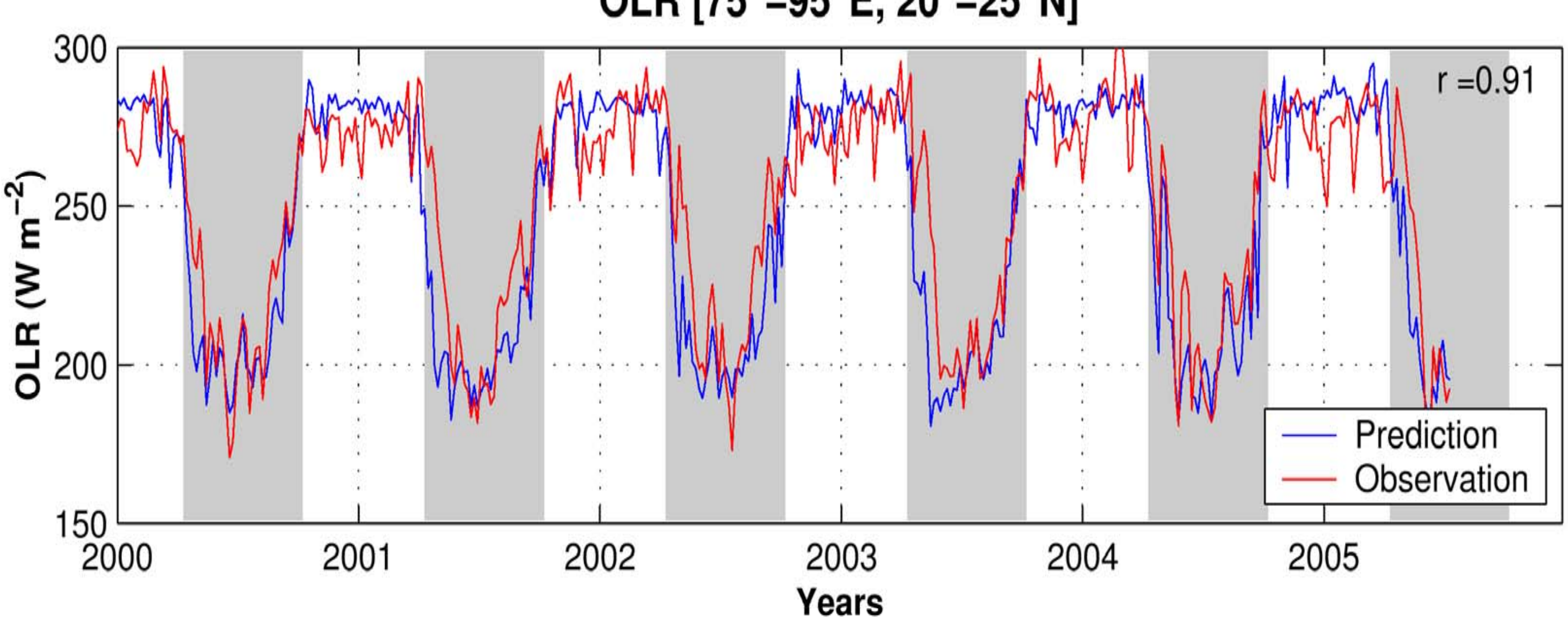


FIGURE 7.8: 4 pentads lead predictions and observations over central India during the hindcast period. Grey shades indicate the summer monsoon season. Correlation coefficient between the two is also shown.