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# The composite structure of synoptic systems and it's connection with active/break phases of monsoon

RAVINDRAN Ajaya Mohan

*Canadian Centre For Climate Modeling & Analysis*
*Meteorological Service of Canada - University of Victoria*
*P.O.Box 1700*
*British Colombia, V8W 2Y2 Victoria*
*CANADA*

# The composite structure of synoptic systems and its connection with active/break phases of monsoon

**Ajayamohan Ravindran**

Canadian Center for Climate Modelling and Analysis

Victoria, Canada

**V . Krishnamurthy, COLA, USA; B.N Goswami, IITM, India,**

**W. J. Merryfield and S. Kharin, CCCma, Canada**

# Outline

- LPS and its characteristics
- Revisiting BSISO characteristics
- Index of BSISO and clustering of LPS
- LPS composites and its connection with BSISO
- Recent trends in LPS data, a cause of concern ??
- Summary and some outstanding issues

# LPS Characteristics

- Synoptic scale systems (also called as Low Pressure Systems or LPS) forms periodically over the quasi-stationary monsoon trough.
- Considered as main rain-bearing systems; brings in copious rain in central India.
- Life cycle of ~3-6 days and length scales of the order of 1000 kms.
- Typically forms over the head Bay of Bengal and moves inward.
- Few systems forms over the Arabian Sea and over Land.
- Do not grow to become hurricanes during monsoon !!

# LPS Characteristics

## Dynamics and formation:

- Some form in situ, others can be related to weak pressure waves from east
- Early stage: Barotropic dynamics play a significant role
- Later stage: Baroclinic and CISK dynamics in which energy supplied by latent heat released from convection becomes major energy source

## Not growing as hurricanes:

- Short sea travel before land fall and large easterly wind shear restricting proper organization of deep cumulus convection

## Why WNW direction?

- Cyclonic vorticity associated with initial instability organizes convection and latent heat associated with it results in tropospheric heating
- Response of isolated heating around 20N is mainly in the form of Rossby-gravity wave to the west of the heat source (Gill, 1980)
- This produces strong cyclonic low-level vorticity maximum in the WNW sector of disturbance.
- Due to strong cyclonic vorticity + Rossby-gravity wave to the west of the heat source, convergence of moisture shifts to WNW sector

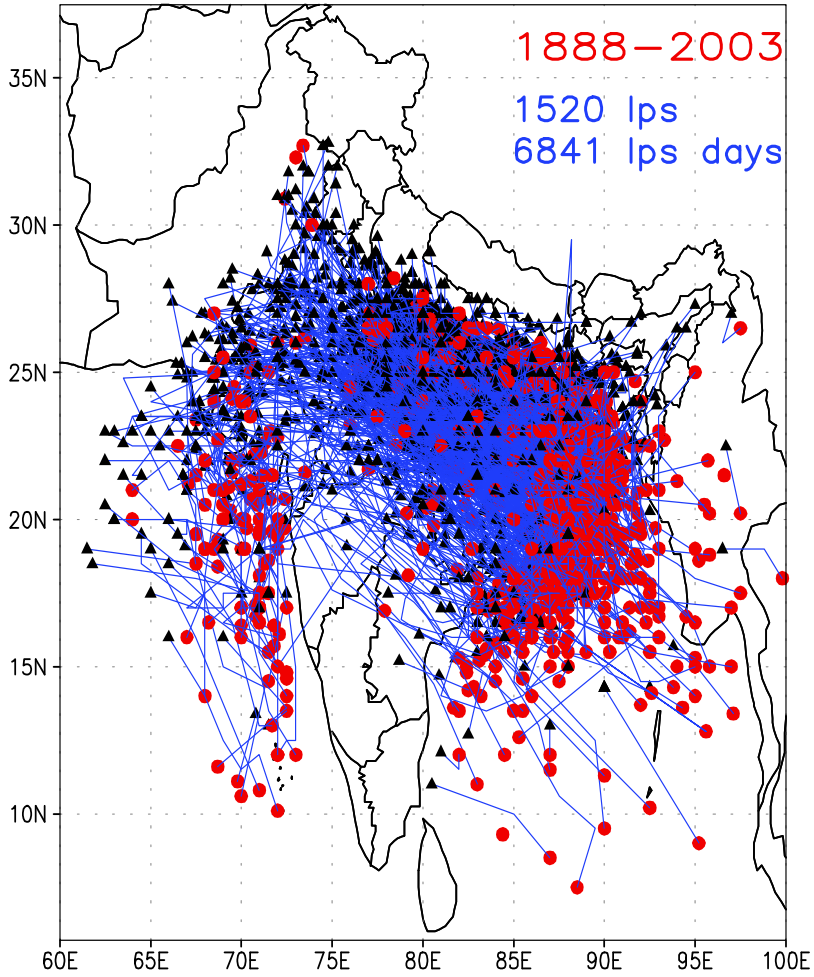
# IMD Classification

| LPS Category | Low | Depression | Deep Depression | Cyclonic Storms | Severe Cyclonic Storms |
|---|---|---|---|---|---|
| Estimated wind speed ($ms^{-1}$) | < 8.5 | 8.5-13.5 | 13.5-16.5 | 16.5-23.5 | 23.5-31.5 |
| SAI Weighting | 4.25 | 11 | 15 | 20 | 27.5 |

- ✓ Estimated from daily weather charts of surface pressure.

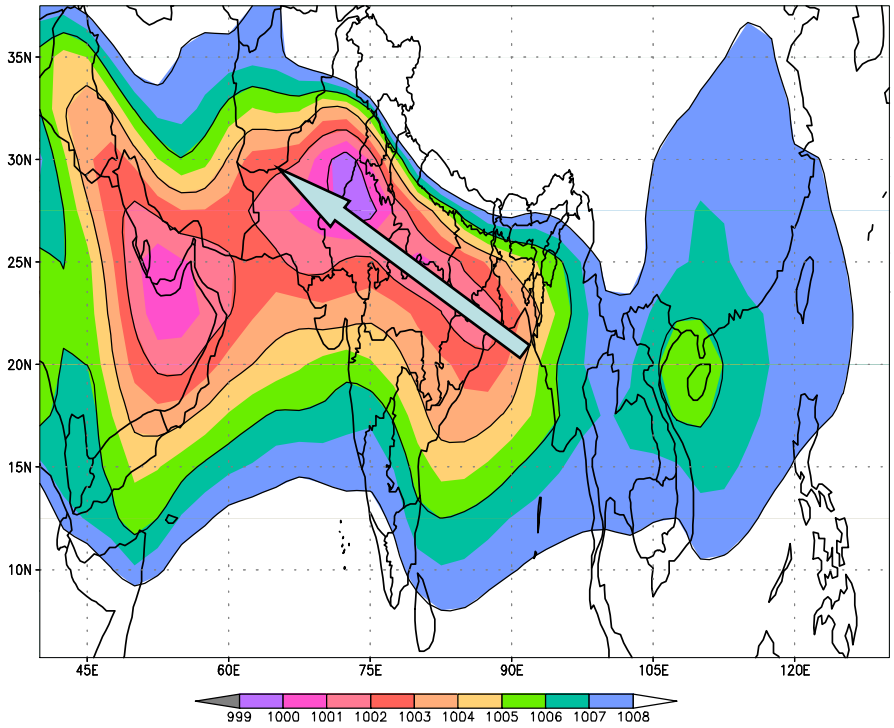
- ✓ Daily records of genesis, position and intensities of all LPS formed during monsoon season collected for 116 years (1888-2003) [Mooley and Shukla, 1987; Sikka, 2006]

## LPS Characteristics contd…



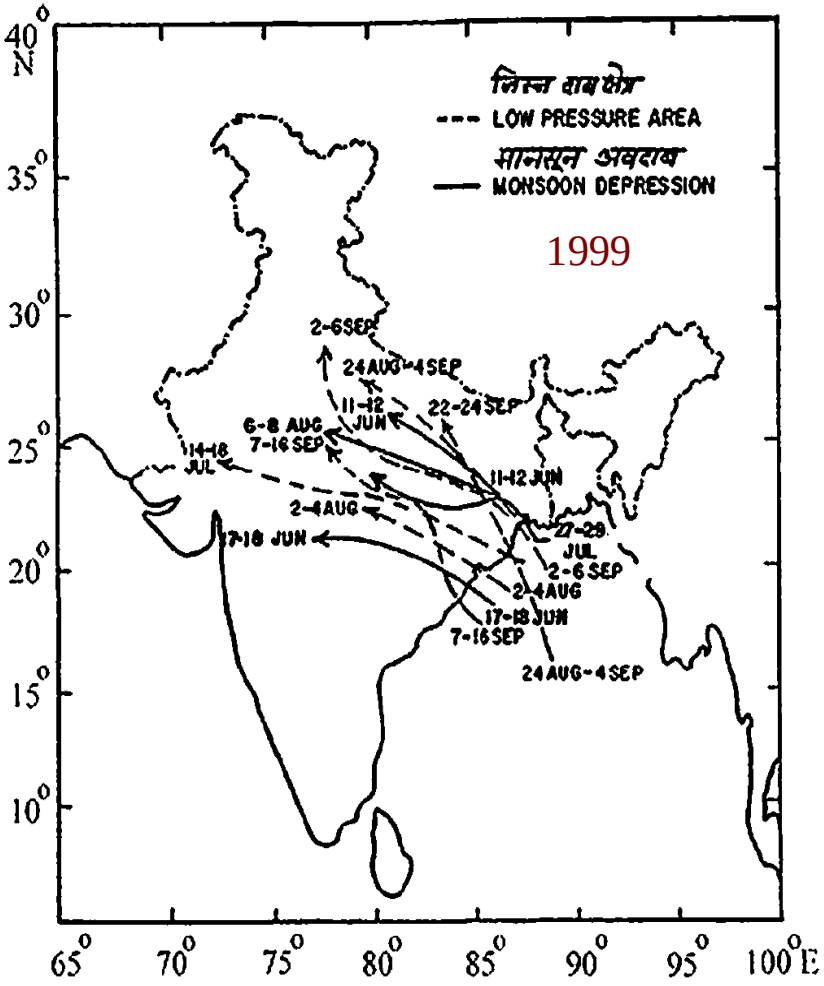

- ✓ Over Central India (important rivers)
- ✓ Systems forming over BOB has a north-westward track
- ✓ Arabian Sea systems do not always follow an eastward track
- ✓ ~13 systems/year and ~59 lps days/ 122 days on average; with large interannual variability.

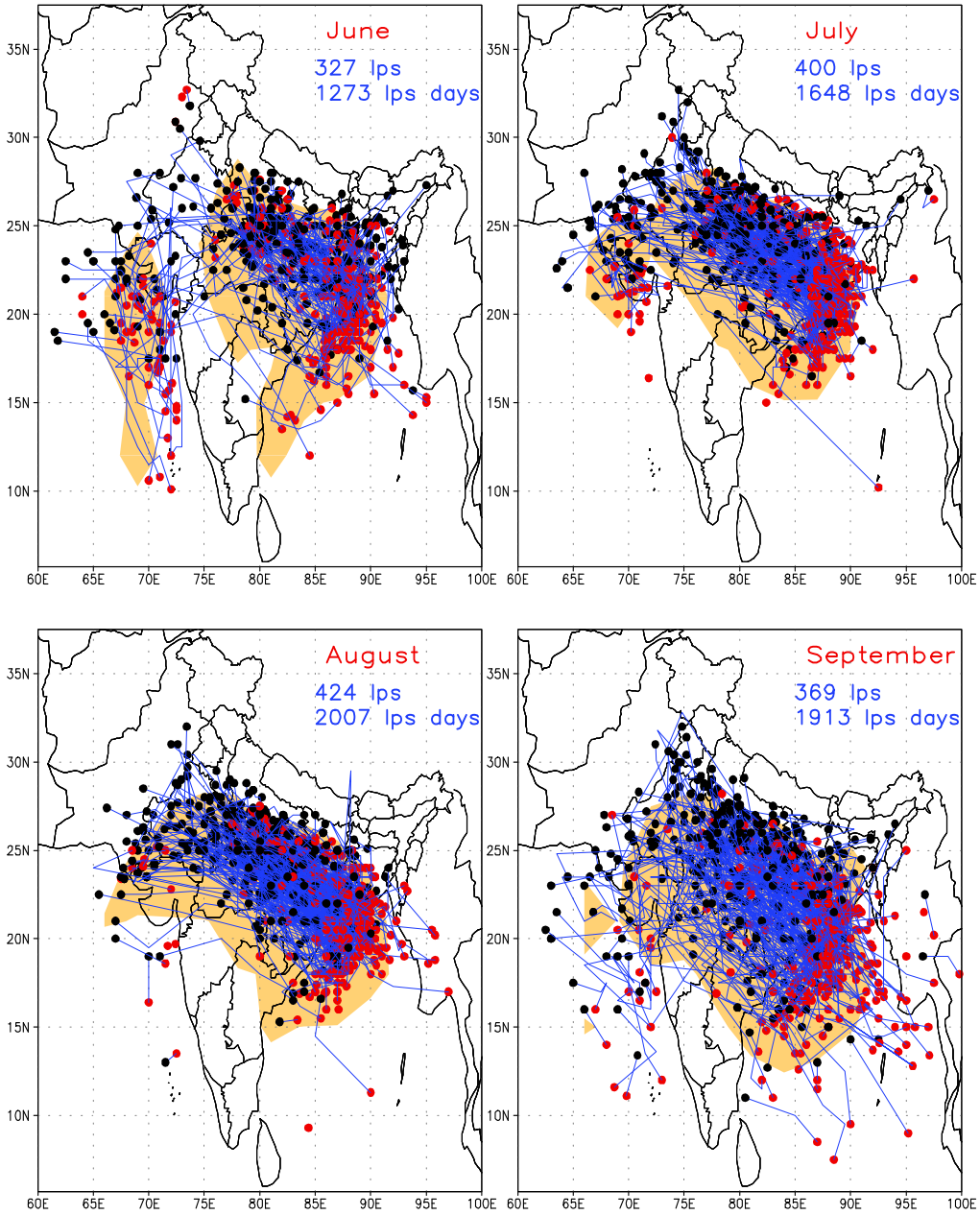
## JJAS Mean Sea Level Pressure




## LPS Characteristics contd…

- ✓ Monsoon trough offers a track for LPS to ride along
- ✓ Close inter-linkage between scales (planetary & synoptic)
- ✓ When the trough moves north (coincides with break monsoon), generally no LPS forms over BOB

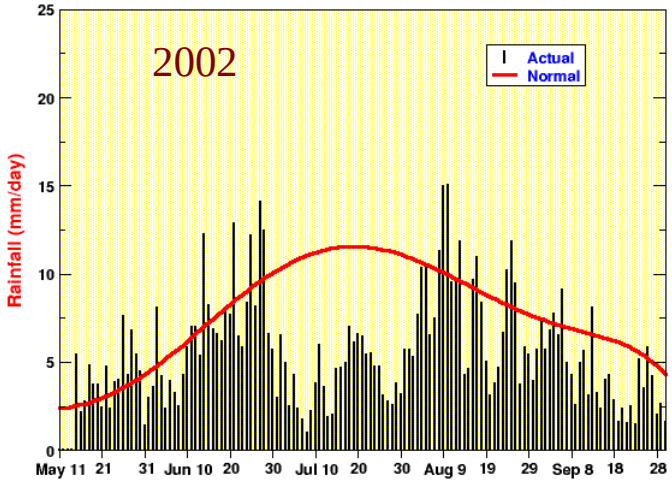

निम्न दाब क्षेत्र
LOW PRESSURE AREA
मानसून अवदाब
MONSOON DEPRESSION
1999
40° N
35°
30°
25°
20°
15°
10°
65°
70°
75°
80°
85°
90°
95°
100° E
2-6 SEP
24 AUG-4 SEP
11-12 JUN
22-24 SEP
6-8 AUG
7-16 SEP
14-18 JUL
11-12 JUN
2-4 AUG
17-29 JUL
7-18 JUN
2-6 SEP
2-4 AUG
17-18 JUN
7-16 SEP
24 AUG-4 SEP

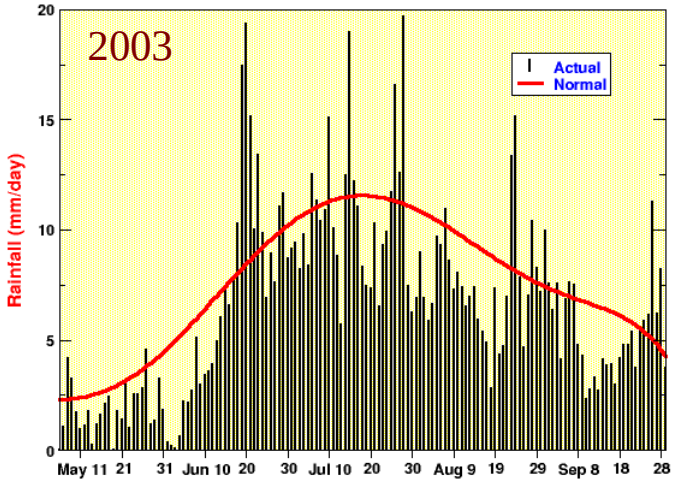



## Monthly Distribution of LPS

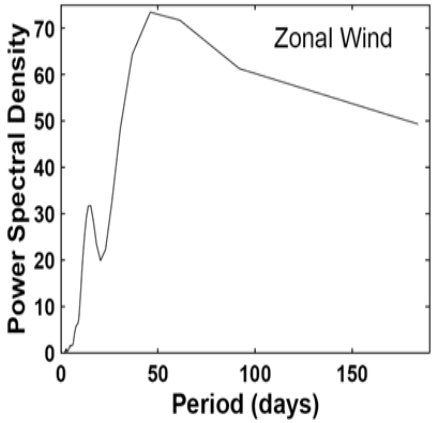
- ✓ Large spread in September
- ✓ AS systems active in June and July
- ✓ Systems comparatively stay longer in July/August

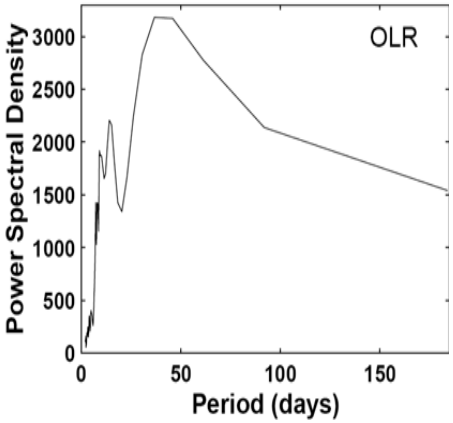
# BSISO Characteristics




From Monsoon Online



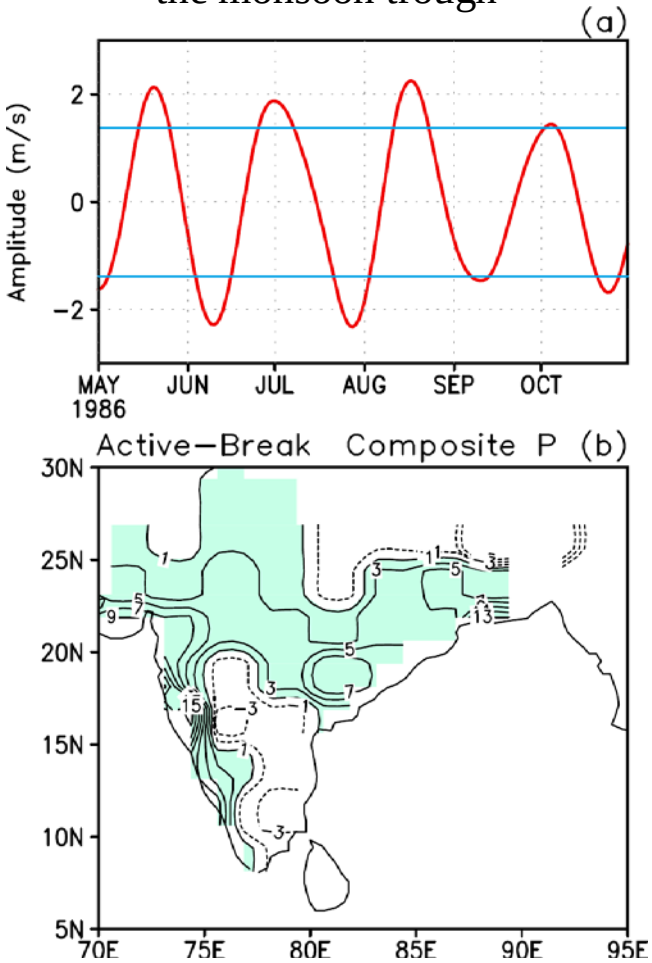




- ✓ Two dominant spectral peaks
- ✓ 10-20 days & 30-60 days; broad range between10-90 days
- ✓ Interannual variability

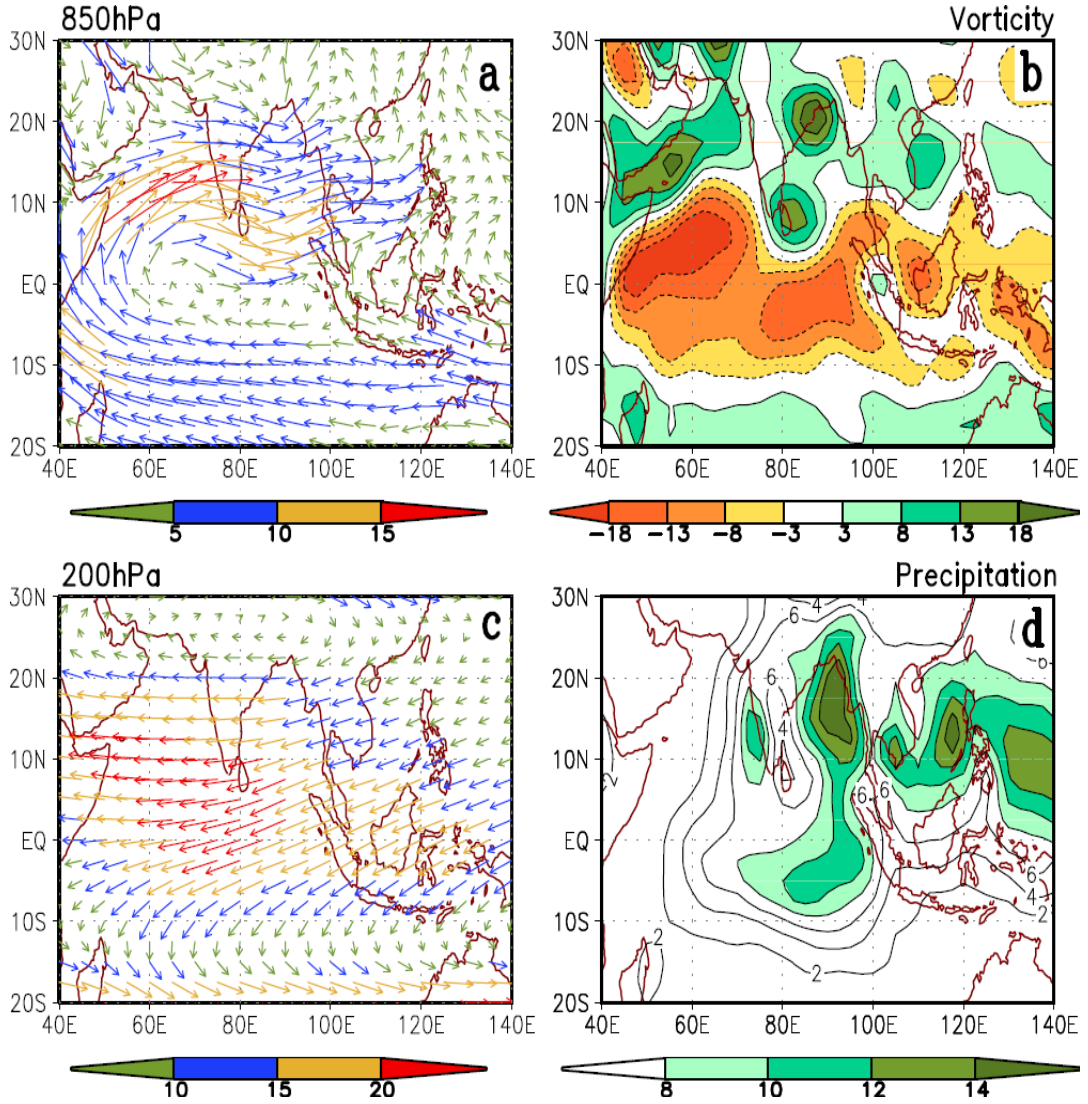
# Criteria to define Active/break phases

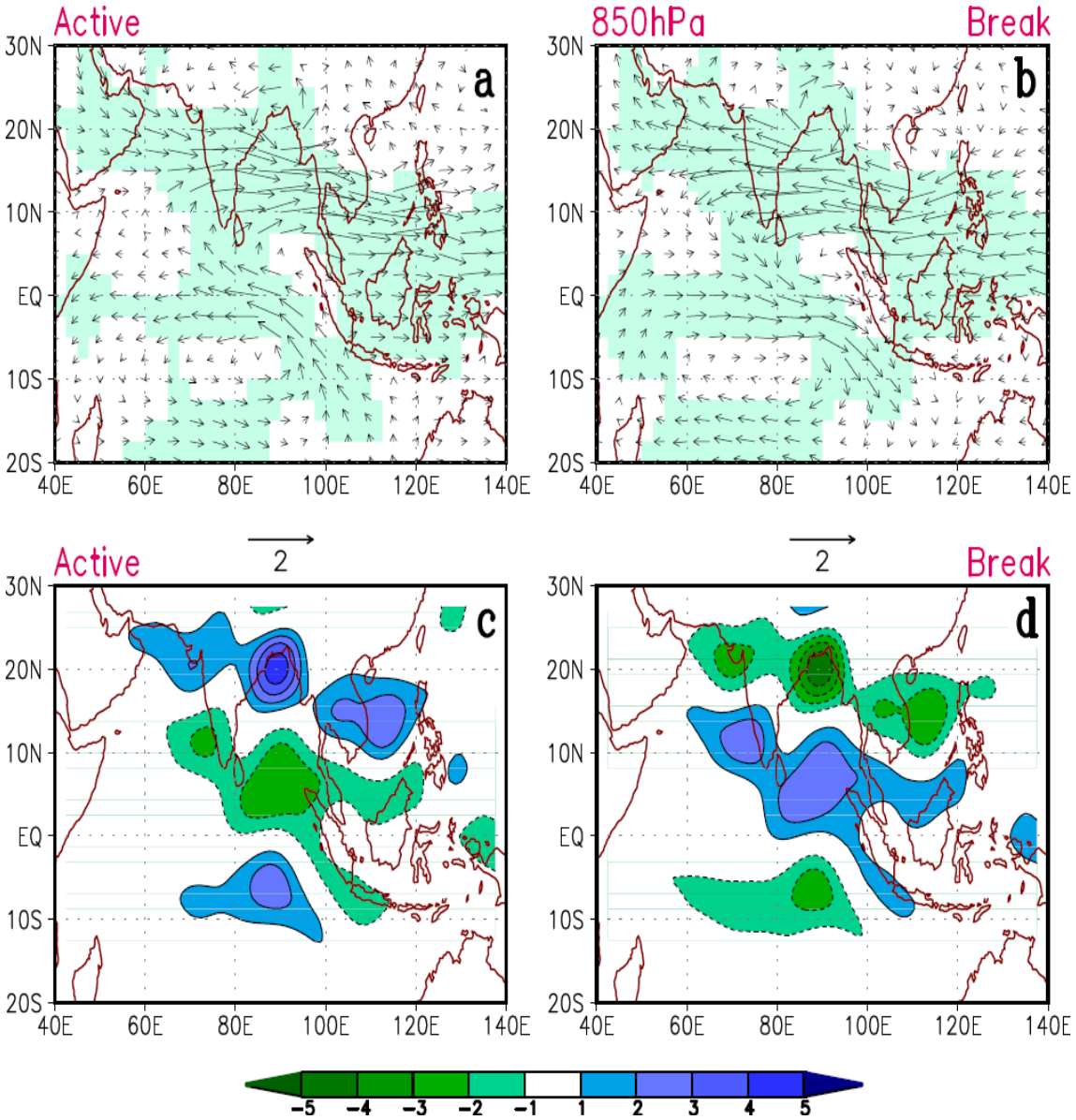
- **Circulation based:**
  - 850hPa zonal winds over a large region (65-95E,10-20N; Webster et al. 1998)
  - From the time series of filtered 850hPa zonal wind over the monsoon trough region (Ajayamohan, 2001, Goswami and Ajayamohan, 2001)
- **Precipitation based:**
  - PC1 of daily precipitation anomalies above or below a certain threshold for 5 consecutive days (Krishnamurthy and Shukla, 2000)
  - Rainfall more than mean over western and eastern parts of India (Gadgil and Joseph, 2003)
  - OLR threshold (Krishnan et al., 2000)

Intraseasonal $U_{850}$ averaged over the monsoon trough

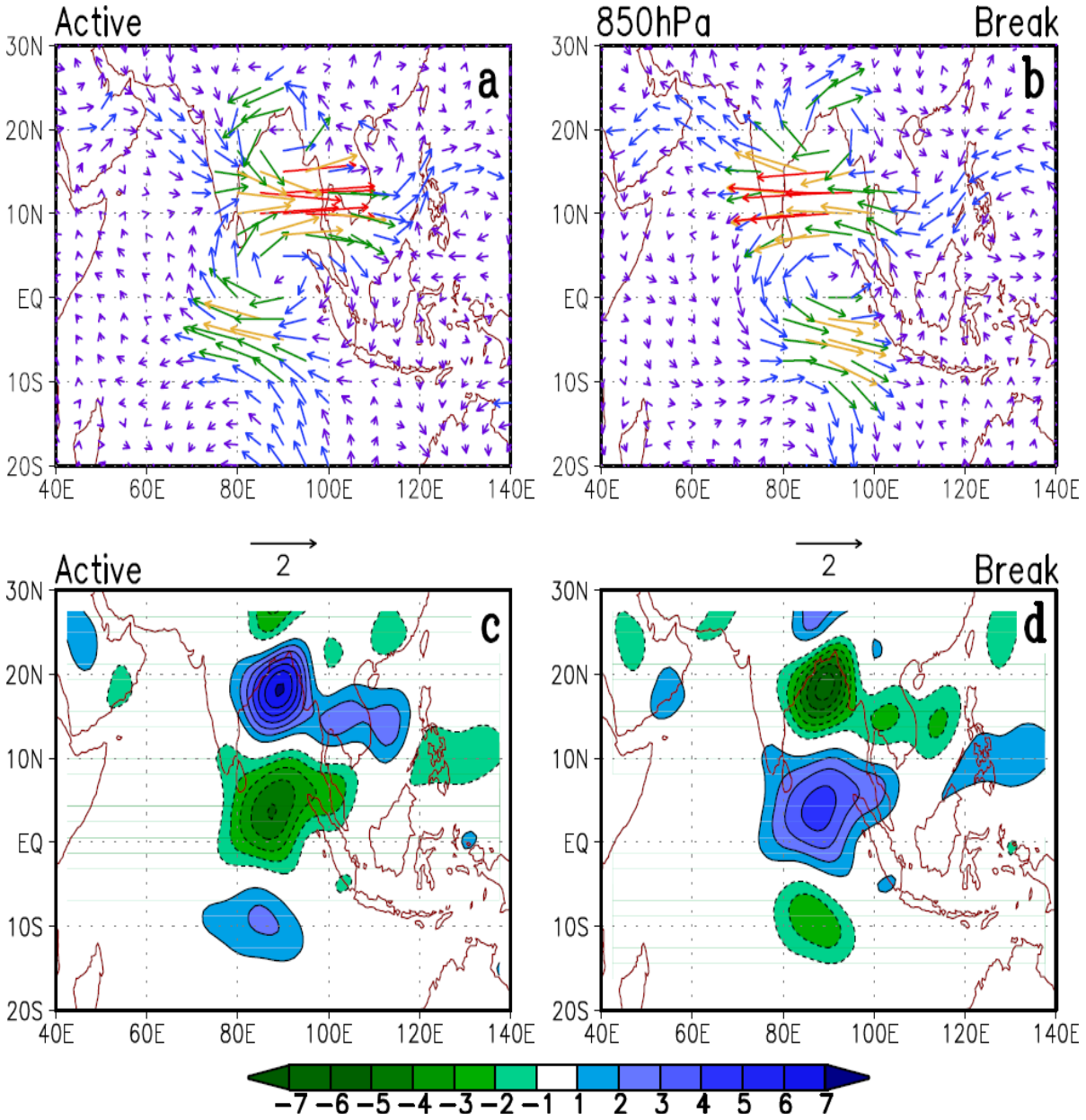


# JJAS Mean Winds & Precipitation

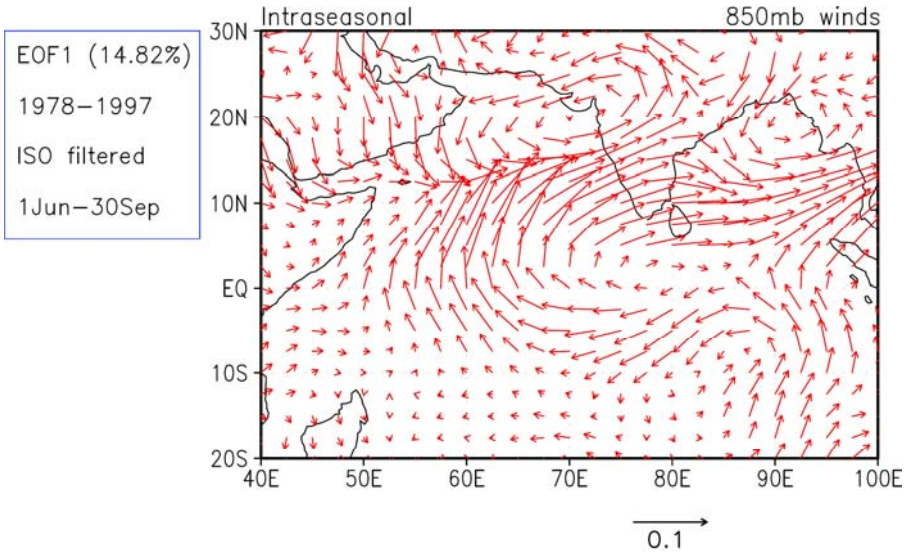


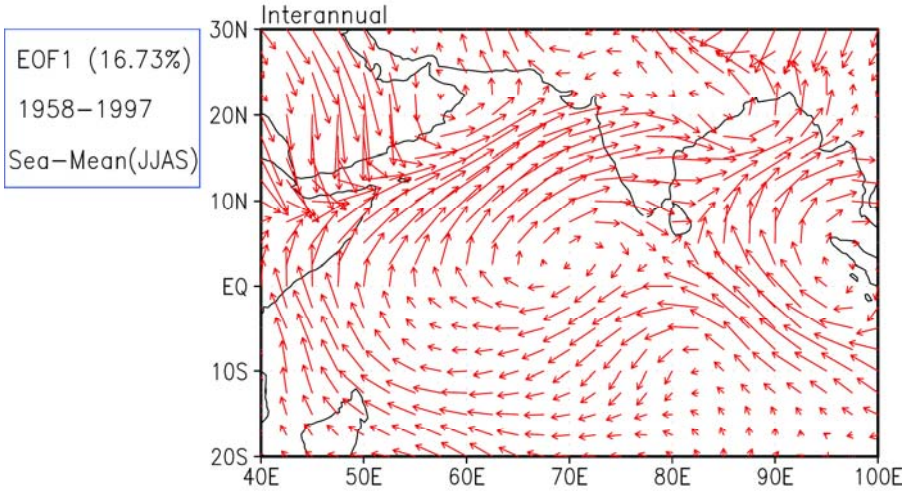


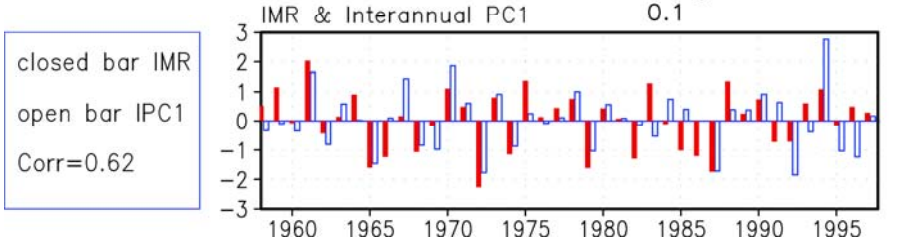

- ✓ Composite Structure of 30-60 day mode




- ✓ Composite Structure of 10-20 day mode

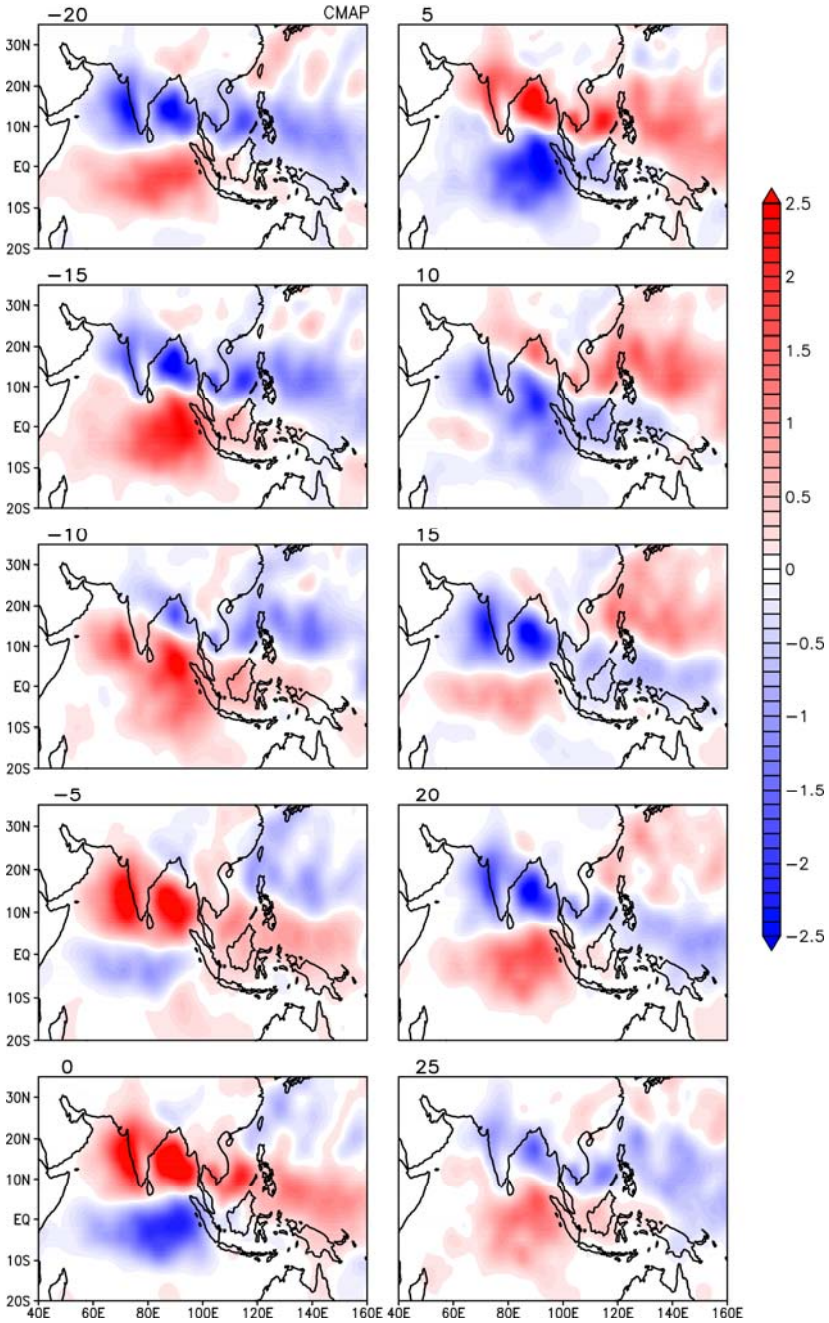



# ISV and IAV: Common Mode of Spatial Variability

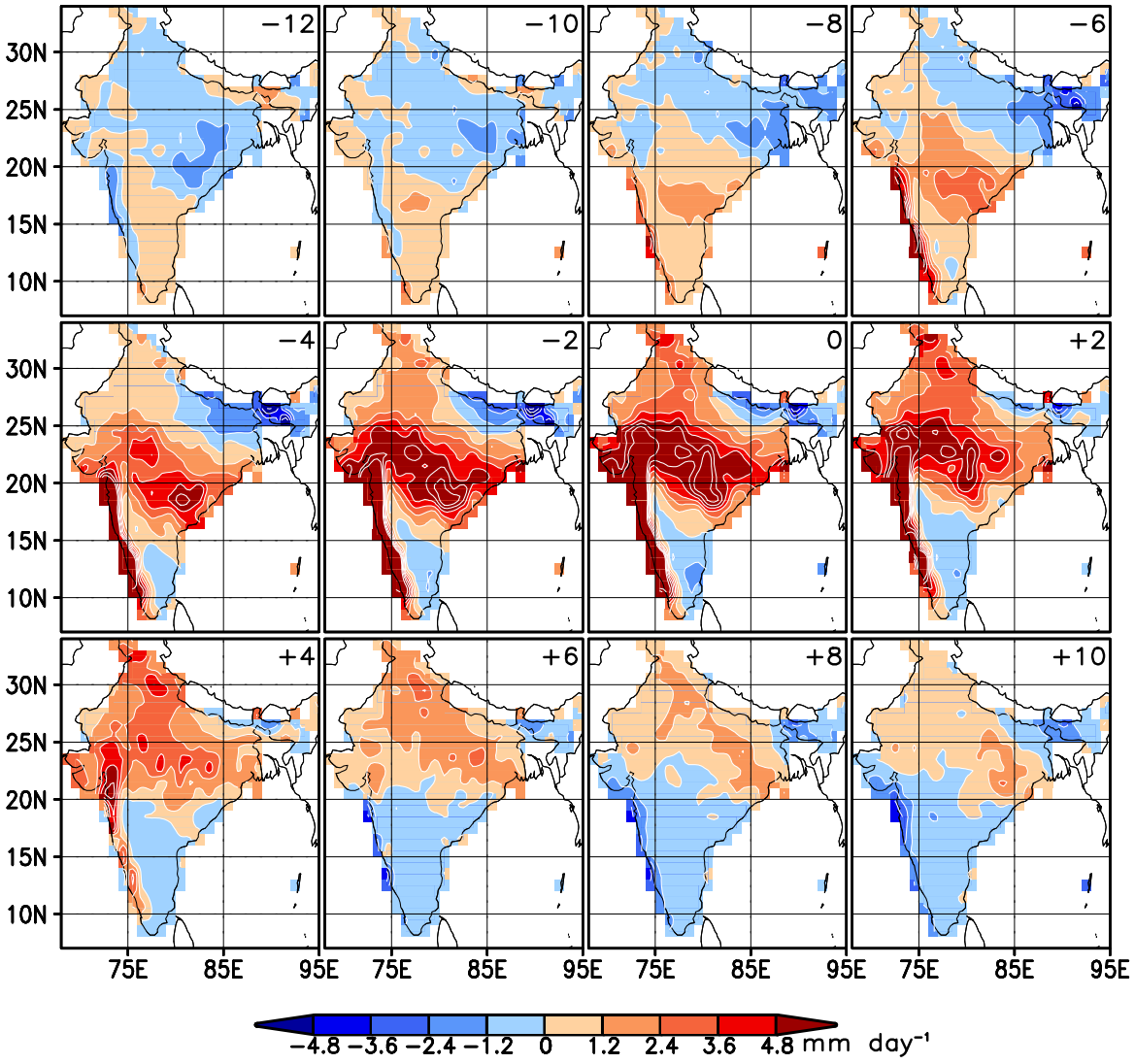
(Goswami and Ajayamohan, 2001)




## ISO Characteristics:

Evolution of BSISO. Note the clear northeastward propagation of precipitation anomalies.

(Ajayamohan and Goswami, 2007)

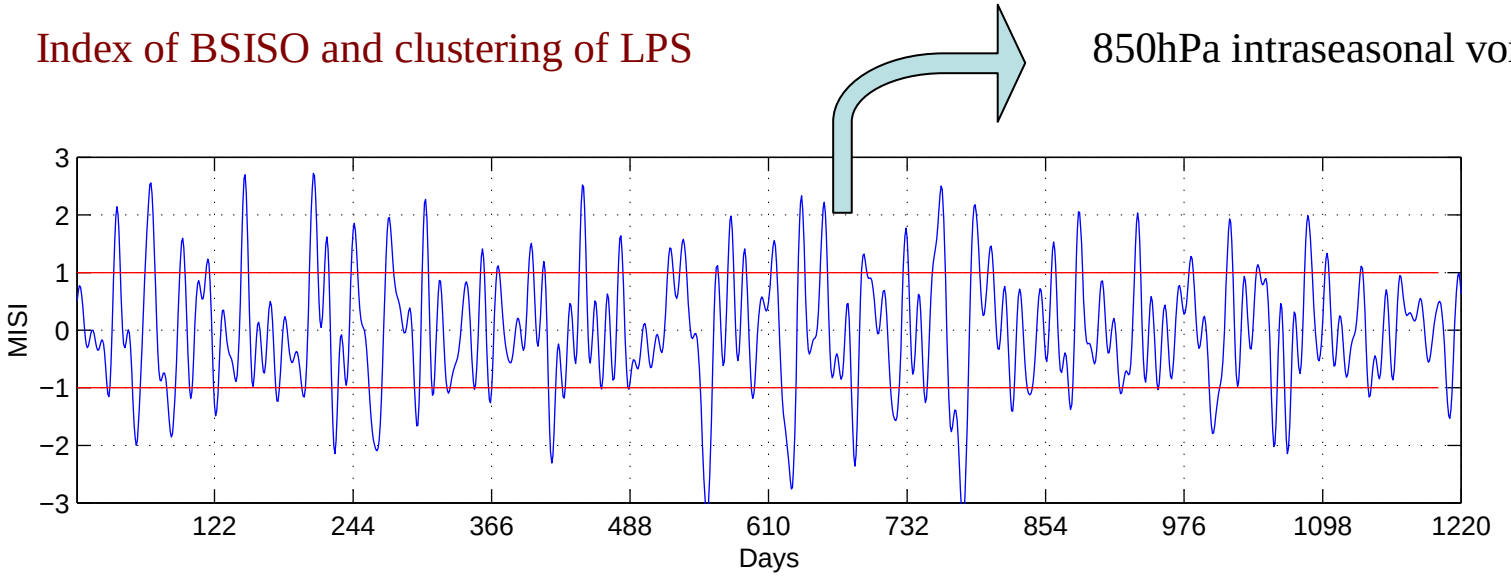



Evolution of continental precipitation

(Krishnamurthy and Shukla, 2007)

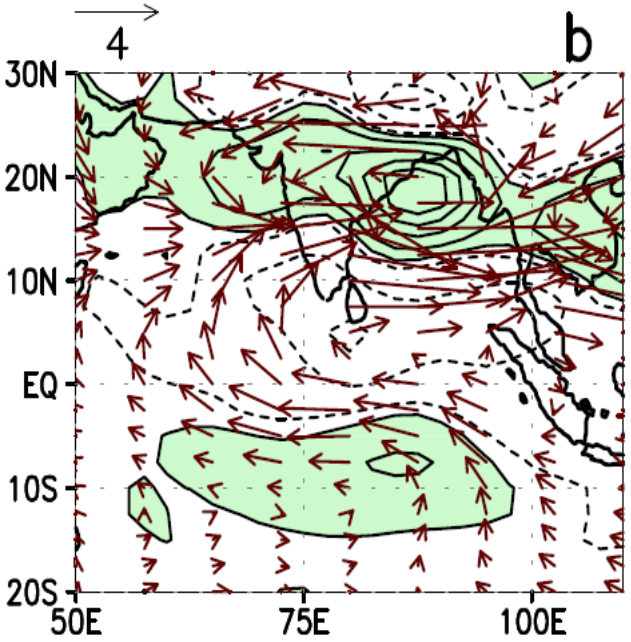
Index of BSISO and clustering of LPS

850hPa intraseasonal vorticity (MISI)

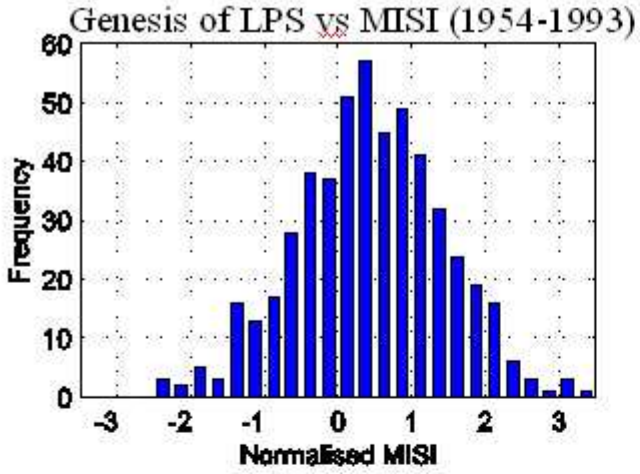



Composite active-break

850 hPa winds & Vorticity



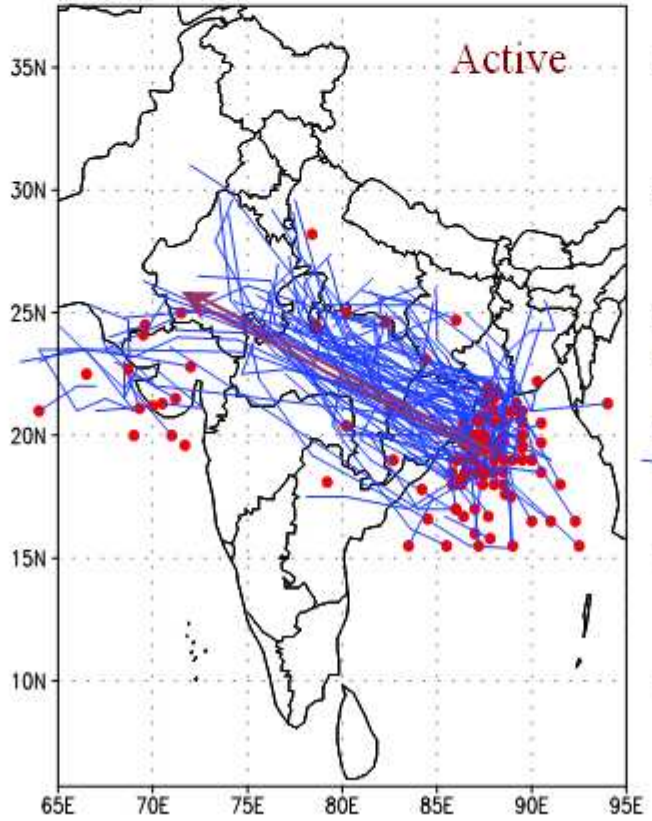

From Ajayamohan, 2001 and Goswami et al. (2003)

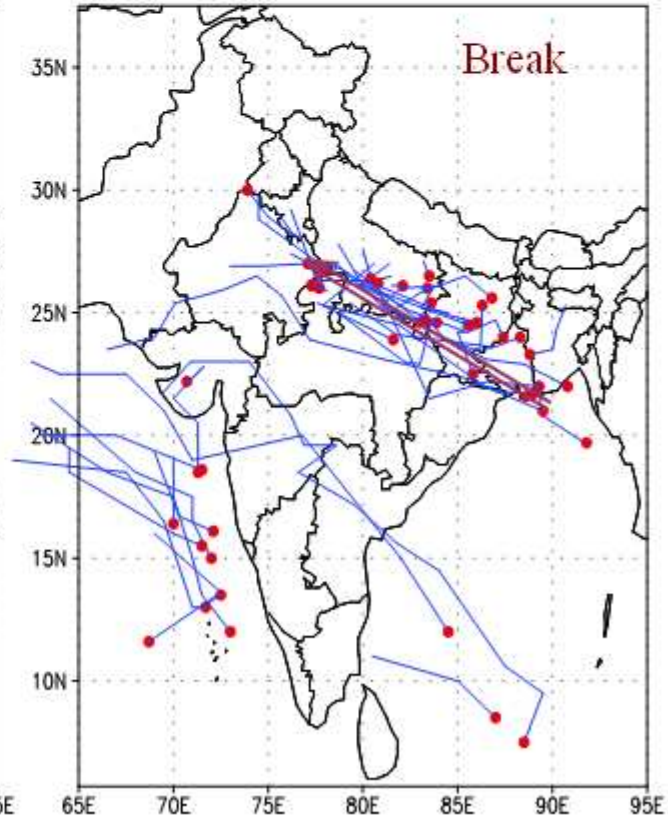



## Contribution of different frequency bands to clustering

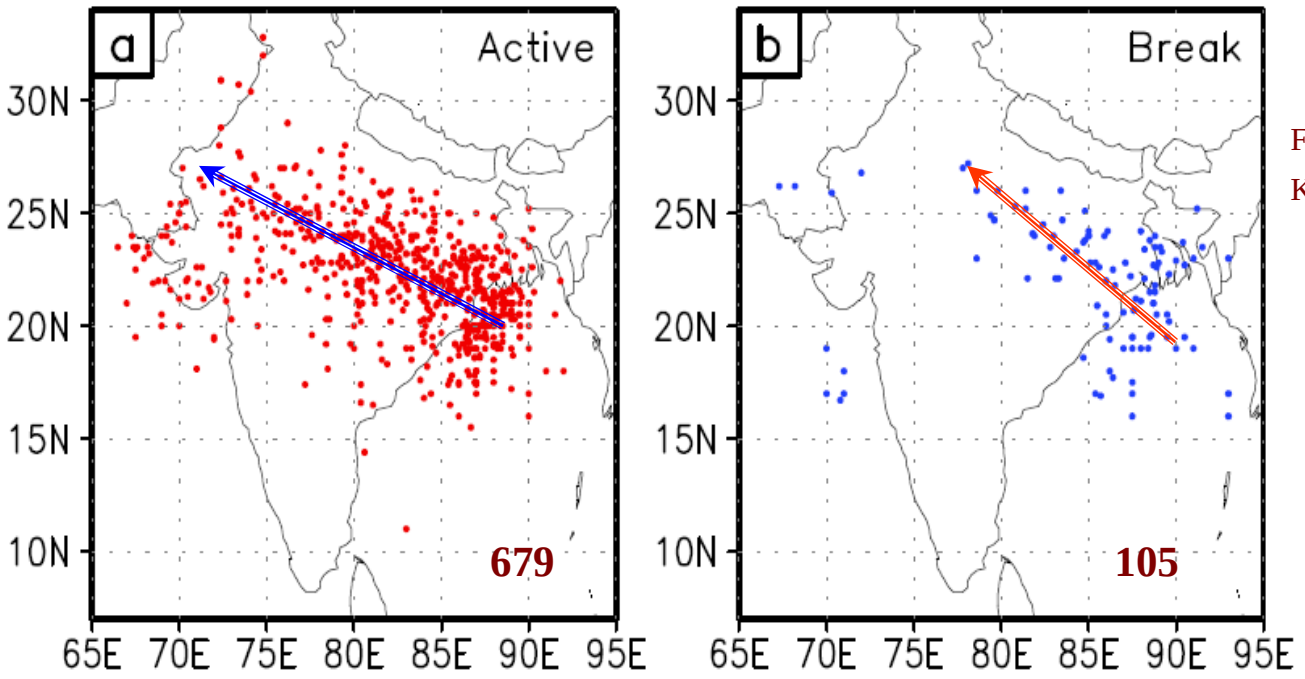
| MISI → | > 0 | < 0 | Ratio | > 1 | < −1 | Ratio |
|---|---|---|---|---|---|---|
| 10-90 days | 350 | 160 | **2.18** | 147 | 42 | **3.50** |
| 30-60 days | 316 | 194 | **1.62** | 115 | 42 | **2.74** |
| 10-20 days | 330 | 180 | **1.83** | 152 | 50 | **3.04** |
| 0-10 days | 259 | 255 | **1.01** | 86 | 87 | **0.98** |

1954-1983



# Active/Break composites of Depression days during 1901-70

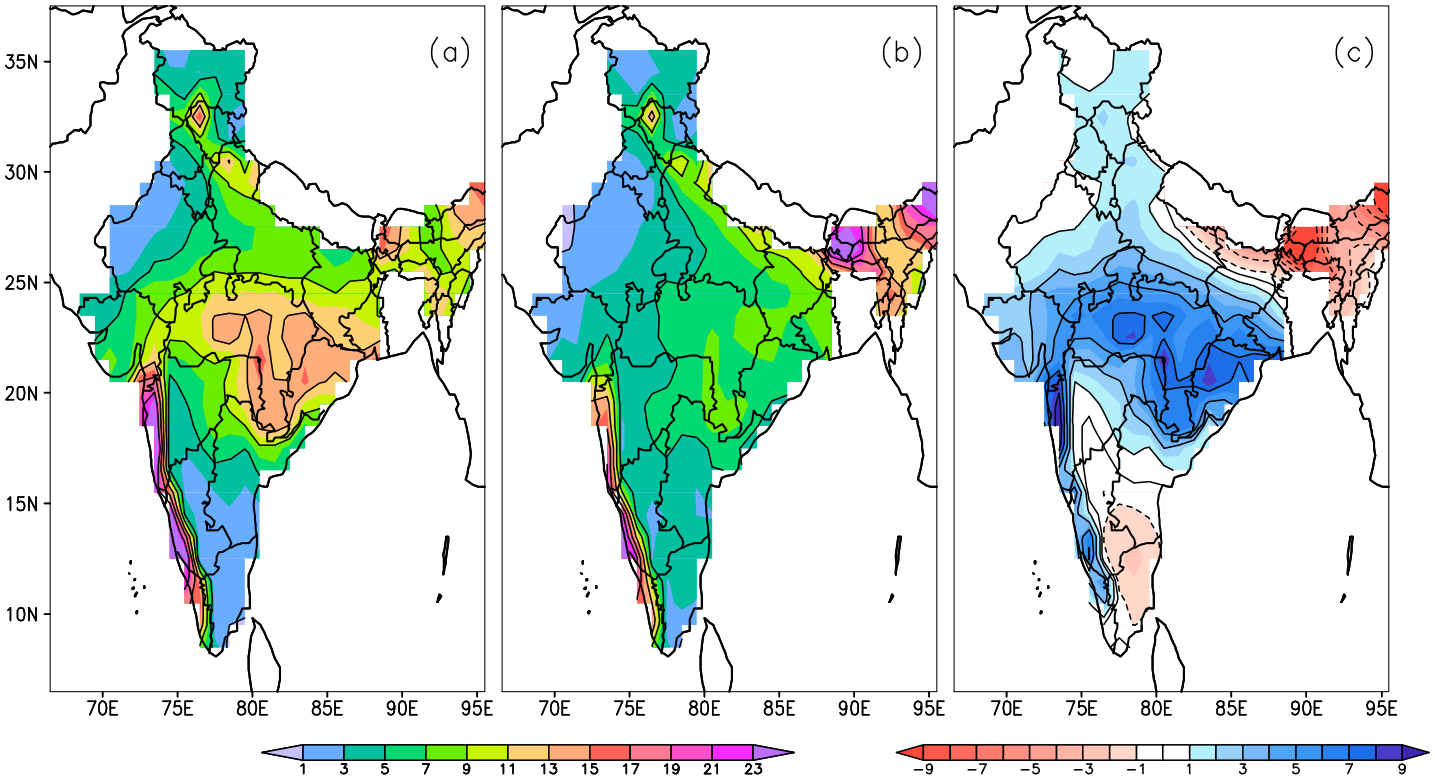



From

Krishnamurthy and Shukla, 2007

# LPS Composites of daily precipitation (1901-2003)

LPS days | Non-LPS days | LPS days-non LPS days

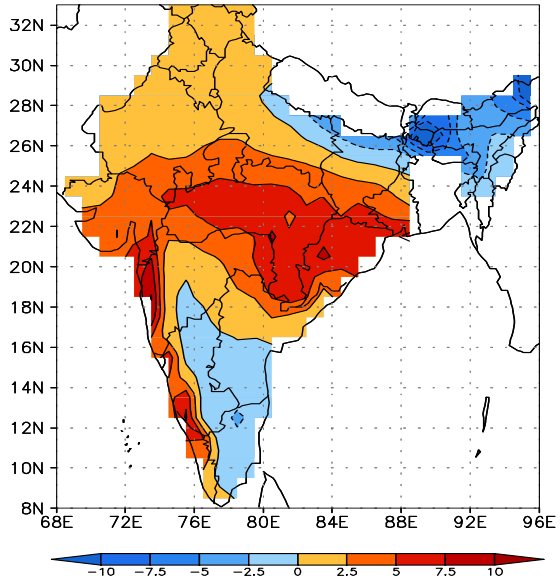


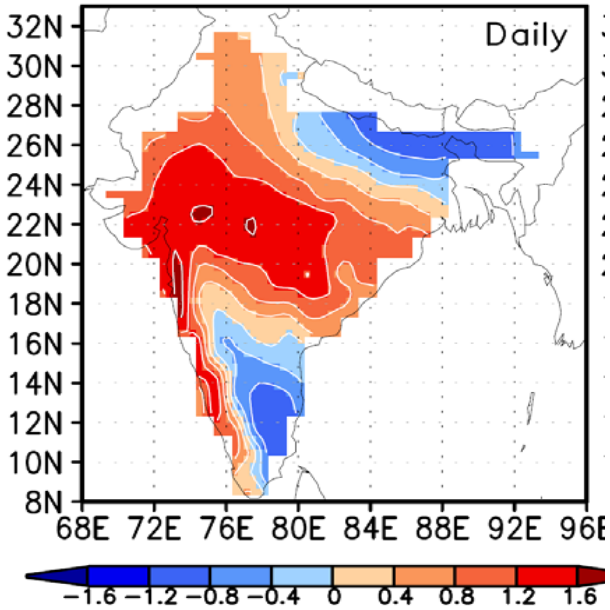

✓ From Ajayamohan and Krishnamurthy, 2008

# LPS days represent the most dominant pattern of precipitation variability

LPS days –non LPS days composite

1901-2003



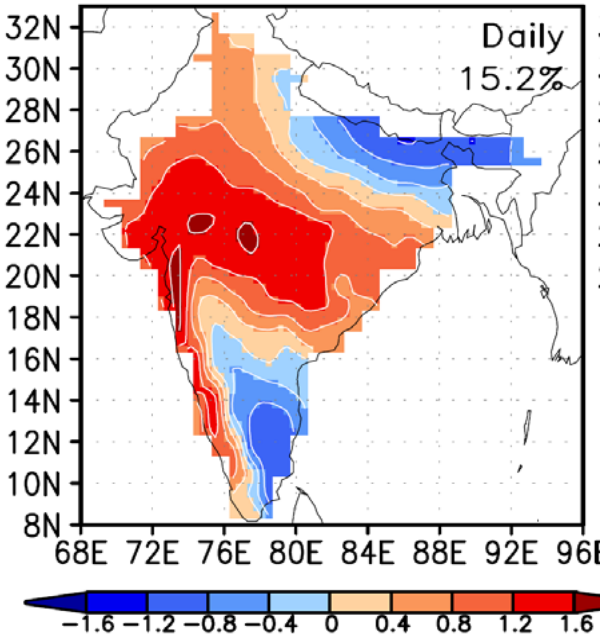




Active – Break

Composite

1901-1970

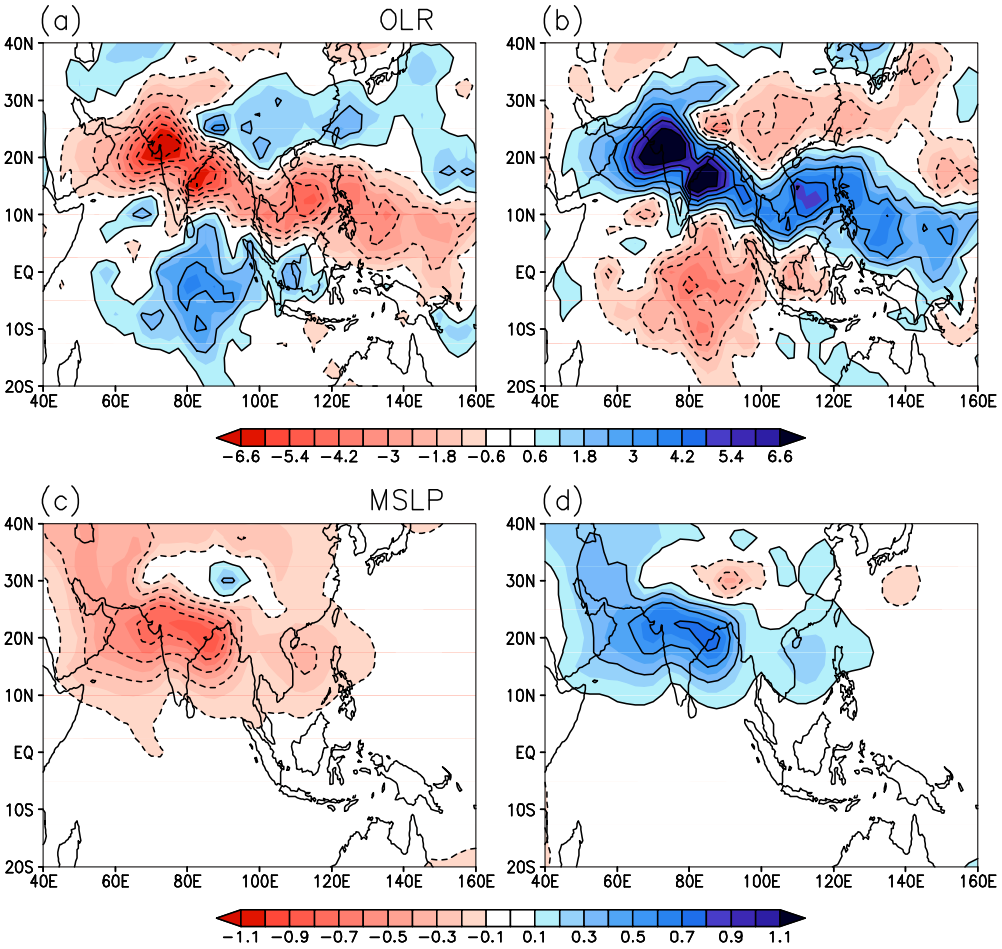
(Krishnamurthy and Shukla, 2000)



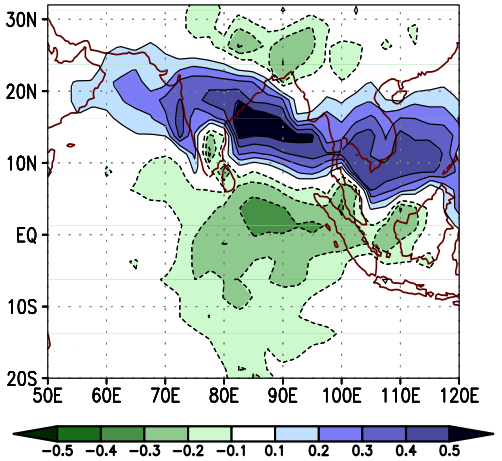

EOF-1 of

daily precip

## LPS days and non LPS days composites

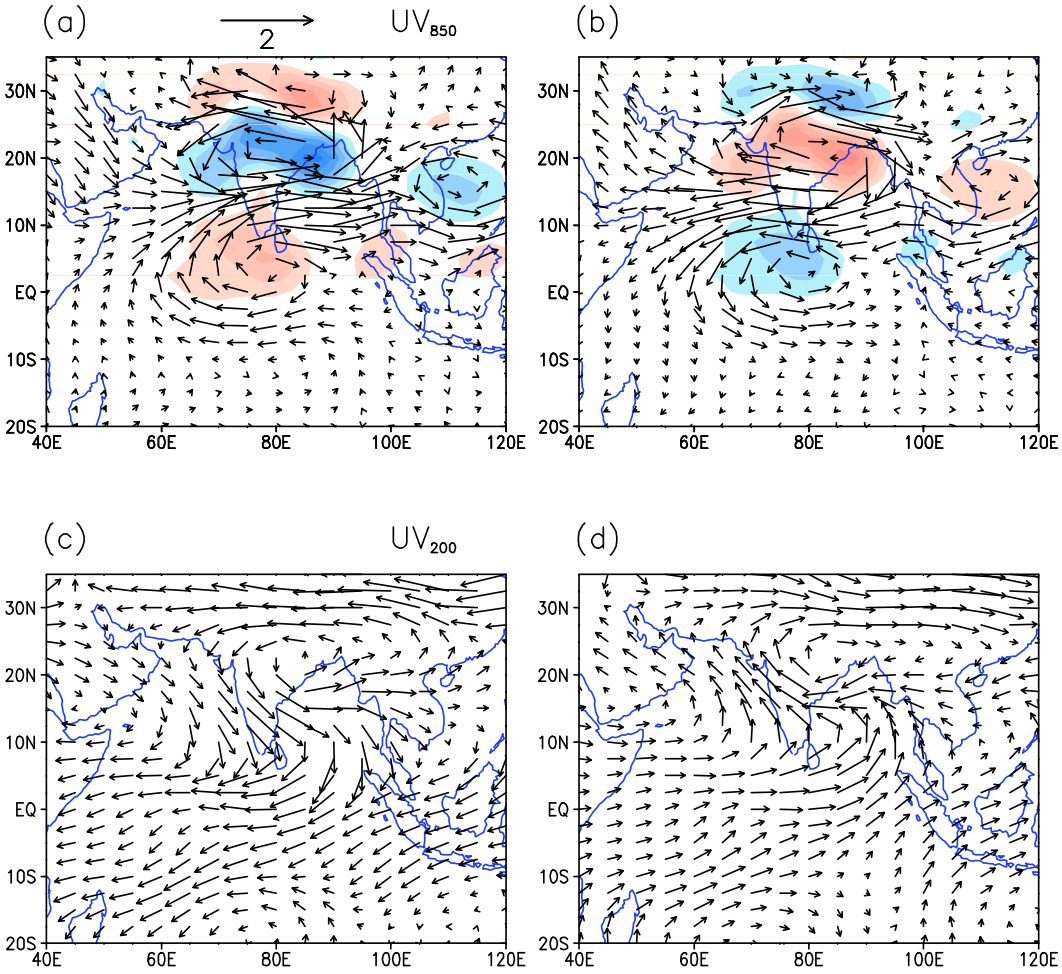



## Active-break OLR anomalies



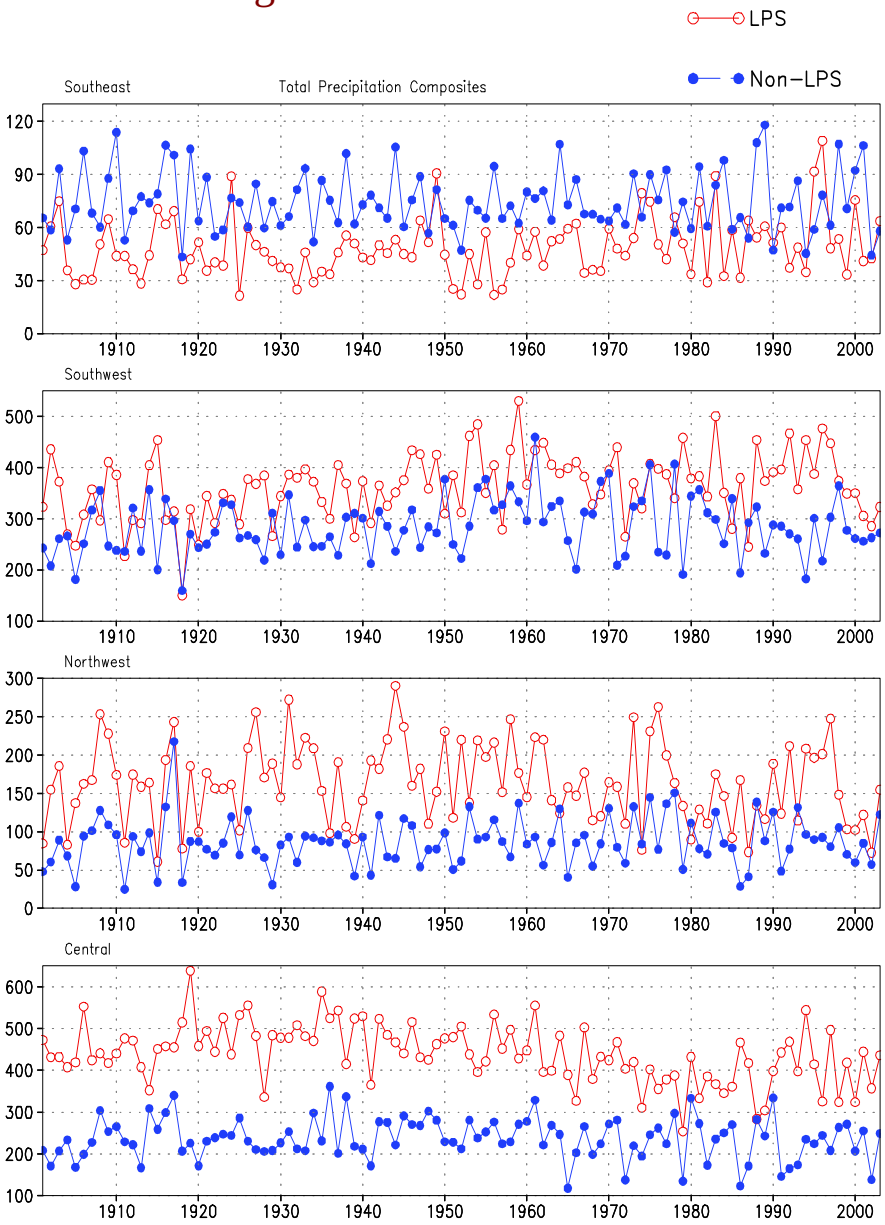
LPS days

Non-LPS days




- ✓ Strengthening of mean circulation in LPS days and weakening of circulation in non-LPS days
- ✓ Similar to active/break phases

# LPS vs regional rainfall



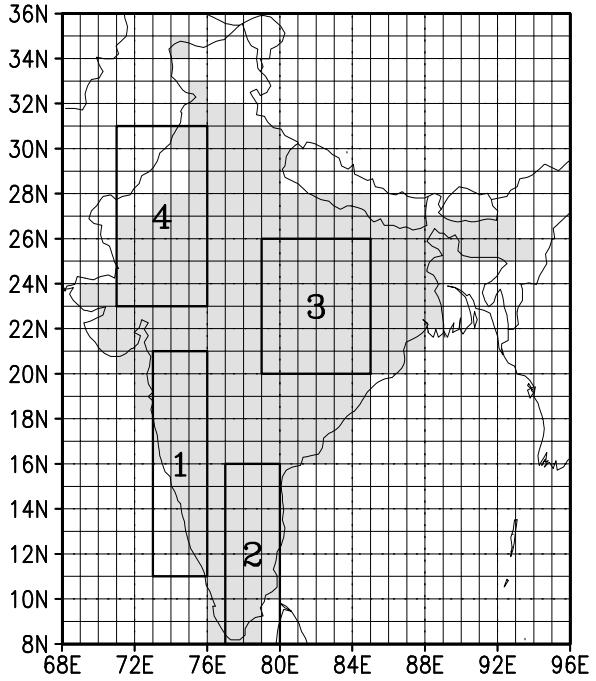
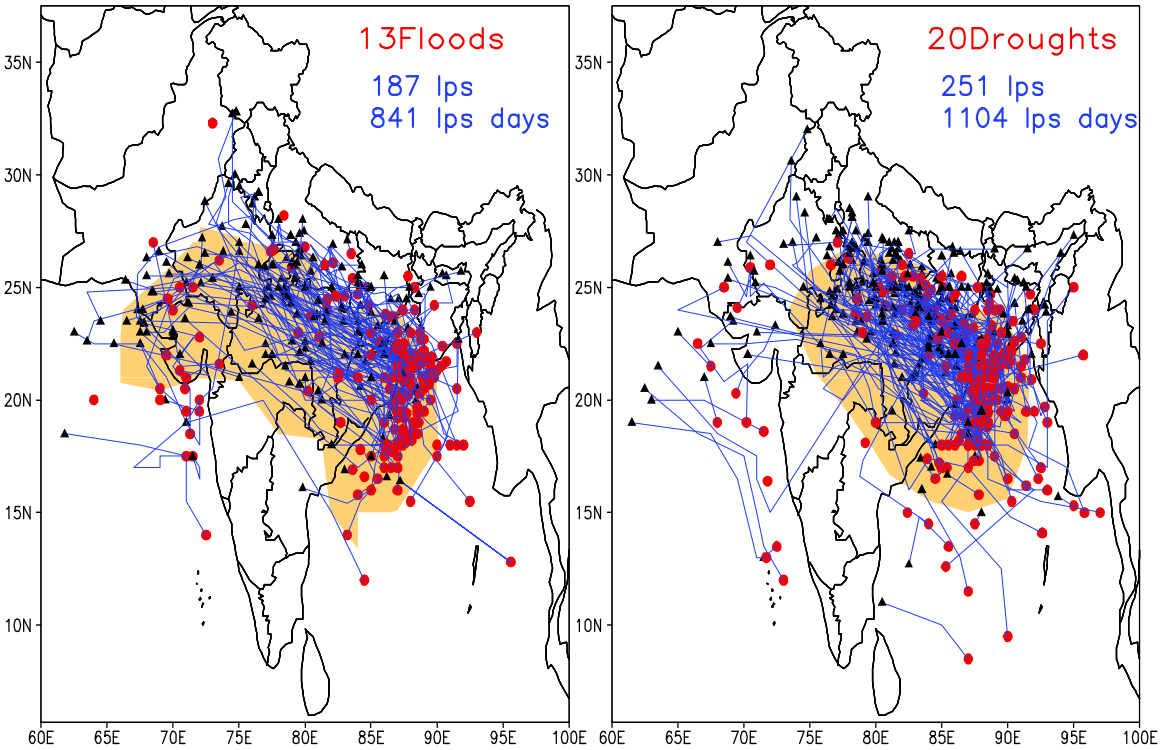
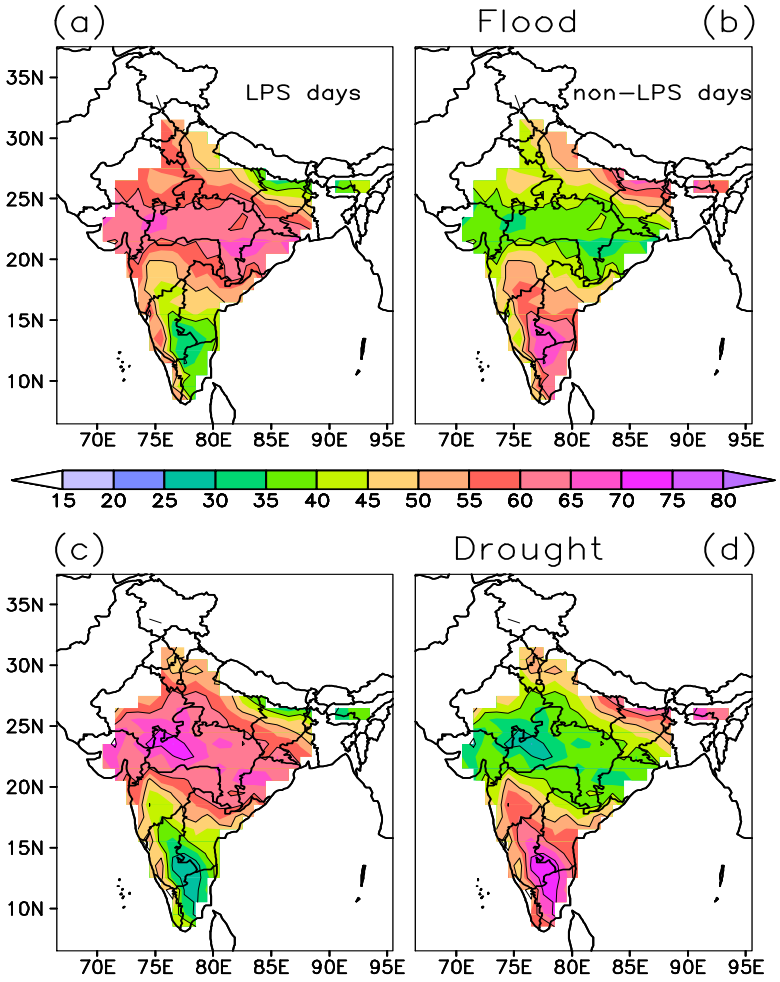




Fig. 1

# Can we demarcate floods and droughts based on LPS ?

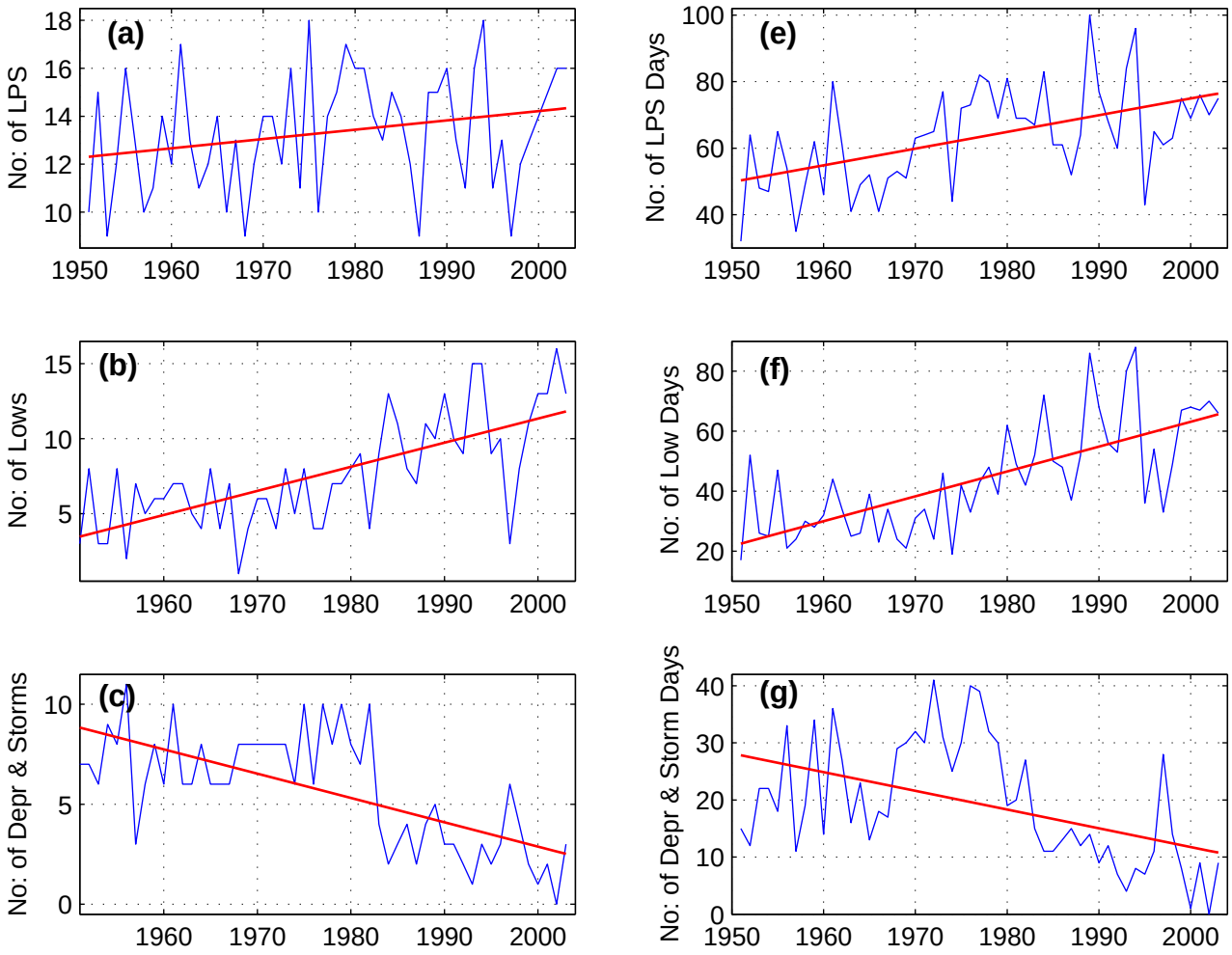



- Shaded region: SAI, an LPS index
- More activity in N.W India in flood years
- No clear demarcation ….




% Contribution of precipitation during flood and drought years during LPS and non-LPS days calculated wrt to total precipitation

# Trends in recent LPS data

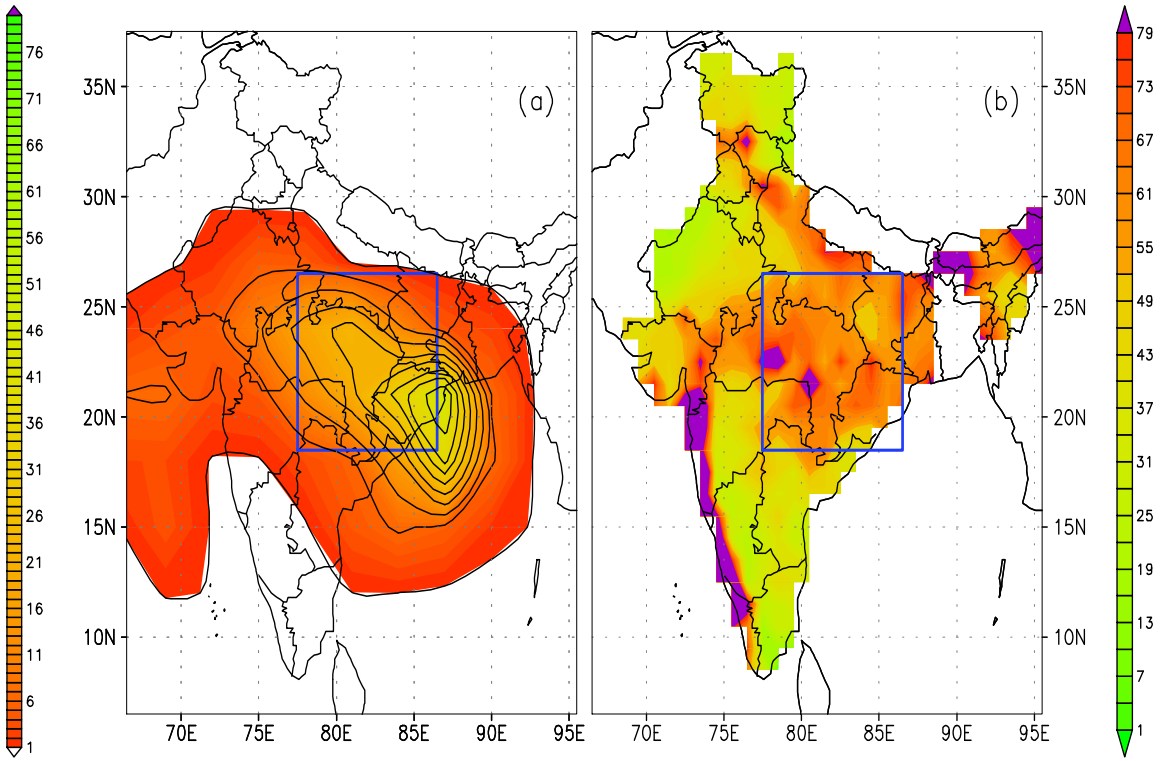



Rajeevan et al, 2000

Sikka, 2006

Trends are also noted in the decadal frequency of depressions with their westward movement crossing 80°, 75°, 70° E (Pattnaik et al., 2004)

## Mean SAI and average intensity of extreme rainfall ( > 98.3$^{th}$ percentile of daily rainfall)




From Ajayamohan et al. ,2008

- ✓ Annual Synoptic Activity Index (SAI; aggregate of all LPS parameters) is defined by

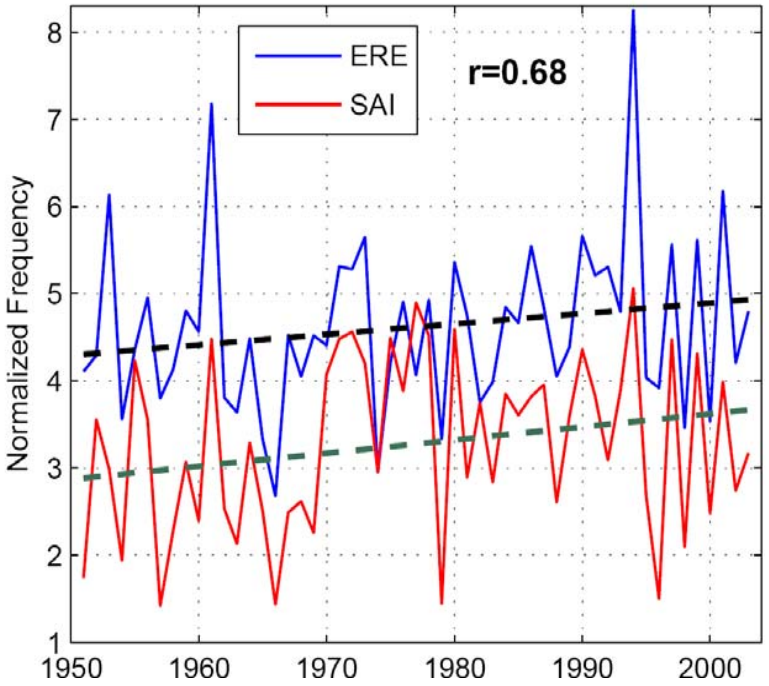
(a) Counting the number of LPS within each grid box

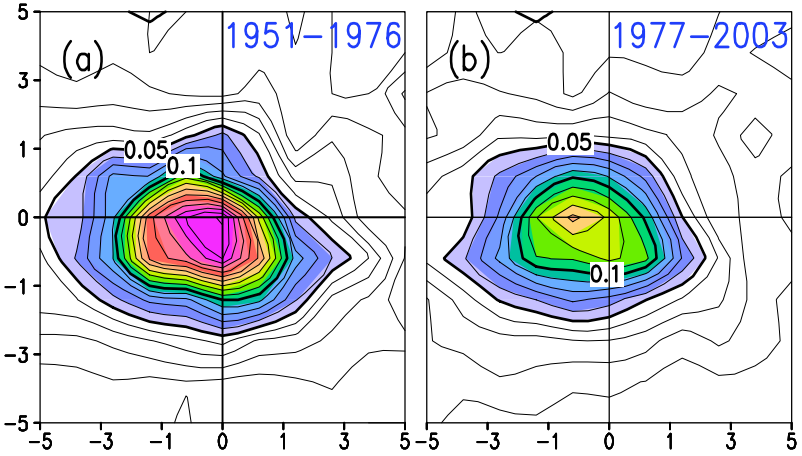
(b) Weighting each count by a measure of intensity

(c) Summing this quantity over each monsoon season

## Frequency of extreme rainfall events and synoptic activity index : strong association

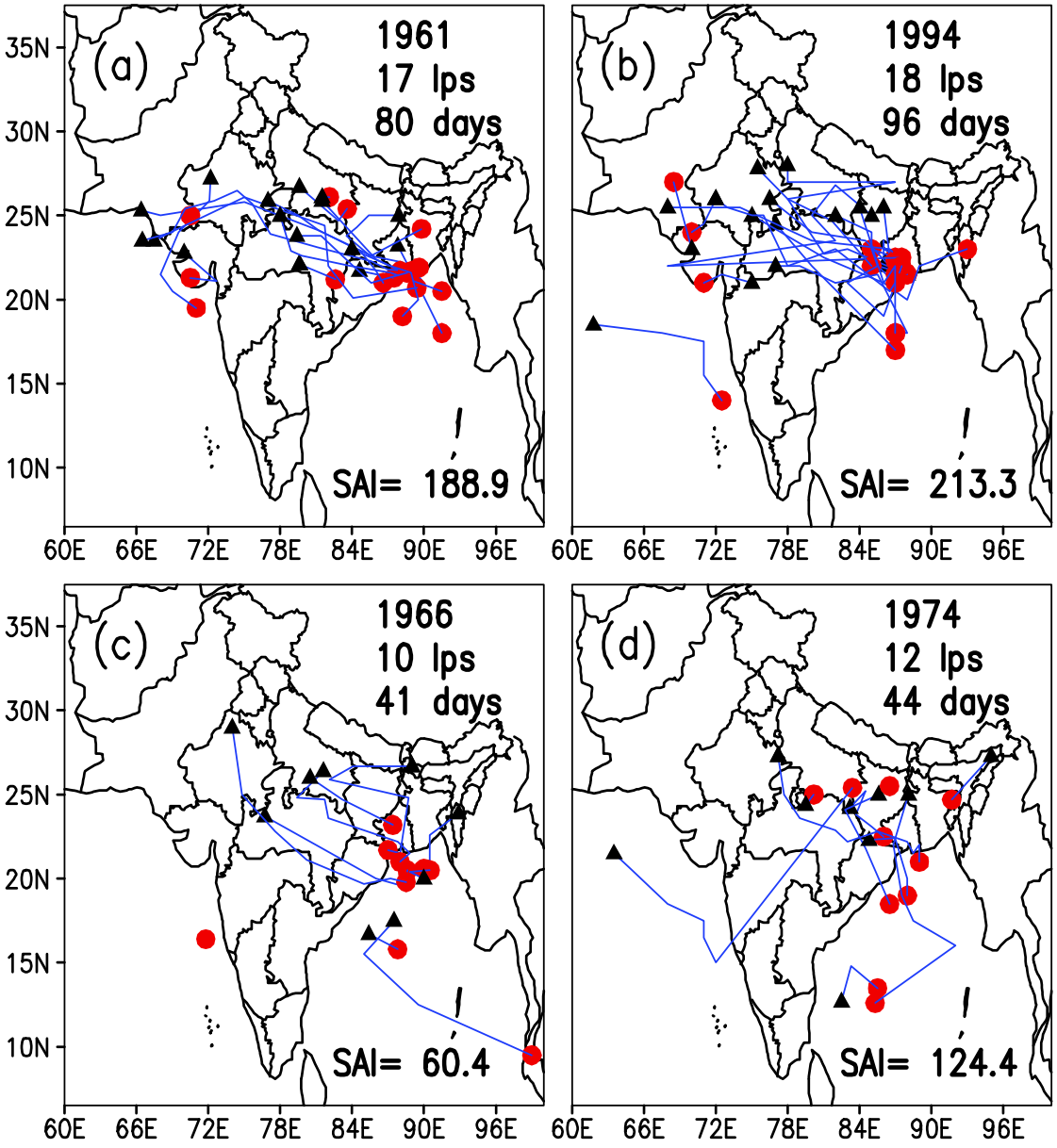
14% increase in ERE accompanies a 45% increase in LPS days, mitigated by the reduction in mean storm intensity



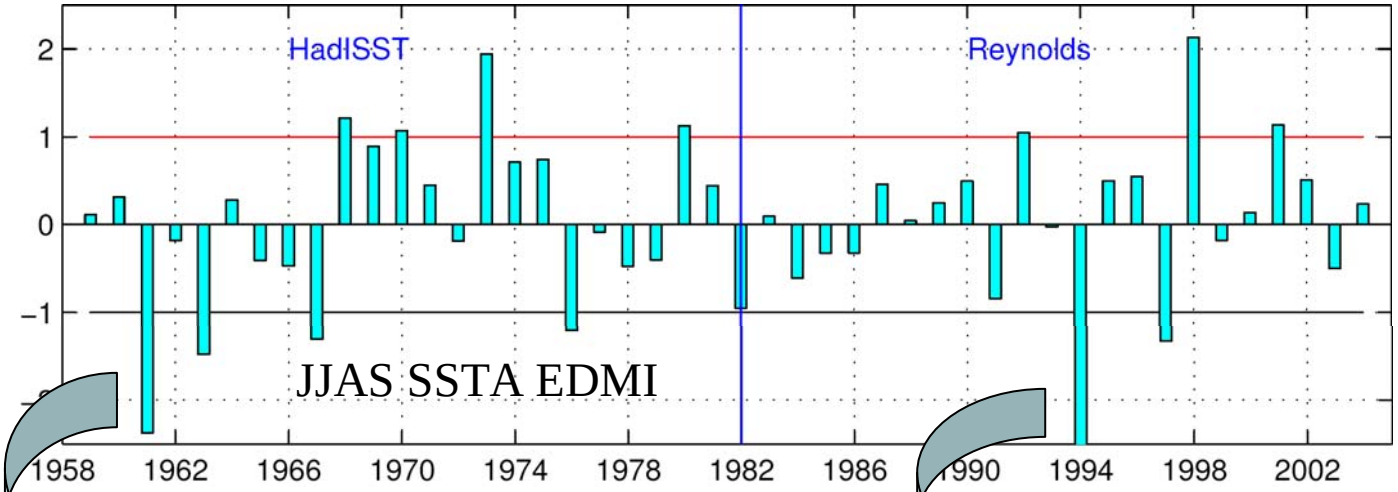

## Average daily probability of occurrence of ERE within ±5° of an LPS center

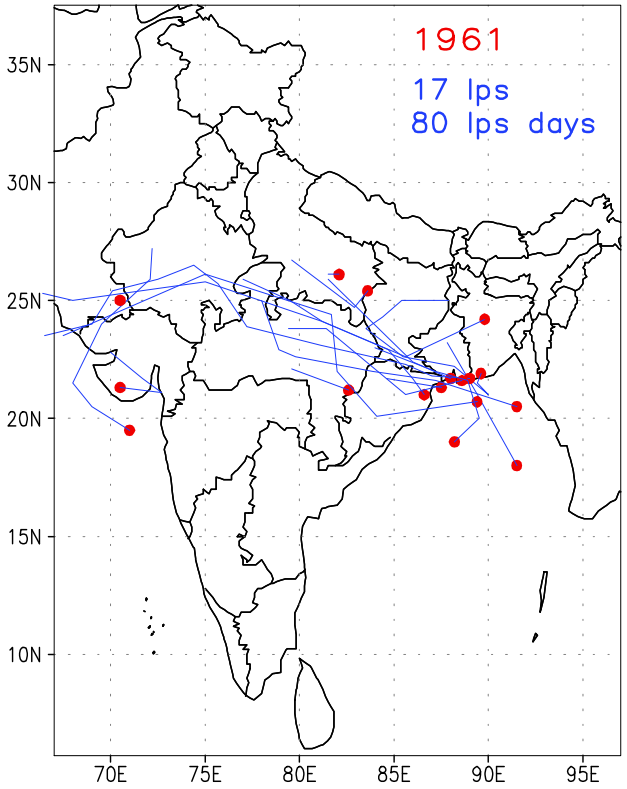
- ✓ Strongly peaked near the LPS center (~500kms)
- ✓ Concentrated towards southward and westward of the LPS center
- ✓ ~62% of ERE is LPS related, if we categorize ERE as LPS related if they occur within ±5°
- ✓ Probability of ERE occurring near individual LPS has decreased in recent decades
- ✓ Net effect is a 22% increase in LPS related ERE and a 2.5% increase in non-LPS related ERE

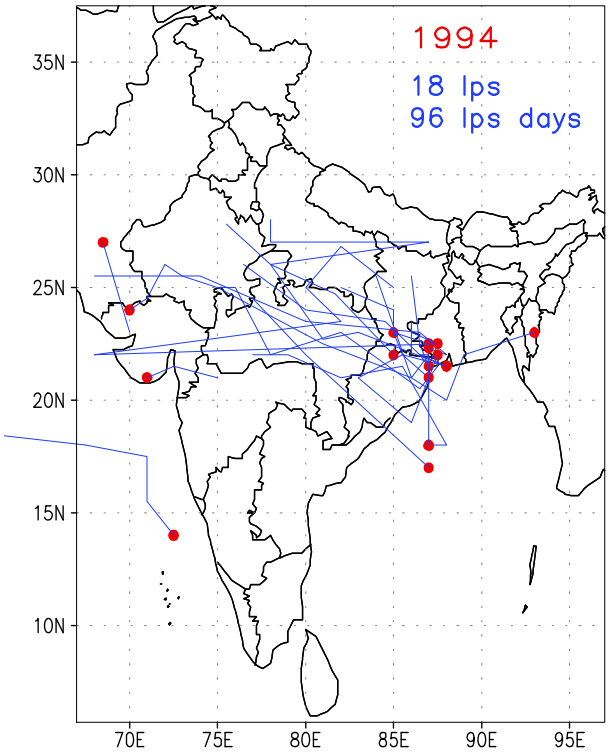



- ✓ Paths of LPS in years with high ERE incidence and low ERE incidence

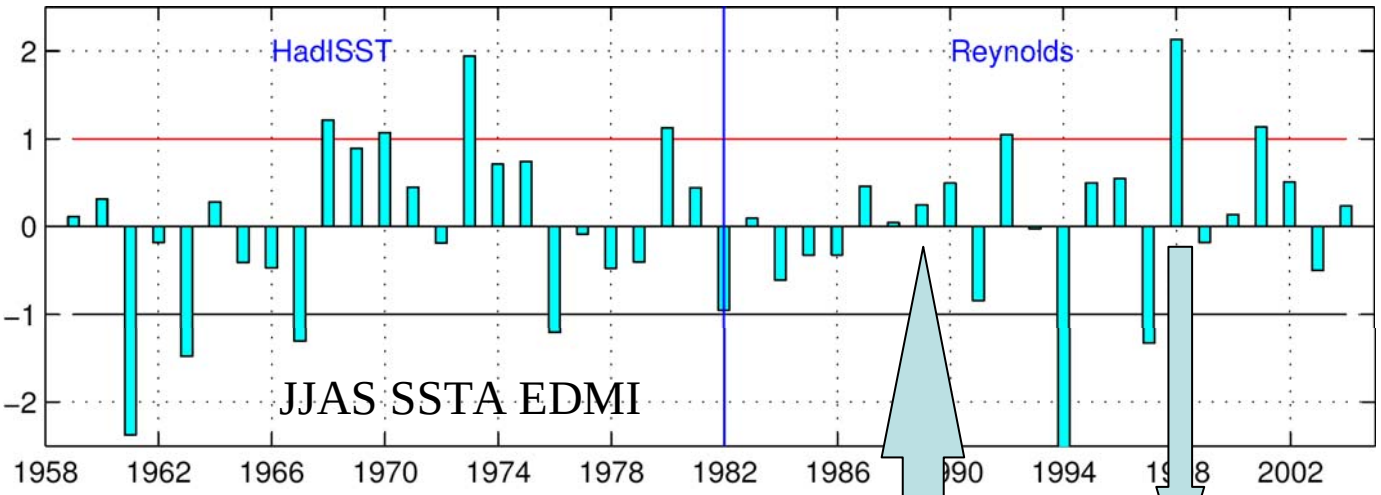
# LPS & IOD

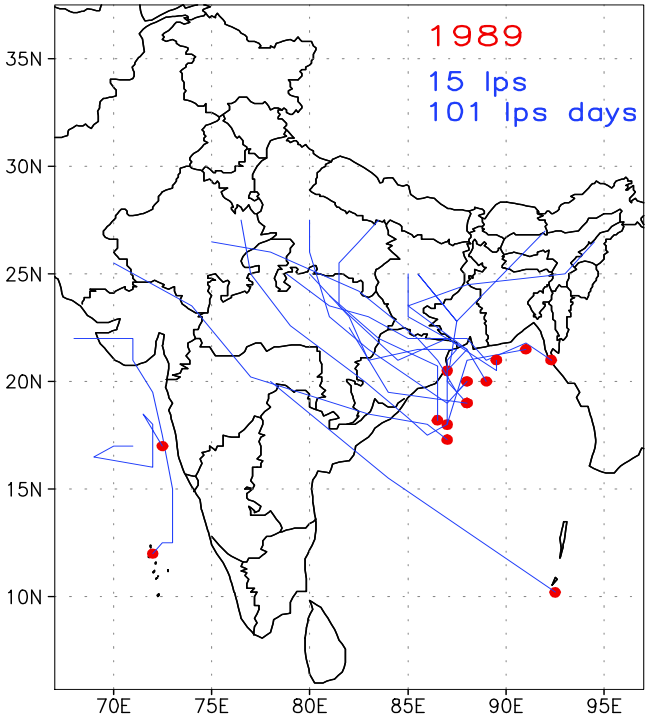

HadISST
Reynolds
JJAS SSTA EDMI
2
1
0
−1
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002

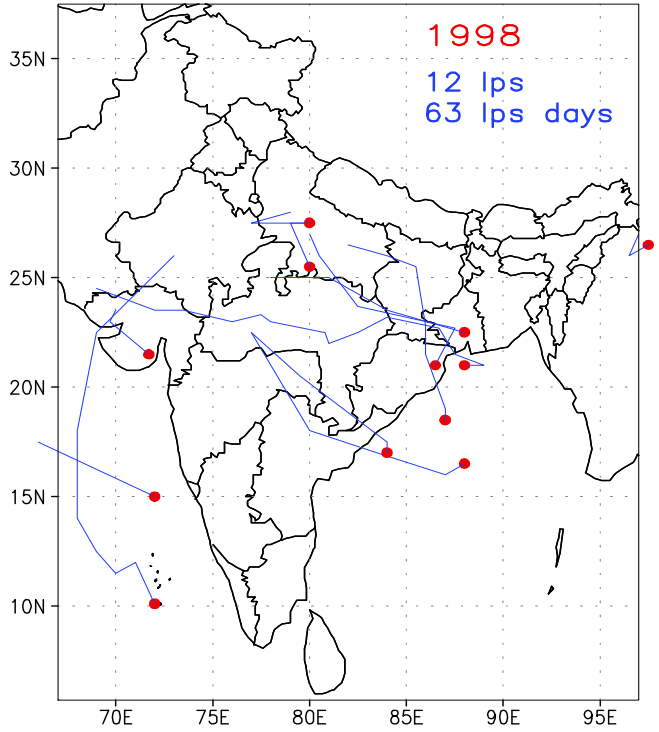

1961
17 lps
80 lps days
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E


1994
18 lps
96 lps days
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E

# LPS & IOD


HadISST
Reynolds
JJAS SSTA EDMI
2
1
0
−1
−2
1958
1962
1966
1970
1974
1978
1982
1986
1994
2002


1989
15 lps
101 lps days
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E


1998
12 lps
63 lps days
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E

# Conclusions

- **Rainfall composite pattern of LPS days represent the most dominant pattern of precipitation variability.**
- **LPS and non-LPS days, yet another method for identifying active and break phases.**
- **Demarcation between flood and drought years based on LPS is not quite clear.**
- **Inter-linkage between scales, LPS (synoptic), active/break phases (intraseasonal) and monsoon trough (planetary) noteworthy.**
- **Synoptic activity increases (post 1950s), because of a rising trend in lows, which outweighs a declining trend in stronger systems.**
- **Strong association between rising trend in synoptic activity and frequency of extreme rainfall events.**

# Some Outstanding Issues

- How useful is the information about LPS (genesis and tracks) in monsoon prediction?
- Information of level of LPS activity in advance
- Representing LPS in numerical models
- Tracking LPS using satellites and track prediction algorithms