Understanding and forecasting of intra-seasonal extremes of southwest monsoon circulation and precipitation over India

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INDIA METEOROLOGICAL DEPARTMENT

OUTLINES

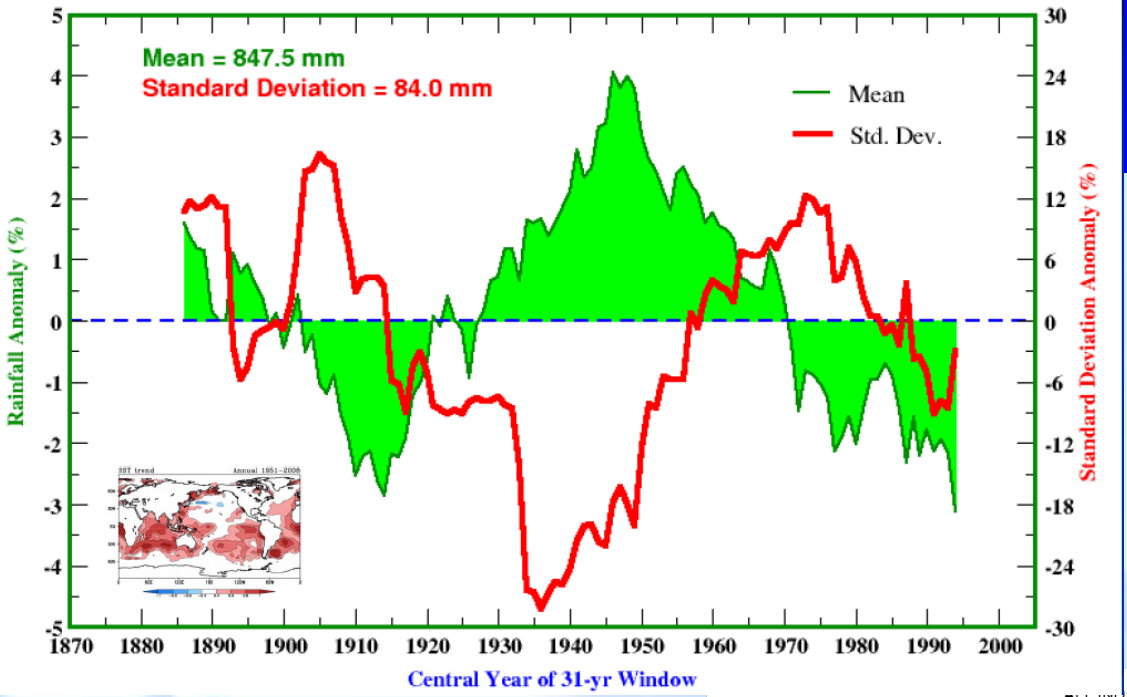
- *Introduction*
- *Intra-seasonal variability of southwest monsoon*
- *Extremes of southwest monsoon circulation and precipitation*
- *Monitoring of Intraseasonal extremes*
- *Prediction of Intraseasonal extremes*
- *Challenges and Opportunities*

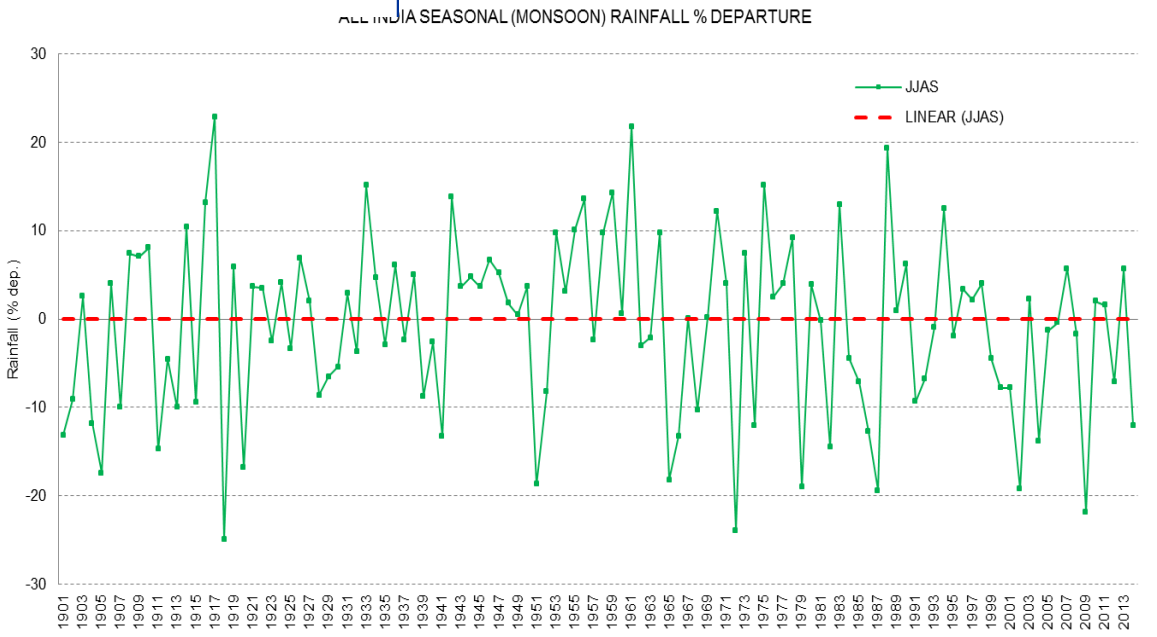
Time Scales of Monsoon Variability

- Interdecadal/epochal **variability of monsoon**
- Interannual variability:
  - **Variations on the annual cycle of the monsoon producing anomalously wet or dry years.**
  - **Generally influenced by sea-surface temperature variations associated with ENSO or inherent variability in the Indian Ocean.**
- Intraseasonal Variability:
  - **“Envelopes”: or clusters of weather events leading to DIFFERENT SCALES OF INTRASEASONAL VARIATION.**

Observed rainfall trend over India

Source: IMD (2014)





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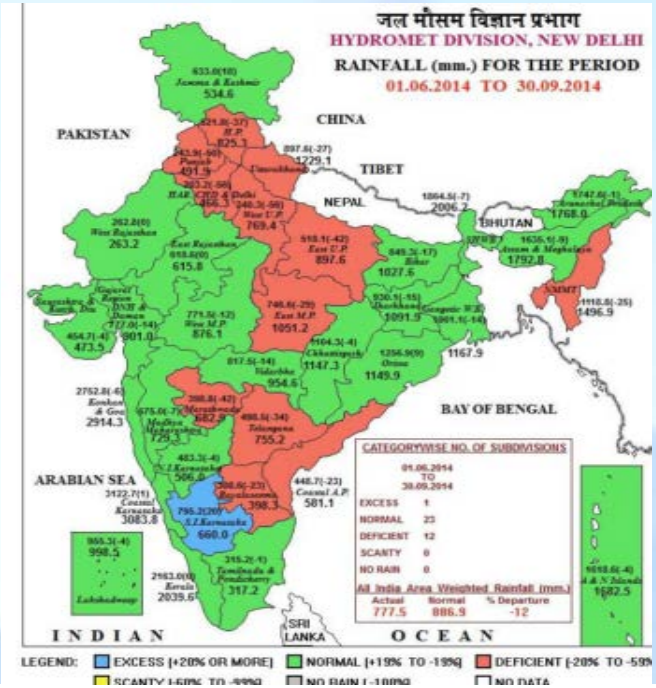
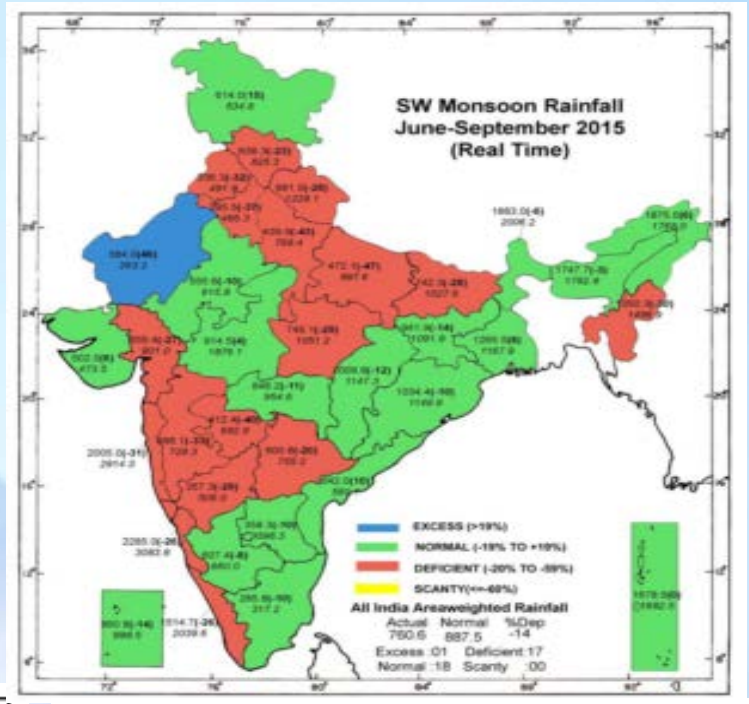
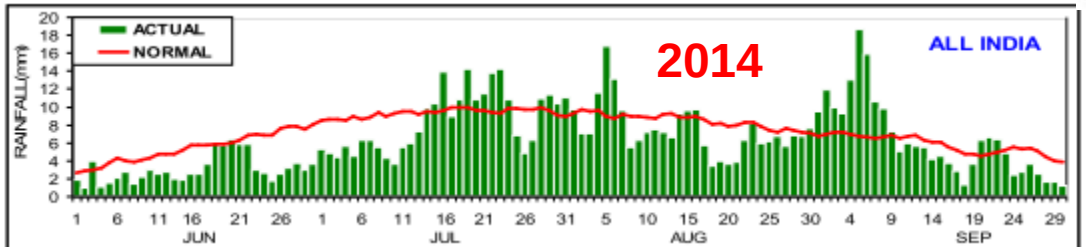
Intraseasonal variations

2014
-12%



2015
-14%





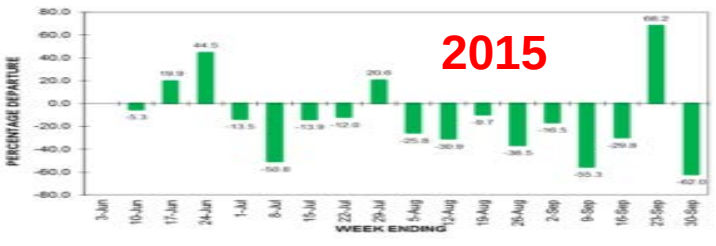
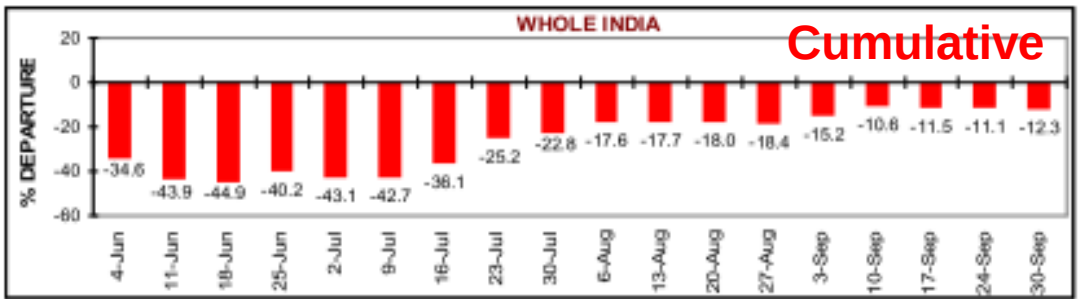
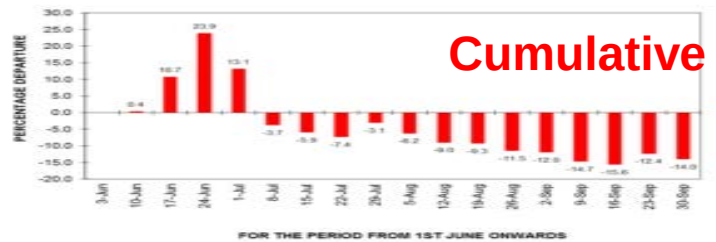


Fig.7: Week - by - Week Progress of the Monsoon Rainfall – 2015





Intraseasonal Oscillations

Tropical weather including Monsoon is a process involving motions consisting of multi-scale in space & time :-

(i) Synoptic : 2-5 days (short to medium)

(ii) Bi-weekly : 10-20 days

(iii) MJO : 30-60 days

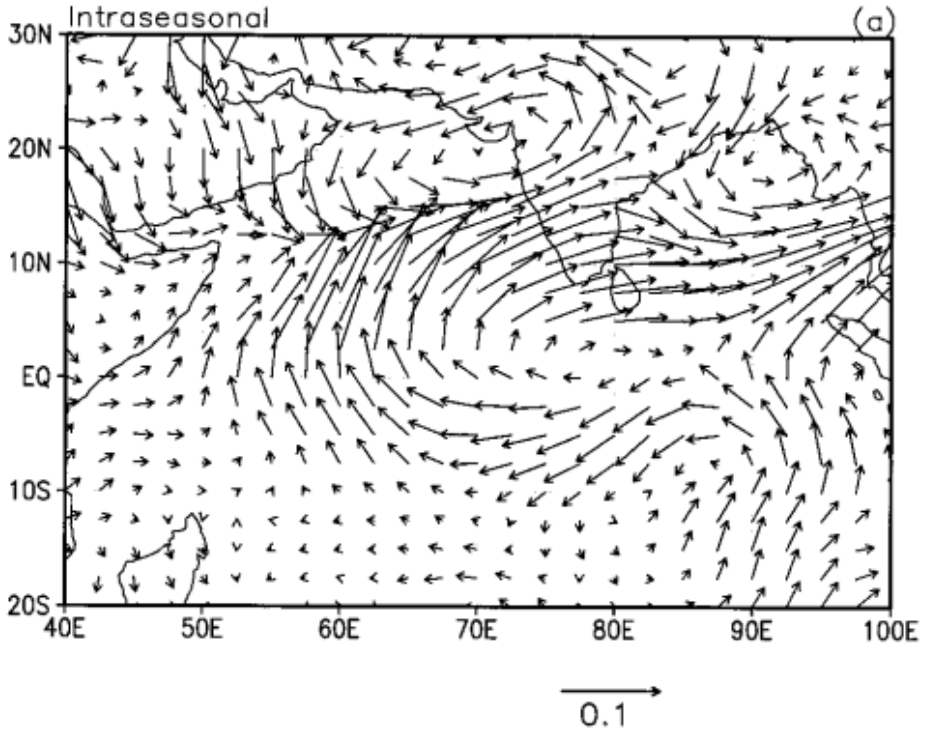
(iv) Seasonal : 90-120 days (Long range)

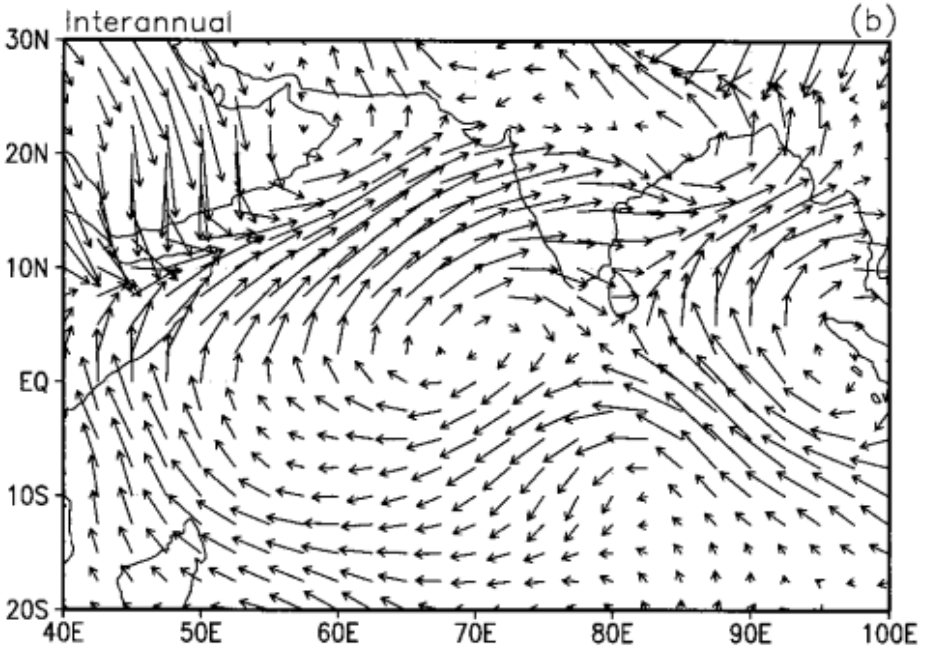
(i) & (ii) and (iii) are the building blocks for the seasonal total rainfall. Thus, there is a need to enhance the forecasting capability of monsoon in all the scales.

Intraseasonal and interannual variability

- The duration and frequency of the INTRA SEASONAL OSCILLATION determines the interannual variability
- active/break spells within a particular monsoon season contribute to the seasonal mean and thus modulates the interannual variability.

- Goswami and Mohan, 2001,
- Suhash et al, 2010





Intraseasonal Extremes

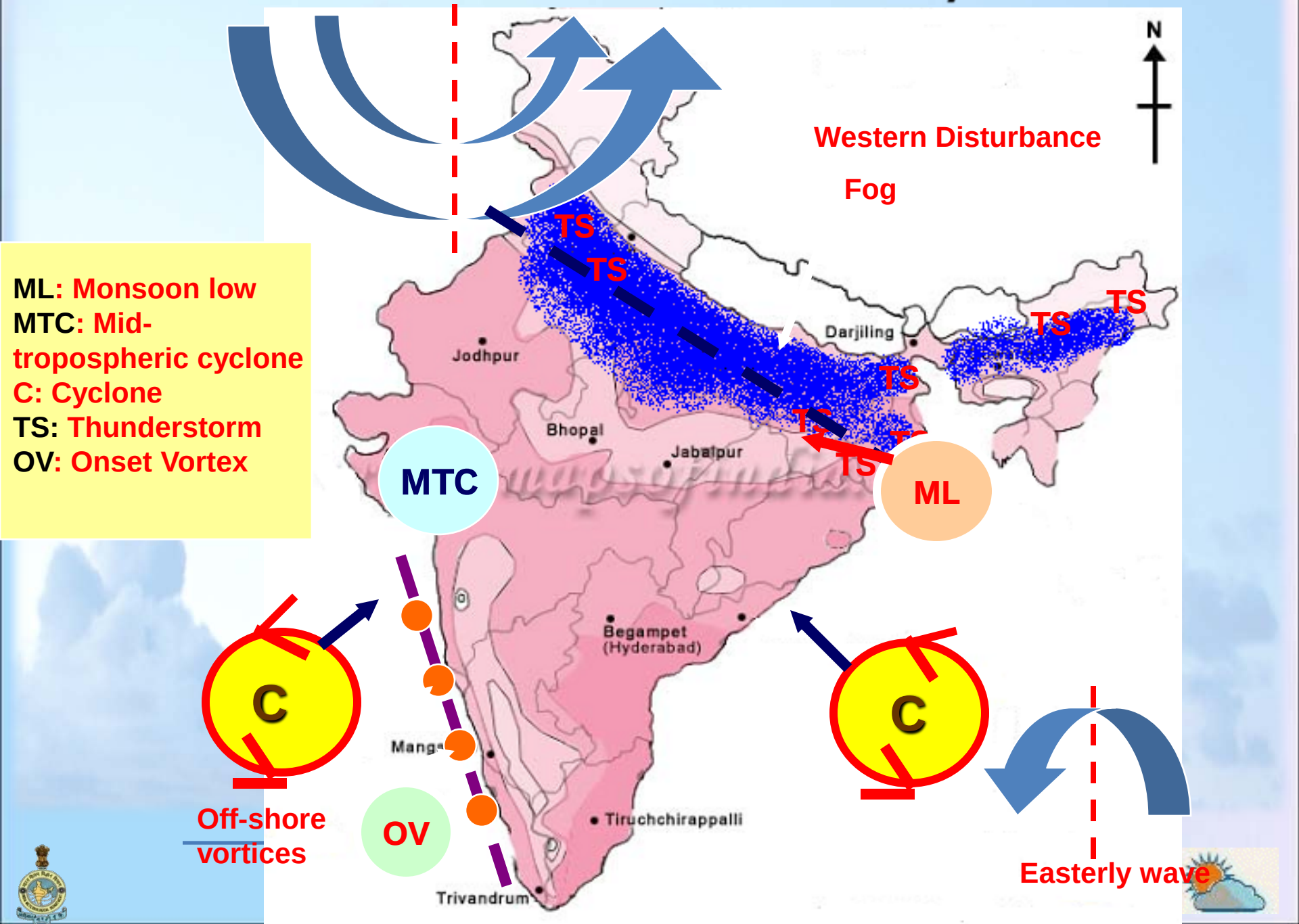
- **Extremes of Monsoon circulation**
  - **Active Break Cycle (Monsoon Trough Oscillation)**
  - **Low pressure systems**
  - **Mid-latitude interactions**
- **Extremes of Precipitation**
  - **Dry spells and wet spells**
  - **Heavy rainfall leading to riverine flooding**
  - **Heavy spell leading to urban flooding**

Intraseasonal variability : Active-Break Cycle

The active/break cycles are link to :-

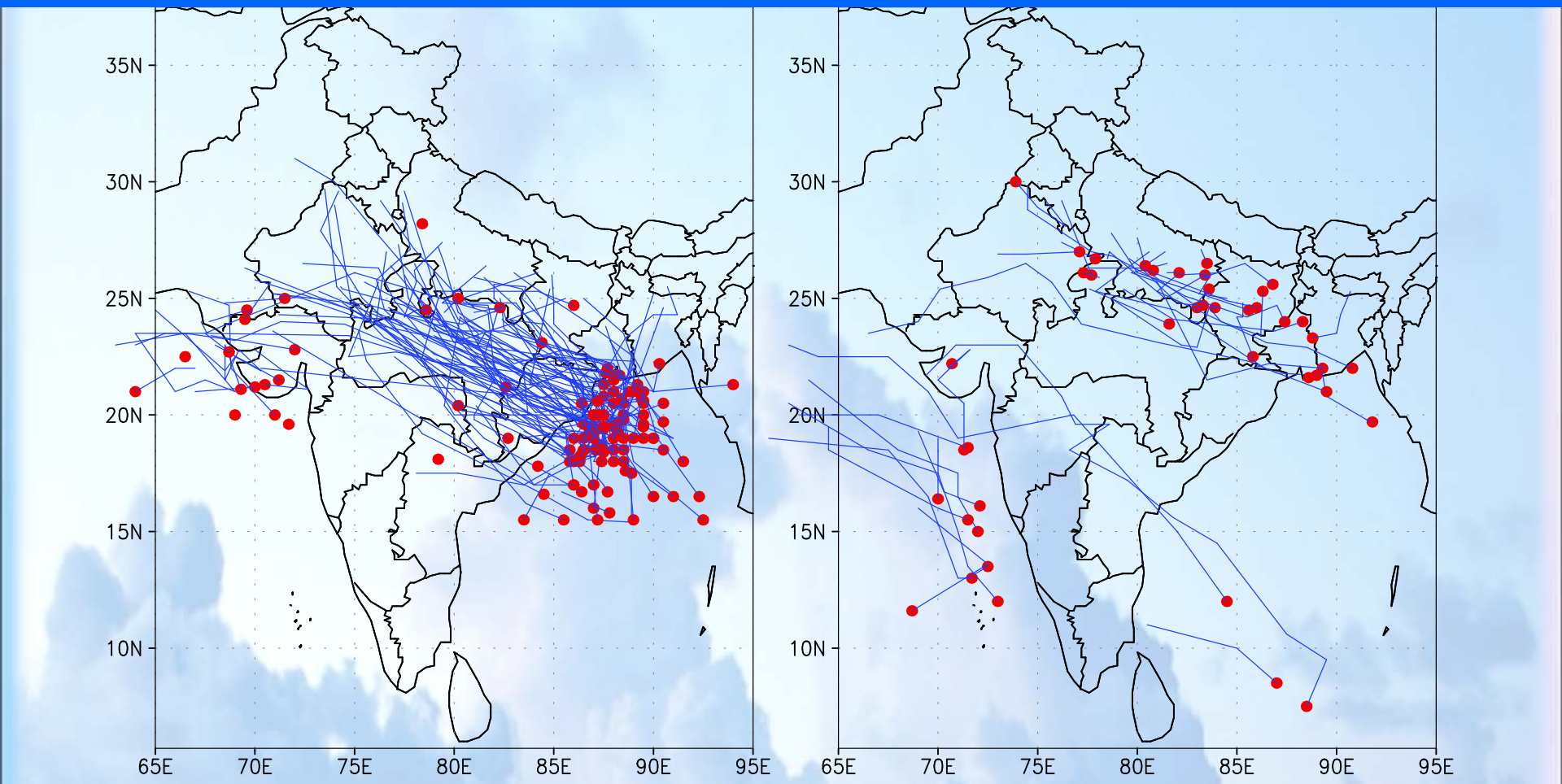
- ❖Oscillation of monsoon trough
- ❖Penetration of midlatitude westerly trough-monsoon break
- ❖Synoptic scale system over north Indian Ocean
- ❖Convection over southern equatorial Indian Ocean
- ❖Convection over NW Pacific/typhoon activity over the region

Location and Normal movement of weather System in India



INTRASEASONAL VARIABILITY AND

Low pressure systems

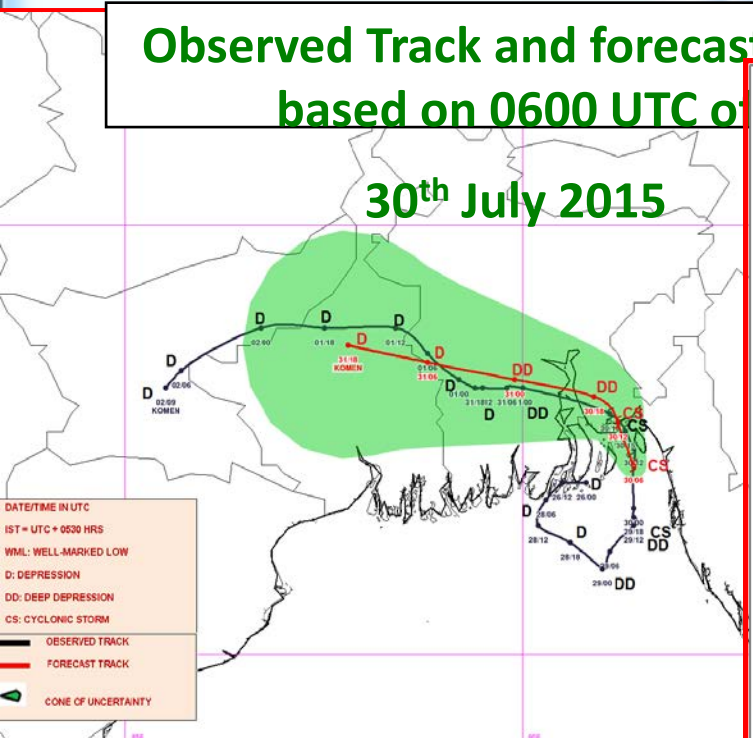


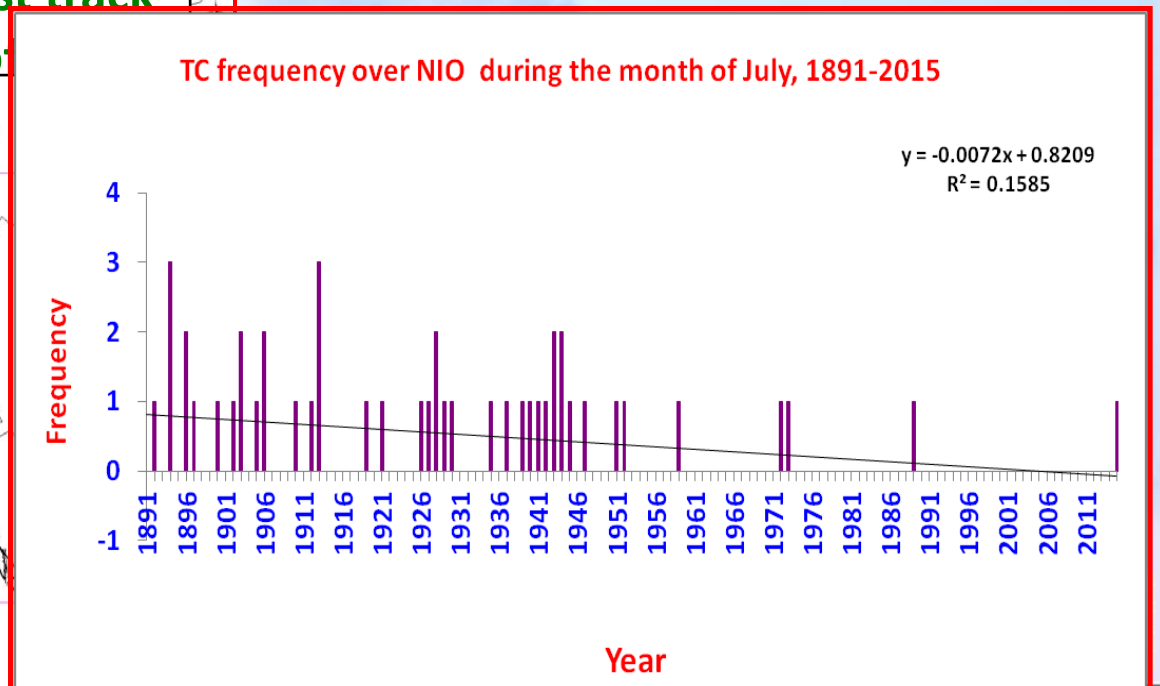
Excess Years **Deficient years**

Model has to forecast the track accurately for location specific heavy rainfall events

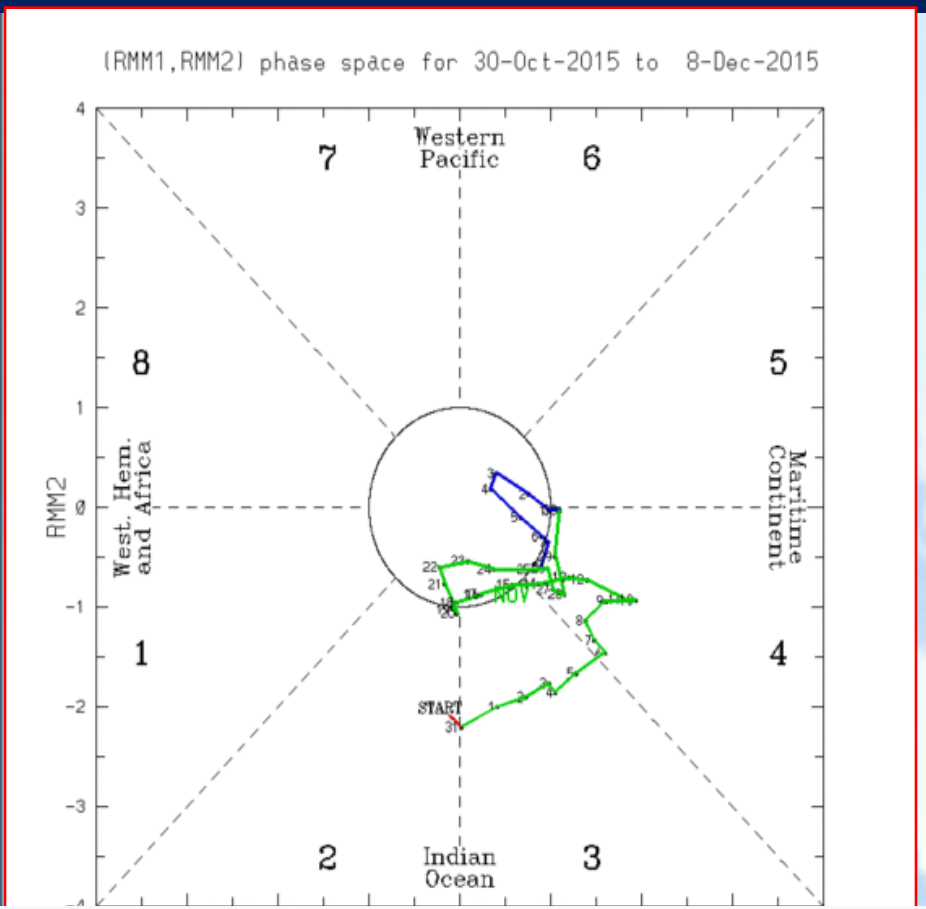
Intraseasonal extremes : Tropical Cyclones during monsoon season

- During the monsoon season, TCs generally form over the NIO during the onset and withdrawal phases.
- TC formation is minimum during the main monsoon months of July & August.
- During 2015, CS Komen formed on 26th July. Last such TC formation during the month of July was in 1989 (after 35 years).





Intraseasonal extremes (LPS) and MJO



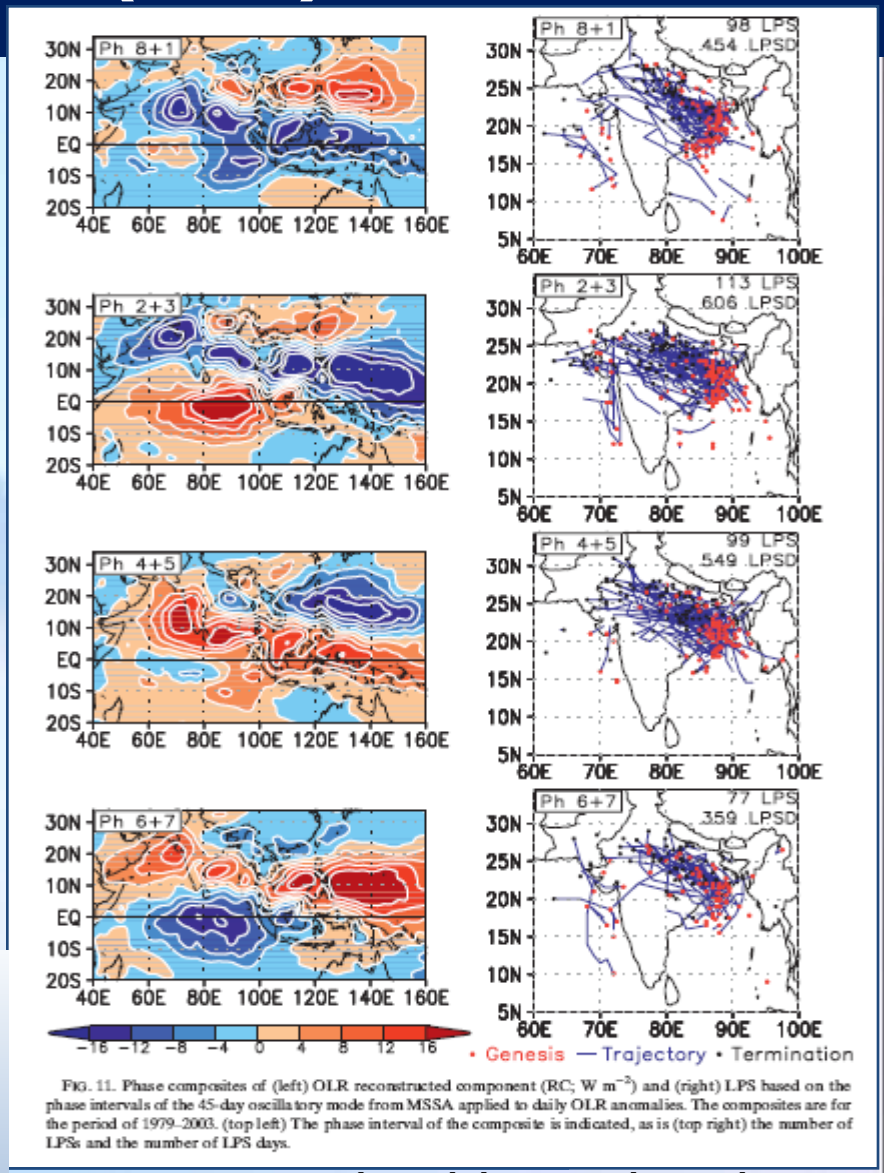


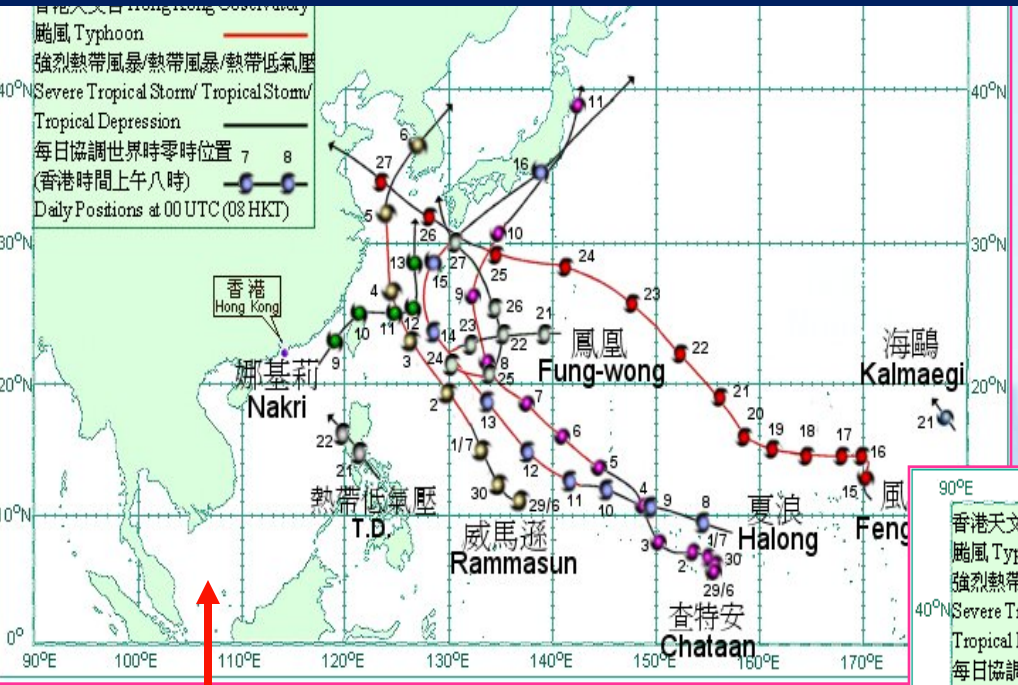
FIG. 11. Phase composites of (left) OLR reconstructed component (RC; W m^{-2}) and (right) LPS based on the phase intervals of the 45-day oscillatory mode from MSSA applied to daily OLR anomalies. The composites are for the period of 1979–2003. (top left) The phase interval of the composite is indicated, as is (top right) the number of LPSs and the number of LPS days.

MJO in phase 2-4 favourable for cyclogenesis over the NIO.

(Mohapatra and Adhikary 2011)

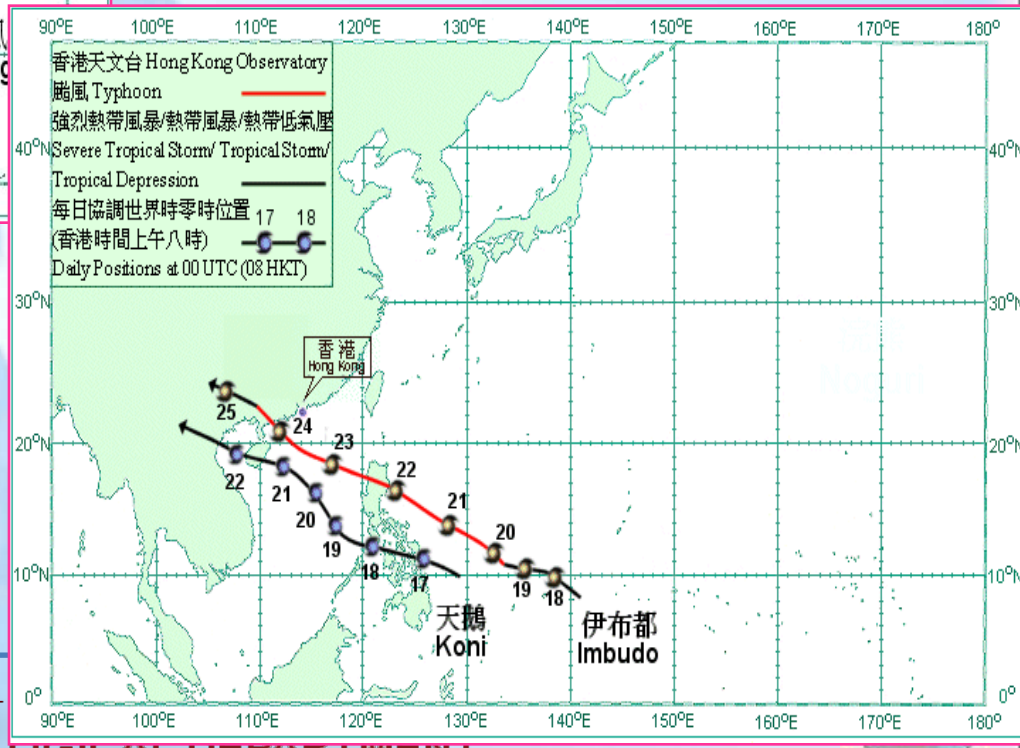
(V. Krishnamurthy and Ajayamohan 2010)

Intraseasonal extremes (LPS) and El Nino



July 2002

July 2003



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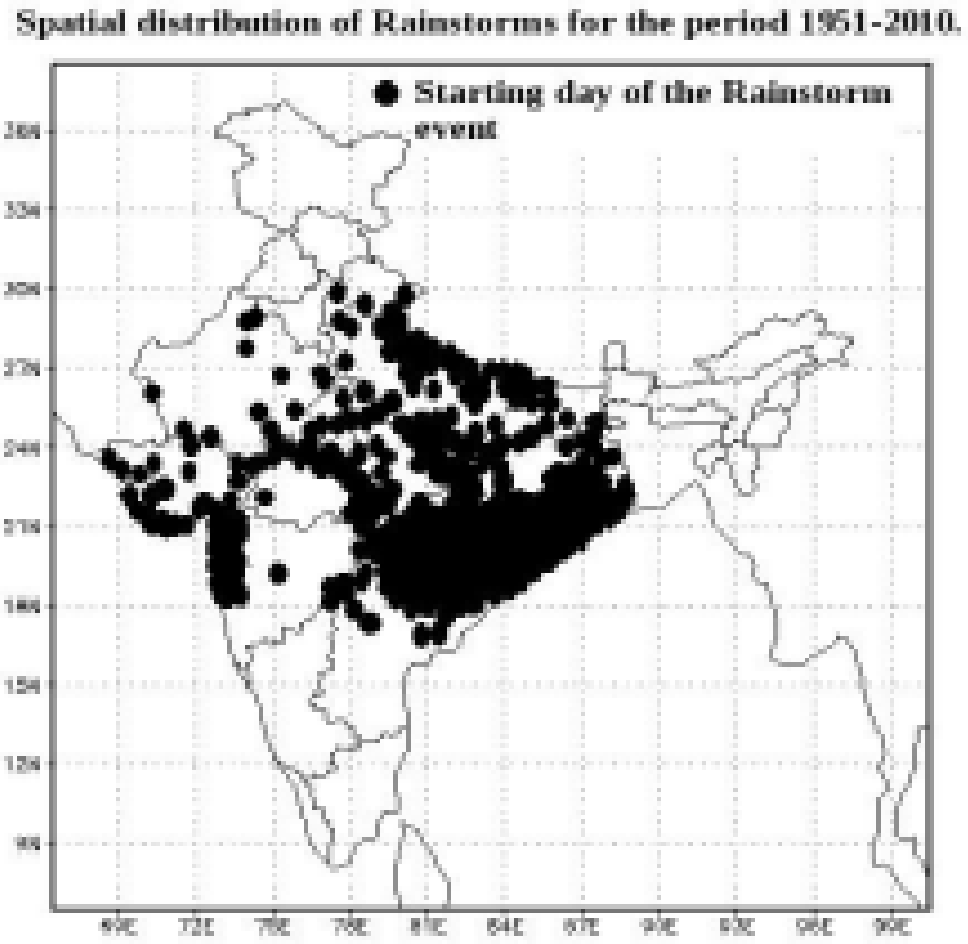
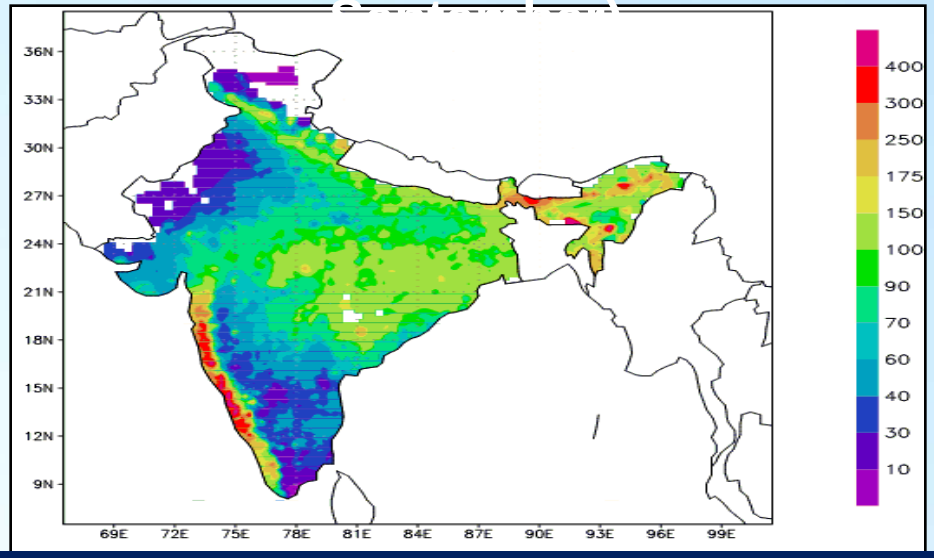
Origin of Rainstorms



Out of these 338 rainstorms identified during the monsoon season, 149 rainstorms (44%) over the Indian subcontinent were associated with monsoon depressions and above formed over the Bay of Bengal. Out of the 149 systems, 131 were monsoon depressions (max wind speed exceeding 17 knots), 14 Cyclonic Storms (CS) and 4 Severe Cyclonic Storms (SCS).

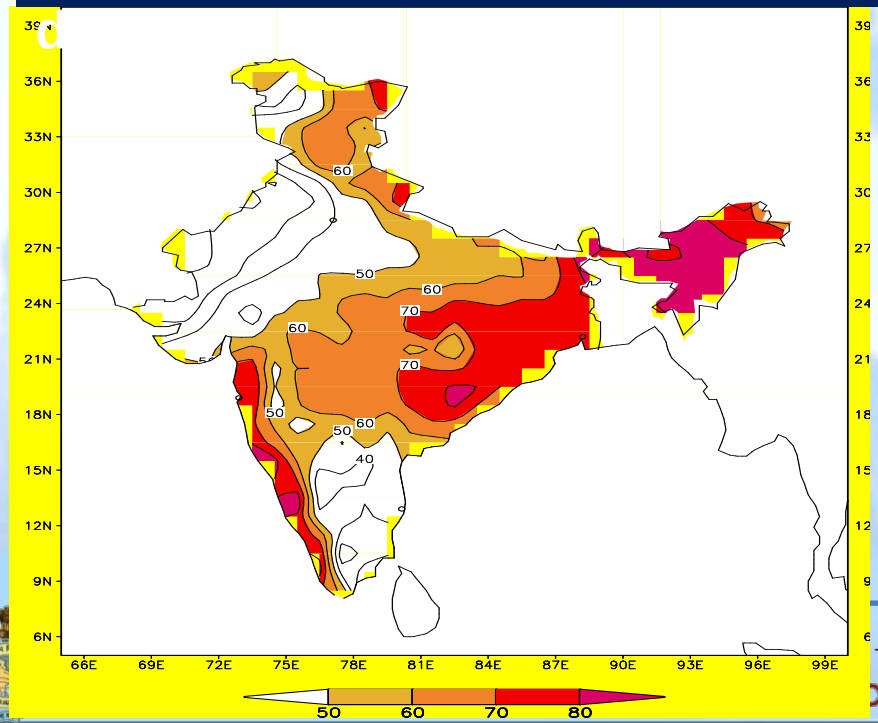
Karuna Sagar, M.Rajeevan and SVB Rao 2015, Natural Hazards

Indian Southwest Monsoon (June to

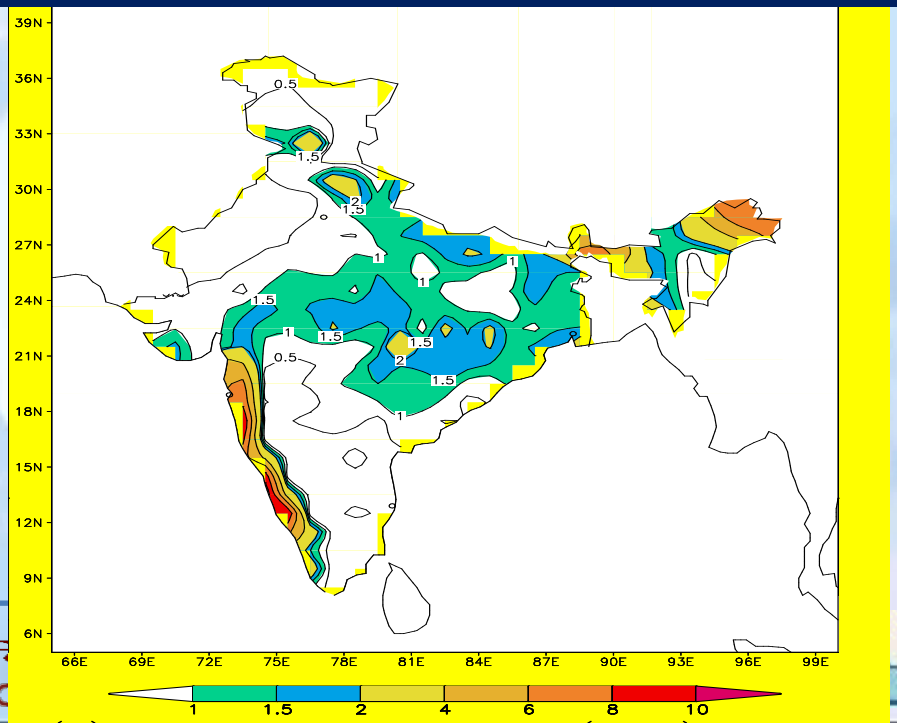


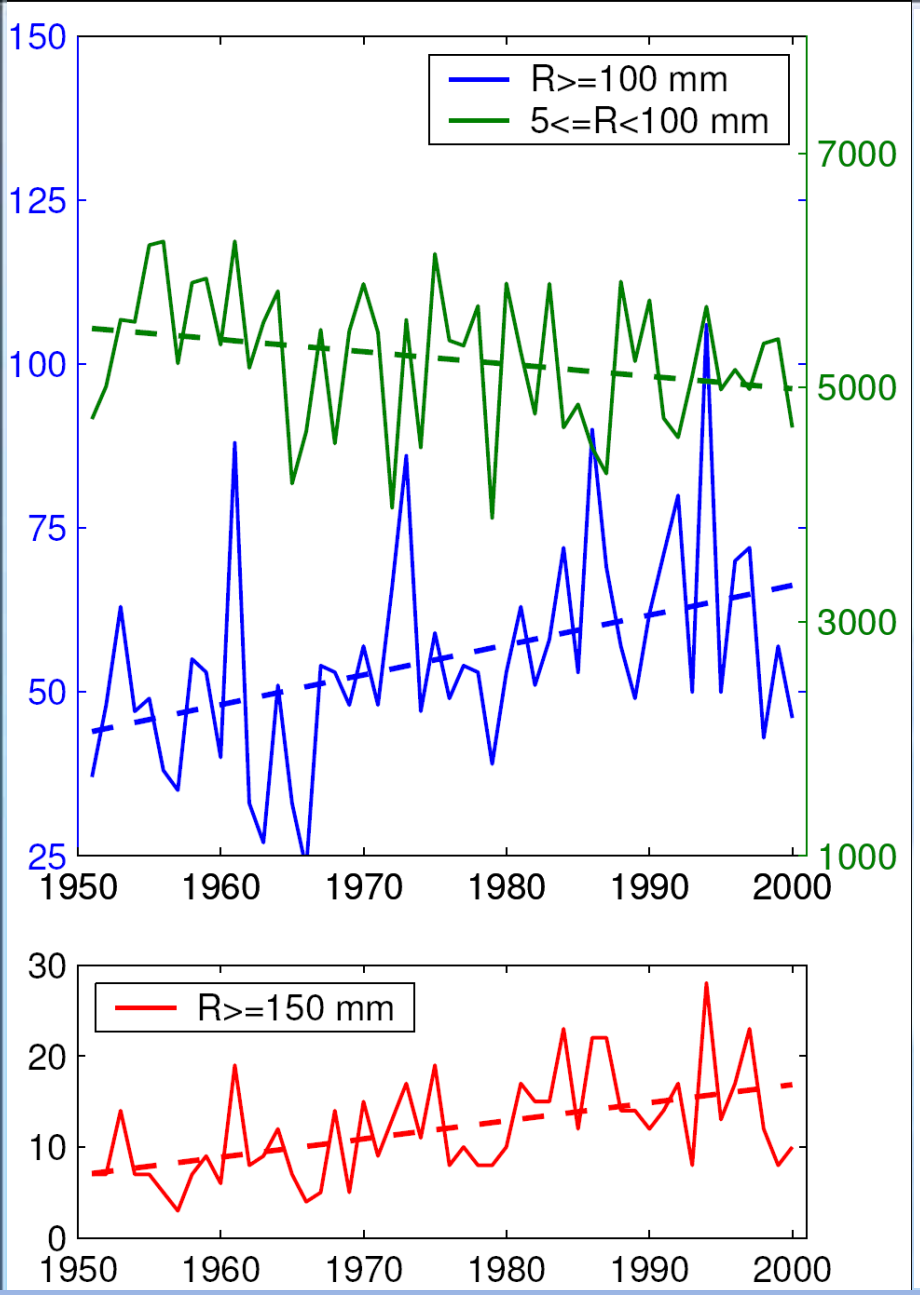
JJAS mean rainfall (cm)

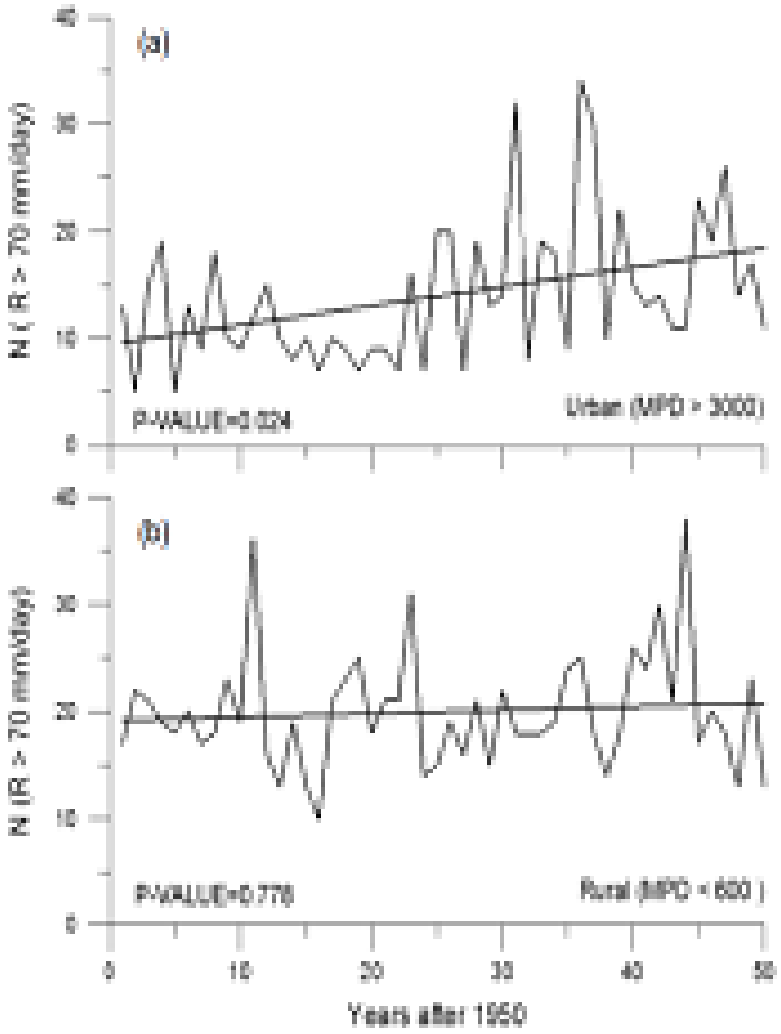
Mean % of Heavy rainfall days



Mean % of Very heavy rainfall





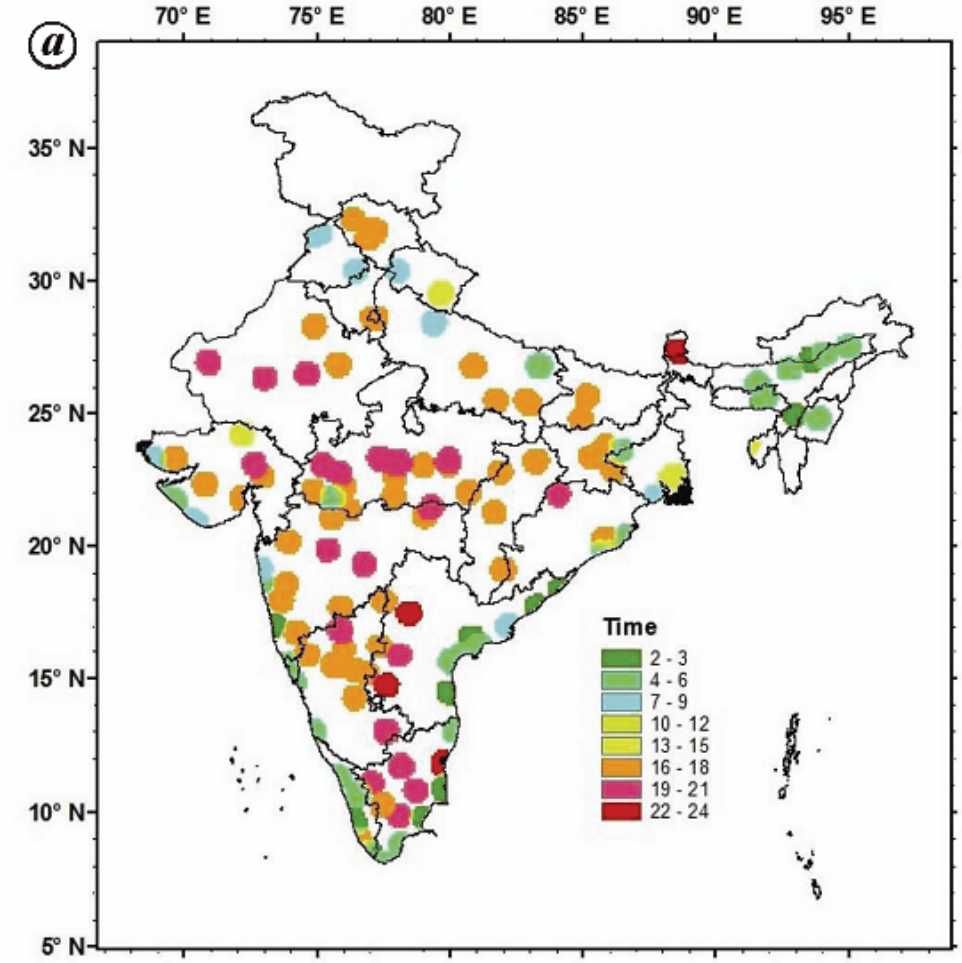


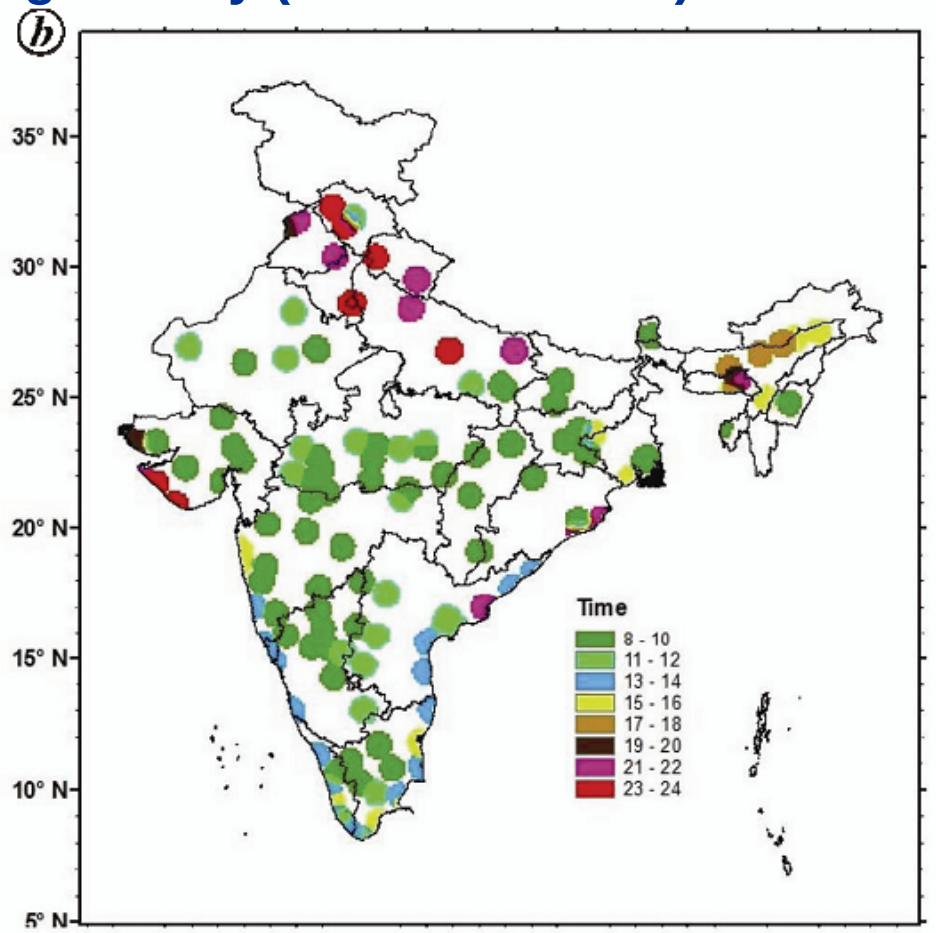
Kishtawal et al. 2010, Int J Climatology

Goswami et al, 2006
Pattanaik and Rajeevan (2010) Met. Appl.
Rajeevan et al., 2006

Intraseasonal Extremes : Heavy Spells

- Heavy spell leads to flash floods, especially in urban areas
- Time of occurrence of rainfall during the day (>0 and >30 mm)



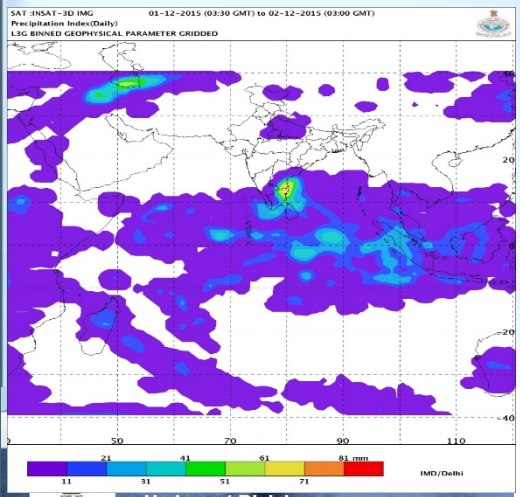


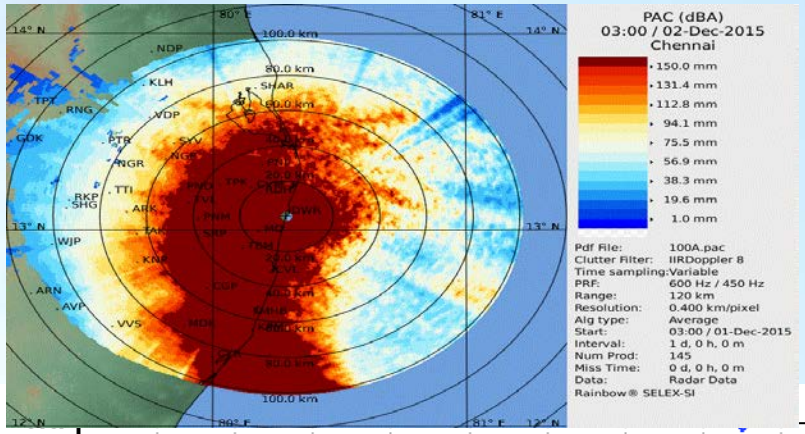
- Ray Et al, 2015 (Current Science)

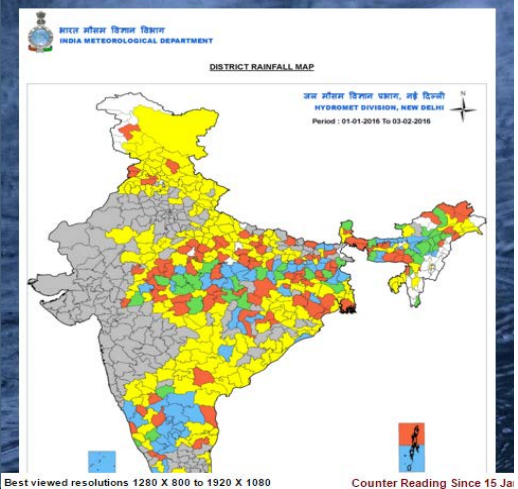
Existing Rainfall monitoring system and need

- Enhanced observational network (both direct and remotely sensed) alongwith merged dataset for monitoring every hourly
- Need for Meso network (1AWS/4 sq. km)

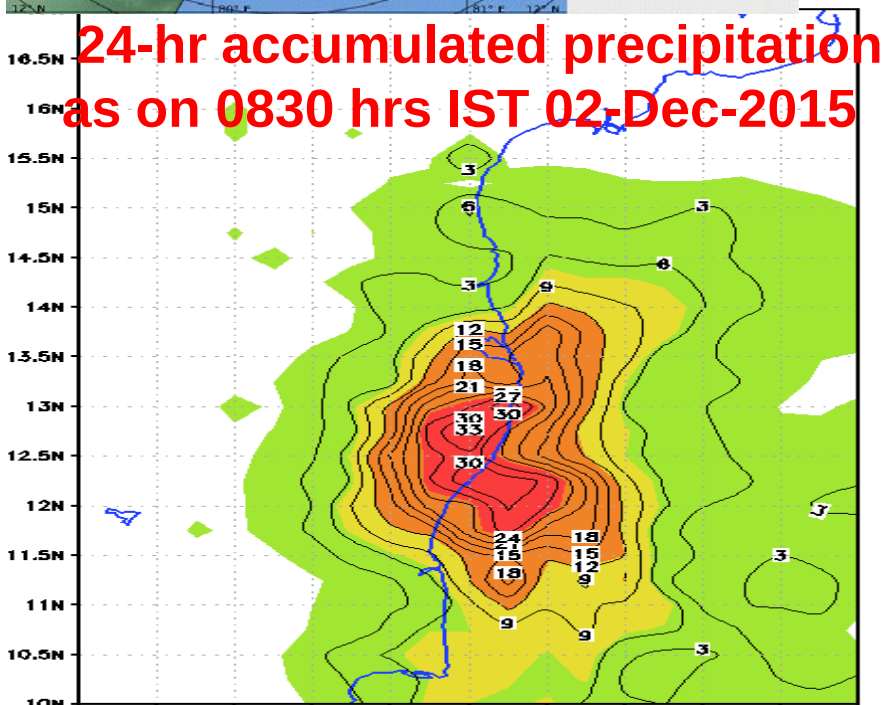
DWR Chennai – 24-hr rainfall, 02-12-2015/ 0830 hrs IST

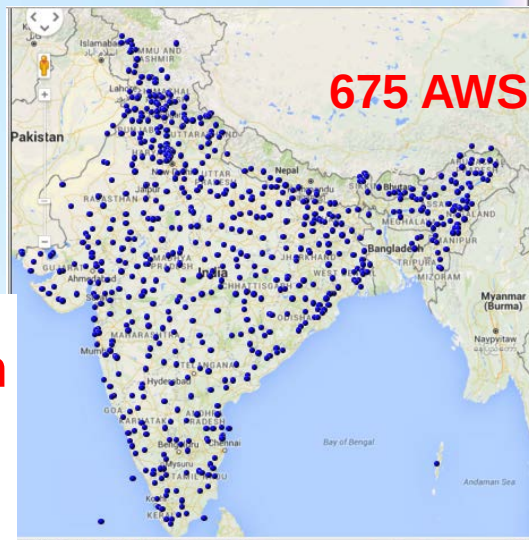


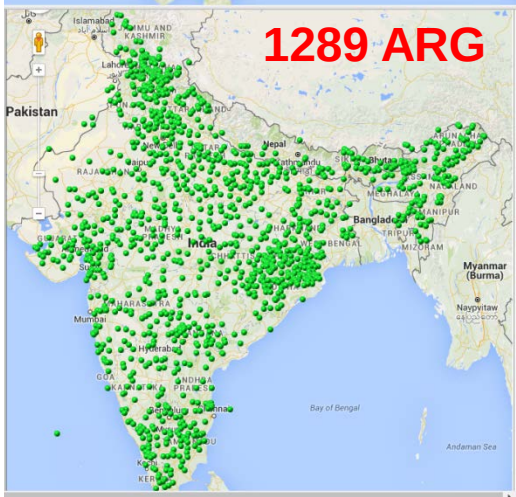




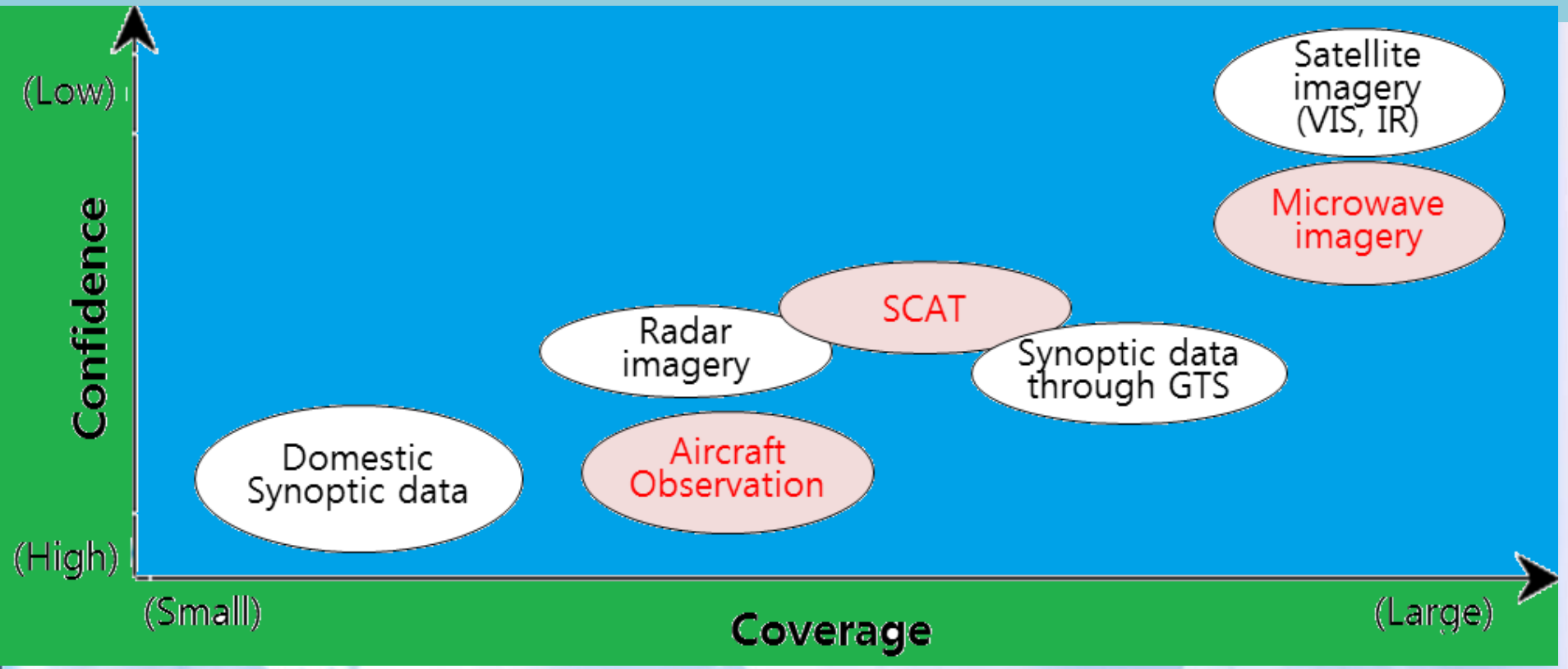
24-hr accumulated precipitation as on 0830 hrs IST 02-Dec-2015





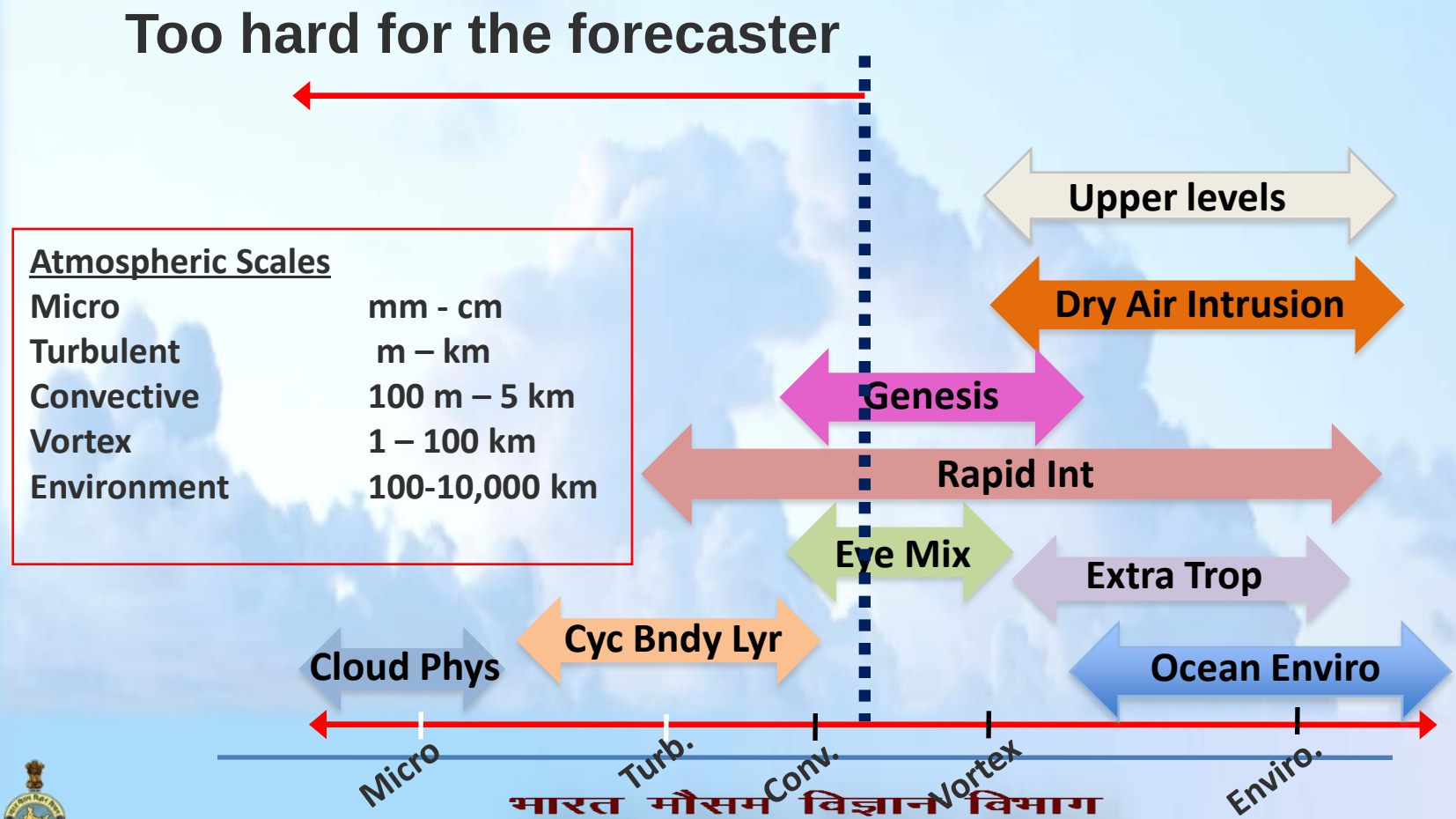


Monitoring of Intraseasonal Extremes



- **There is need for augmentation of observational network in land, Ocean and atmosphere**

Scales of Weather systems and Monitoring Requirement



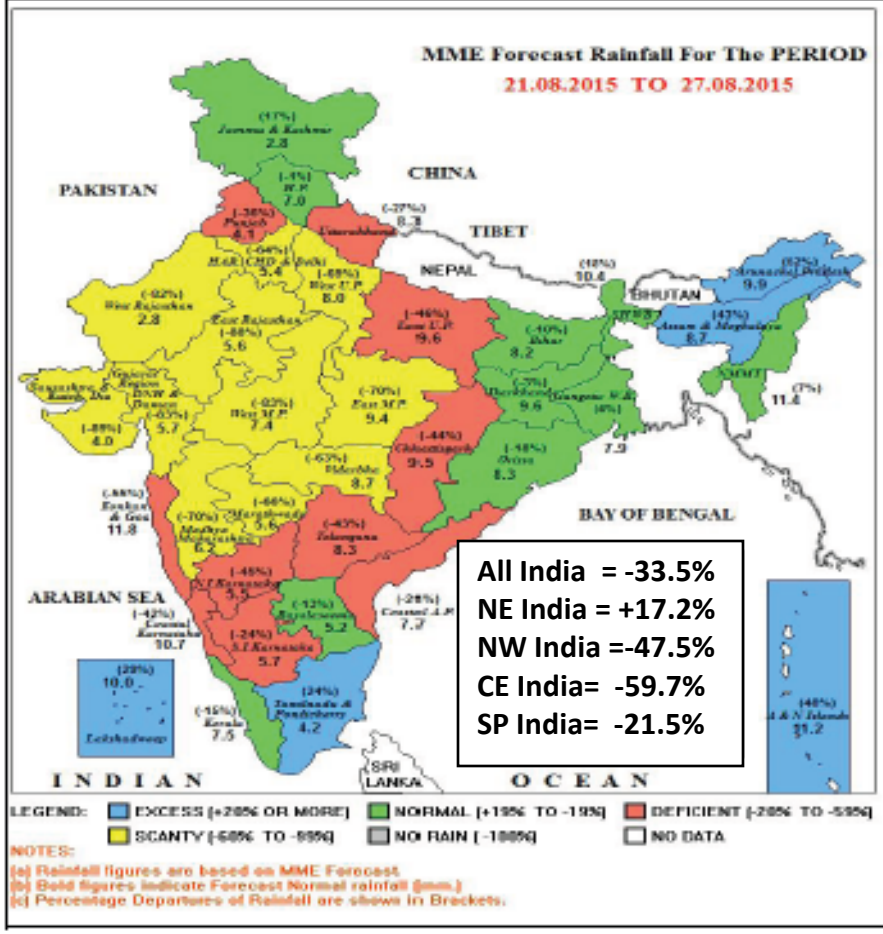
Future Requirements : Observation

Need for enhanced space based observations over data sparse regions through deployment of:

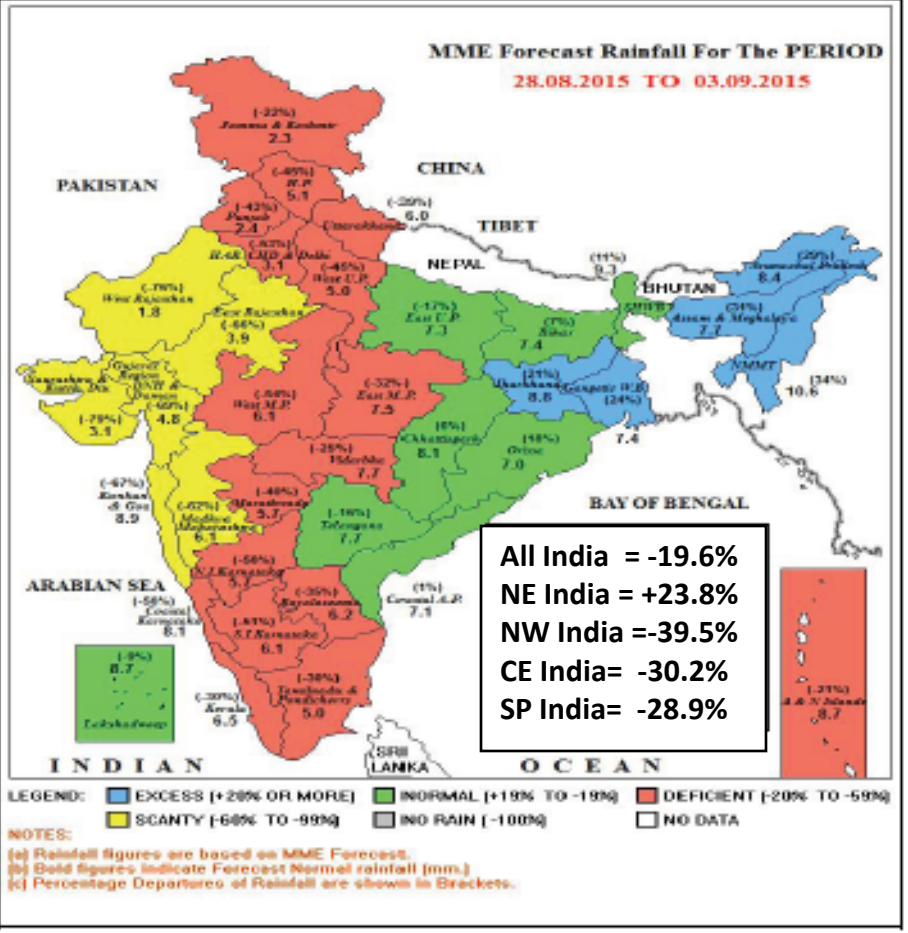
- **INSAT-3D (R) with Rapid scan facility (Advanced base line Imager) like Himawari**
- **array of Polar orbiting satellites (IEO and LEO) for high resolution data**
- **Geostationary satellite with microwave payload**
- **Scatterometry based satellite**
- **Multi-satellite derived wind**
- **Augmentation of satellite based marine observations**
- **GPS RO observations and networking with other global satellites**
- **GPM/Lightening detection/SMOS/LIDAR**
- **Increase in accuracy of vertical profiles**
- **High resolution soil moisture, evapotranspiration measurements**

Prediction of Dry Spells and wet spells: Met sub-division level forecasts for 2 weeks (IMD)

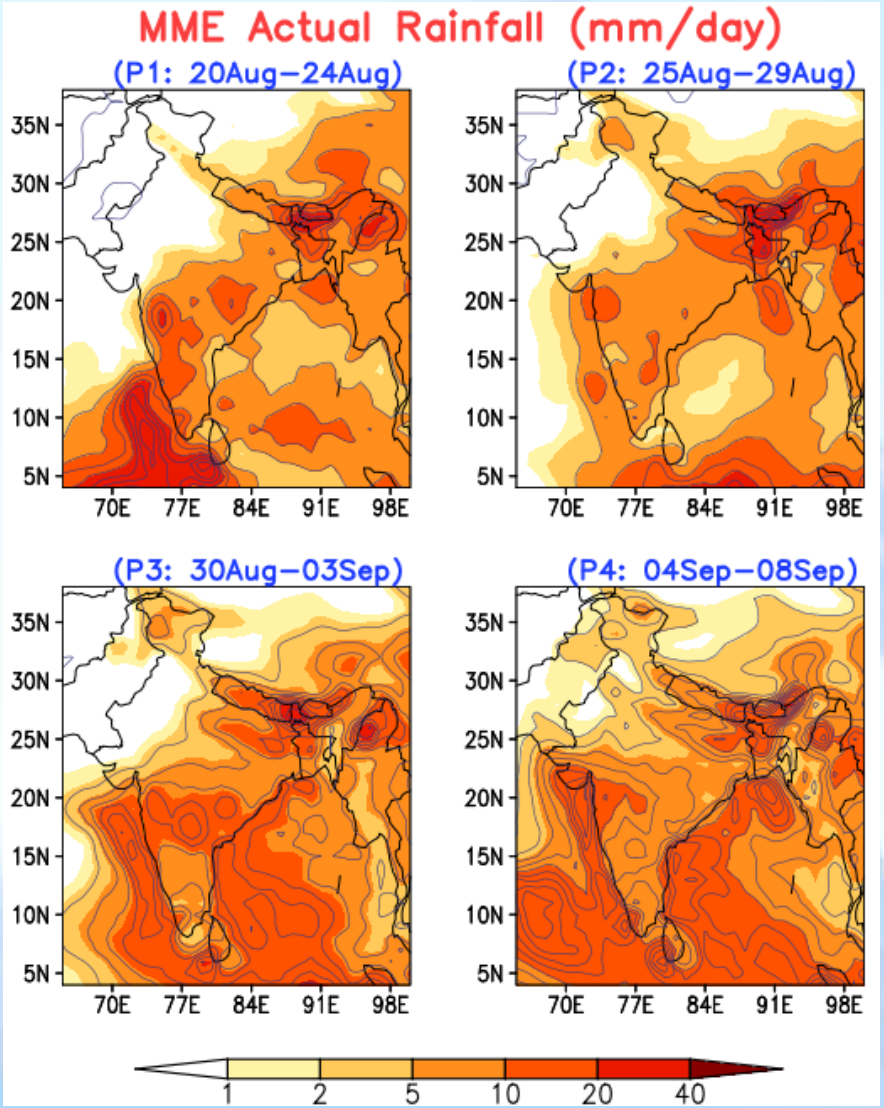
(a) Met. Subdivision rainfall forecast for week 1 based on 19 Aug, 2015 and valid for 21-27 Aug, 2015.

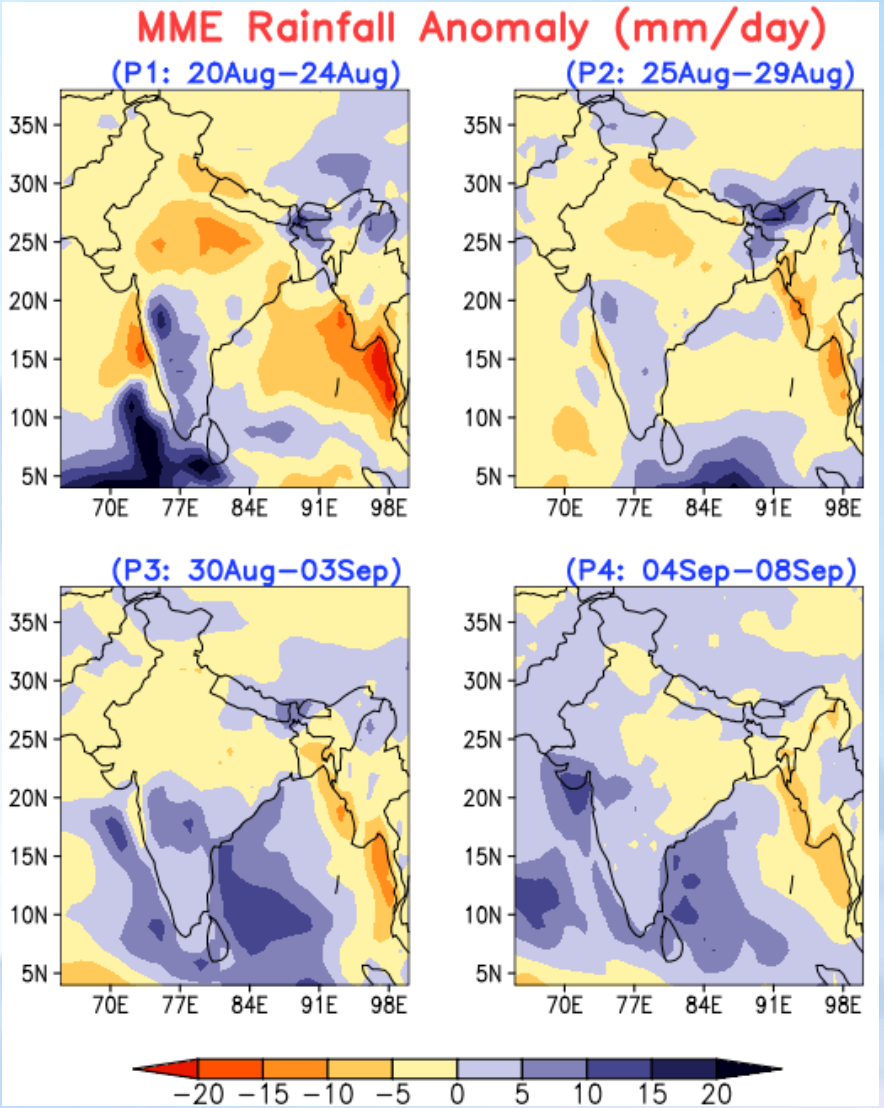


(b) Met. Subdivision rainfall forecast for week 2 based on 19 Aug, 2015 and valid for 28 Aug-03 Sep, 2015.



Pentad wise rainfall predicted by IITM (CFSv2 and GFS_bc)
Forecast for 4 pentads based on 19th August , 2015 IC





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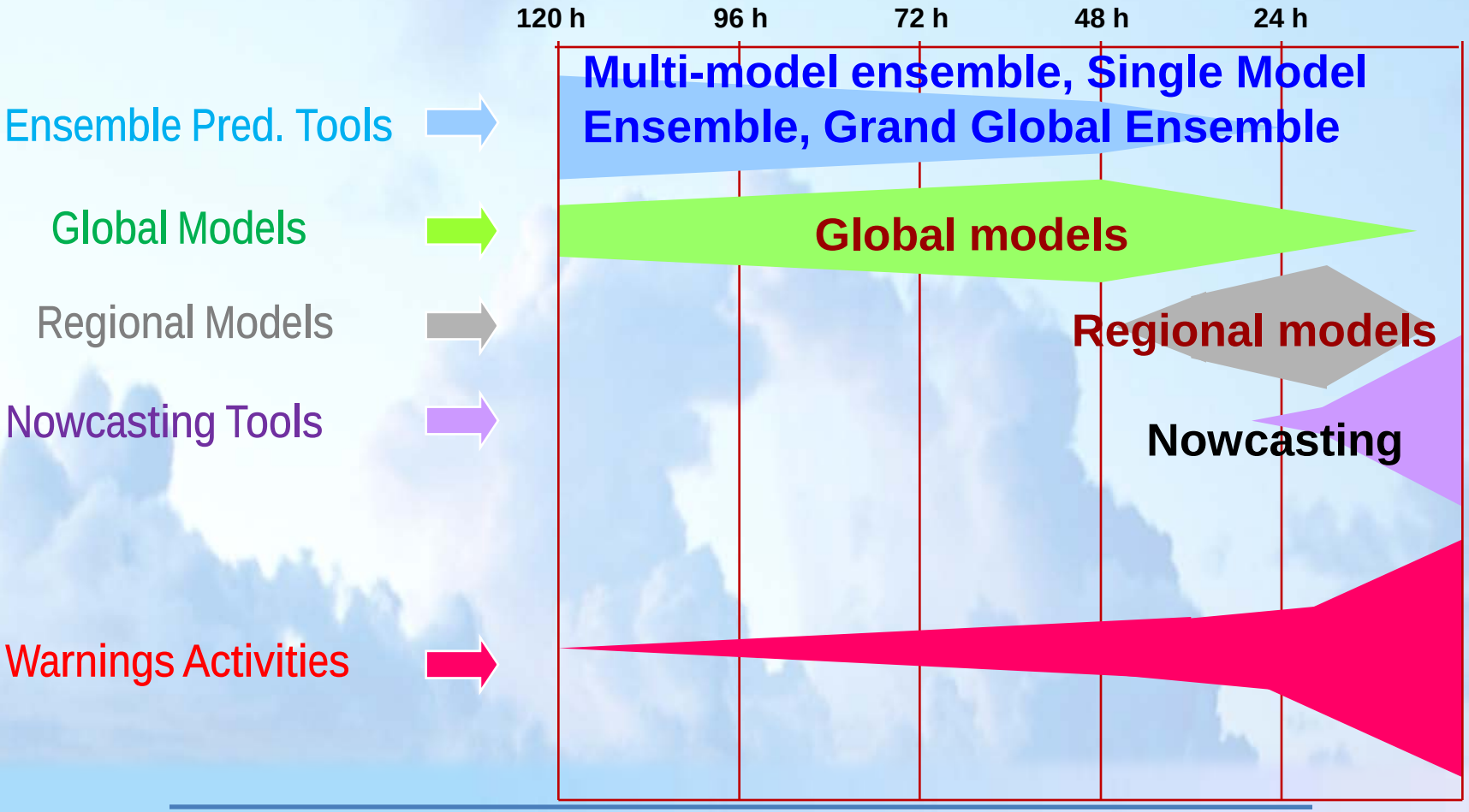
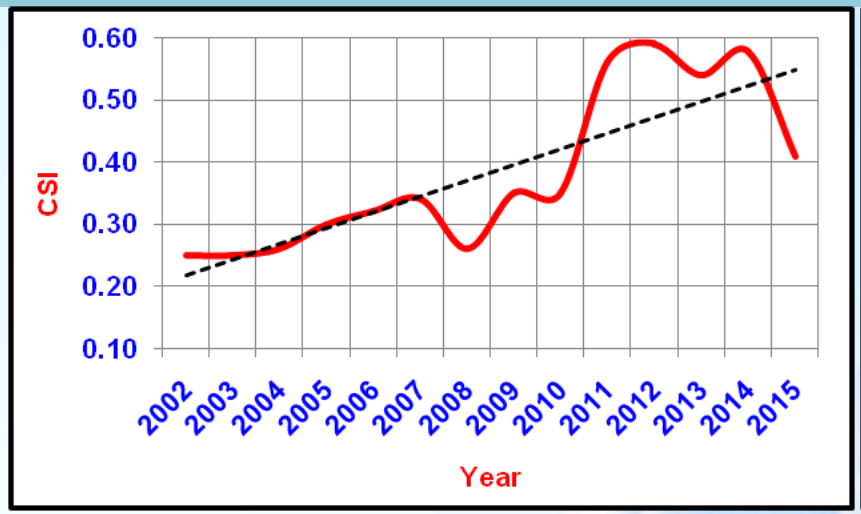
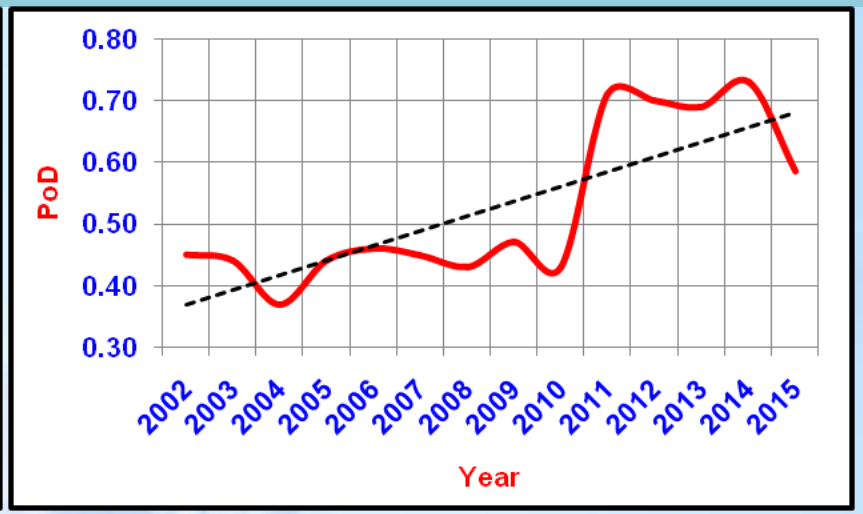
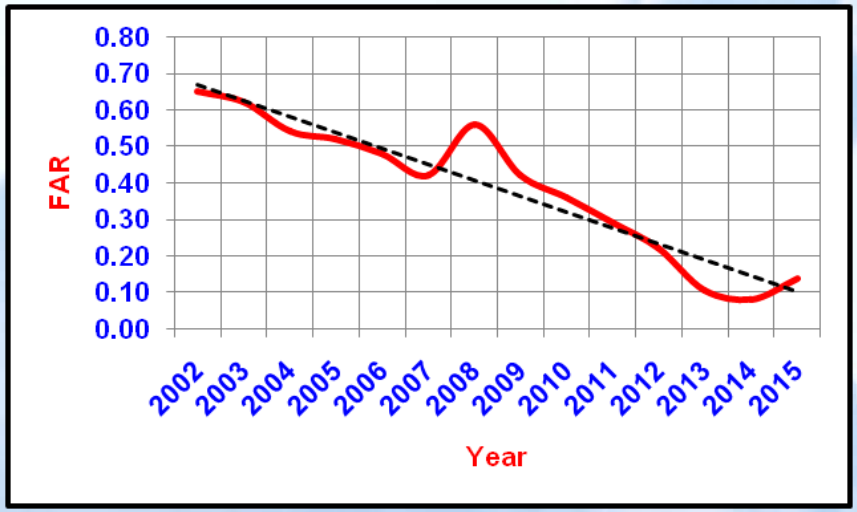
Numerical Weather Prediction (NWP) Modeling : Backbone for Early Warnings

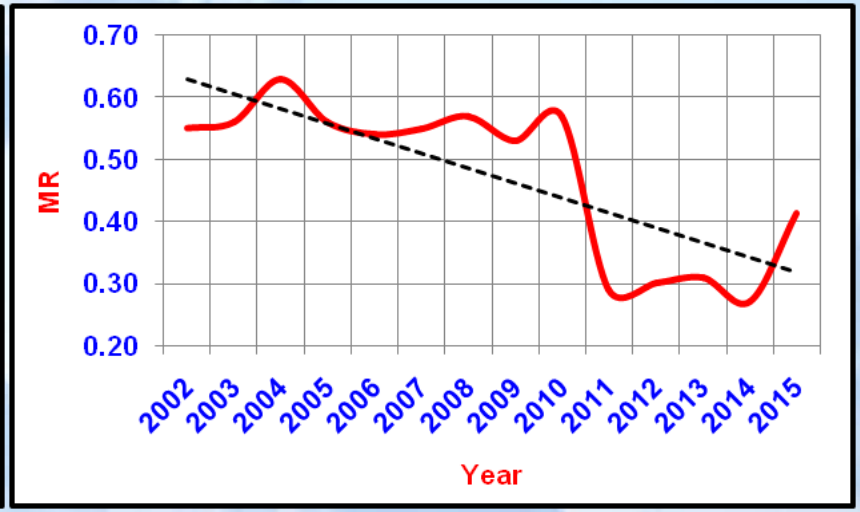


Trend in heavy rainfall warning (2002-15)









Heavy Rainfall (Phailin over Bay of Bengal)

Observed rainfall	24 hr forecast for hvy rainfall or higher and no heavy rainfall		Total	24 hr forecast for extremely heavy rainfall & no extremely heavy rainfall		Total
	YES	NO		YES	NO	
YES	15	6	21	2	0	2
NO	2	3	5	3	21	24
Total	17	9	26	5	21	26
POD	0.7			1.0		
FAR	0.1			0.6		
MR	0.3			0.0		
C-NON	0.6			0.9		
CSI	0.7			0.4		
BIAS Occ.	0.8			2.5		
PC (%)	69.2			88.5		
TSS	0.3			0.9		
HSS	0.2			0.5		

QPF: A Challenge (Phailin)

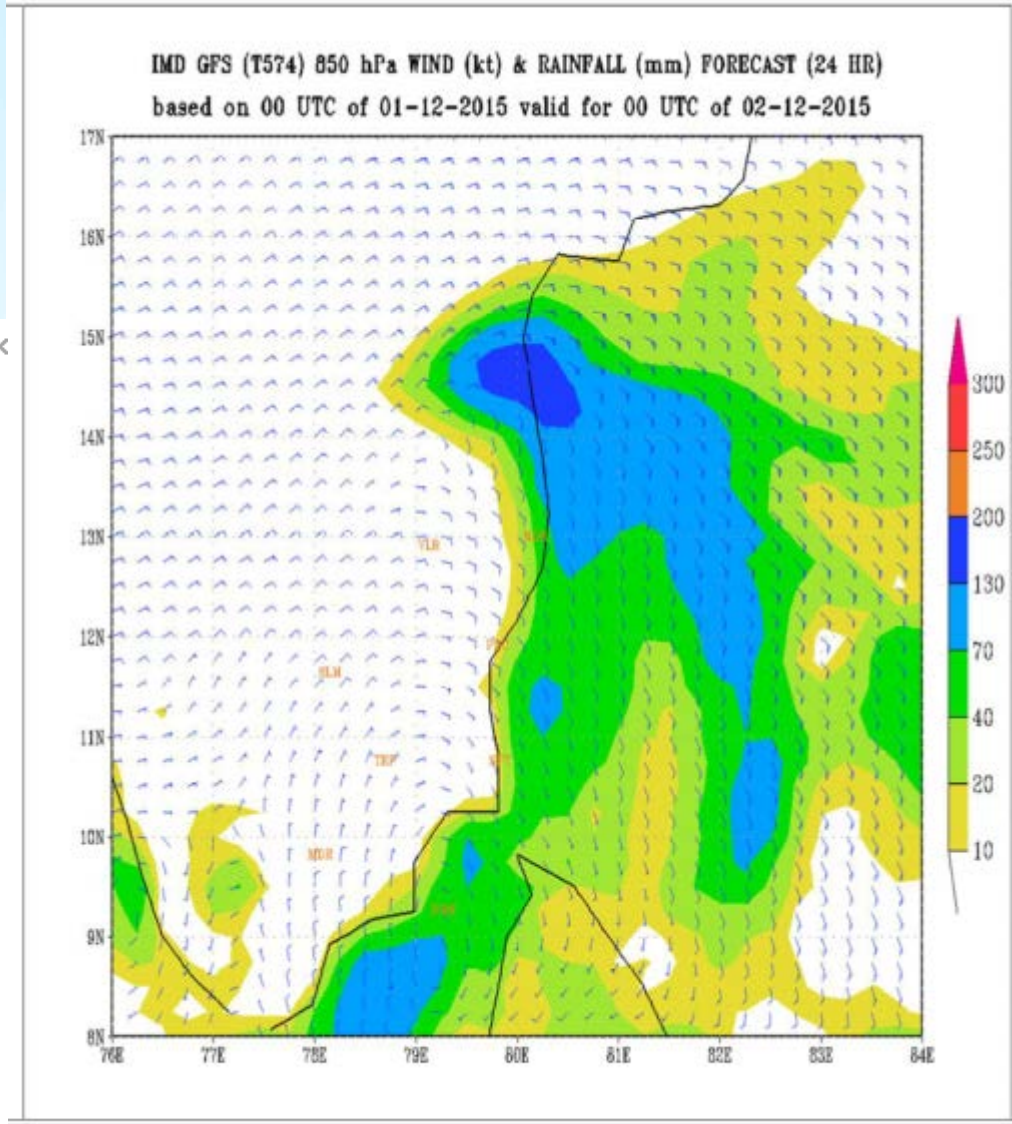
Sl. No.	Basin Name	24 hr QPF issued at 0300 UTC of 11-10-13		24 hr QPF issued at 0300 UTC of 12-10-13		24 hr QPF issued at 0300 UTC of 13-10-13	
		Fcst	Realized	Fcst	Realized	Fcst	Realized
1	Subrnarekha	11-25	11.1	38-50	63.3	>100	54.5
2	Burhabalang	11-25	22.3	38-50	98.6	38-50	46.4
3	Baitarani	26-37	26.8	51-76	114.5	51-75	36.6
4	Upp. Brahmani	11-25	2.5	26-37	32.4	>100	37.9
5	Low.Brahmani	11-25	14.9	51-75	97.6	51-75	26.5
6	Upp. Mahanadi	11-25	0.5	51-75	25.8	>100	38.5
7	Low. Mahanadi	51-75	17.3	>100	77.1	51-75	26.4
8	Rusikulya	51-75	25.7	>100	136.9	26-37	3.5
9	Vansadhara	51-75	11.6	>100	55.6	38-50	5.0

Local, DISTRICT and catchment level R/F FORECAST

District level forecast issued for 5 days with warning for 3 days

Example : On 01/12/2015 Extremely heavy rainfall warning for three districts viz., Chennai, Tiruvallur and Kancheepuram districts was issued for the next day .

24-hr forecast based on 01-12-2015/0000 UTC valid for 02-12-2015/0000 UTC



Local Weather Report and Forecast For: Chennai Dated :Feb 11, 2016

Past 24 Hours Weather Data	
Maximum Temp(°C)	33.2
Departure from Normal(°C)	3
Minimum Temp (°C)	23.5
Departure from Normal(°C)	1
24 Hours Rainfall (mm)	NIL
Todays Sunset (IST)	18:14
Tommorows Sunrise (IST)	06:33
Moonset (IST)	20:59
Moonrise (IST)	08:34

Today's Forecast: The sky condition likely to be partly cloudy. Mist is likely to occur in some areas during morning hours. The maximum and minimum temperature would be around 33 and 23 degree Celsius respectively.

Date	Temperature (°C)		Weather Forecast	
	Minimum	Maximum		
12-Feb	23.0	33.0	MIST	Mist
13-Feb	23.0	33.0	MIST	Mist
14-Feb	22.0	34.0		Partly cloudy sky
15-Feb	22.0	34.0		Partly cloudy sky
16-Feb	22.0	34.0		Partly cloudy sky
17-Feb	22.0	34.0		Partly cloudy sky

Gaps in understanding

(i) active-break spells and their transitions,

(ii) characteristics like genesis, intensification and movement of transient monsoon disturbances,

(iii) meso-scale nature of heavy rainfall in large scale synoptic settings

(iv) contribution of intra-seasonal variation to interannual variation

(v) Role of large scale processes like

El Nino and Southern Oscillation,

Madden Julian Oscillation and

Indian Ocean dipole in the

(a) intraseasonal variation of monsoon circulation,

(b) characteristics of monsoon disturbances and

(c) large scale heavy rainfall.

(vi) Cloud scale processes

Gaps in prediction

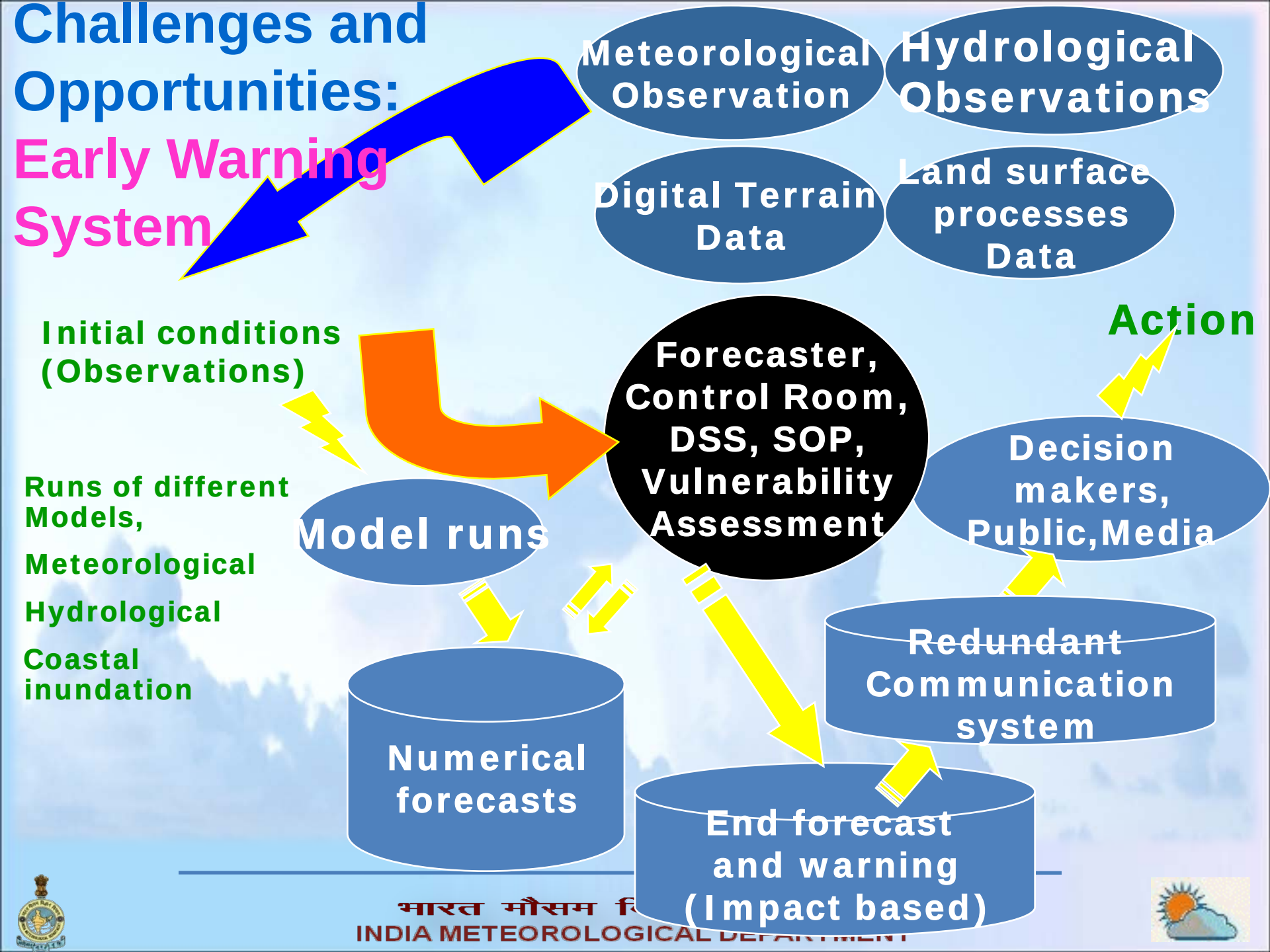
- There have been significant improvements both in the modelling components (Atmospheric GCM and meso-scale models)
- Improvement in the assimilations of non-conventional data
- Improvement of short to medium range prediction of monsoon circulation and rainfall,
- forecasting of location specific heavy rainfall spell and dry spells is the main challenging area in medium and extended range time scale.

- Data assimilation is still challenging, especially remotely sensed satellite and radar data

Challenges and Opportunity

- Monsoon Mission
- Field Experiments : CTCZ, CAIPEX, FDP-STORM, FDP-Cyclone
- Forecasting Experiment : SWFDP
- Modeling : Dynamical (GFS, UM, CFS V2, EPS, MME)
- Collaboration

Challenges and Opportunities: Early Warning System



THANK YOU