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Monsoons, Cyclones & Extreme Events – Role of Oceans

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Climate Change Questions

- Climate change is a topic on every individual's minds, right from school children to Scientists, legislators to corporate leaders.

The main questions are

-
- What is climate change ?
- Do we know whether climate has really changed ? (Indicators of Climate Change)
- Reason for Climate Change? How can we stop it?
- Will the climate change in future also?
- What are its impacts (positive and negative)?
- Why and how can we adapt ourselves to changing Climate?

- Climate change is a long-term change in the average climate of the planet or a region of the planet.

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Definition of Weather & Climate

Weather is the condition of the atmosphere at a particular location and moment. Weather elements are temperature, relative humidity, pressure, wind speed and direction, clouds and precipitation.

Climate of a region is the condition of the atmosphere averaged over many years (weather elements of an hour , day, month or year averaged over a period of 30 years or more)

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THERE ARE TWO TYPES OF CLIMATE CHANGE OBSERVED

Type-1: Decadal Change – a few decades of increase followed by a few decades of decrease, a sort of decadal oscillation

Type-2: long term trends, either decreasing or increasing

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The Concern ?

The "greenhouse effect" is a natural process that allows the earth to be warm enough to sustain life. The greenhouse effect keeps the Earth warmer than it would otherwise be - without it life on earth would not be possible.

Man-made global emissions of carbon dioxide are less than 4% of total (natural plus man-made) annual emissions. Apparently, nature also removes slightly more carbon dioxide than it emits every year, effectively cutting the annual rate of growth of atmospheric carbon dioxide concentration in half.

The concern is whether increasing amounts of man-made greenhouse gases may be warming the earth enough to significantly change weather patterns.

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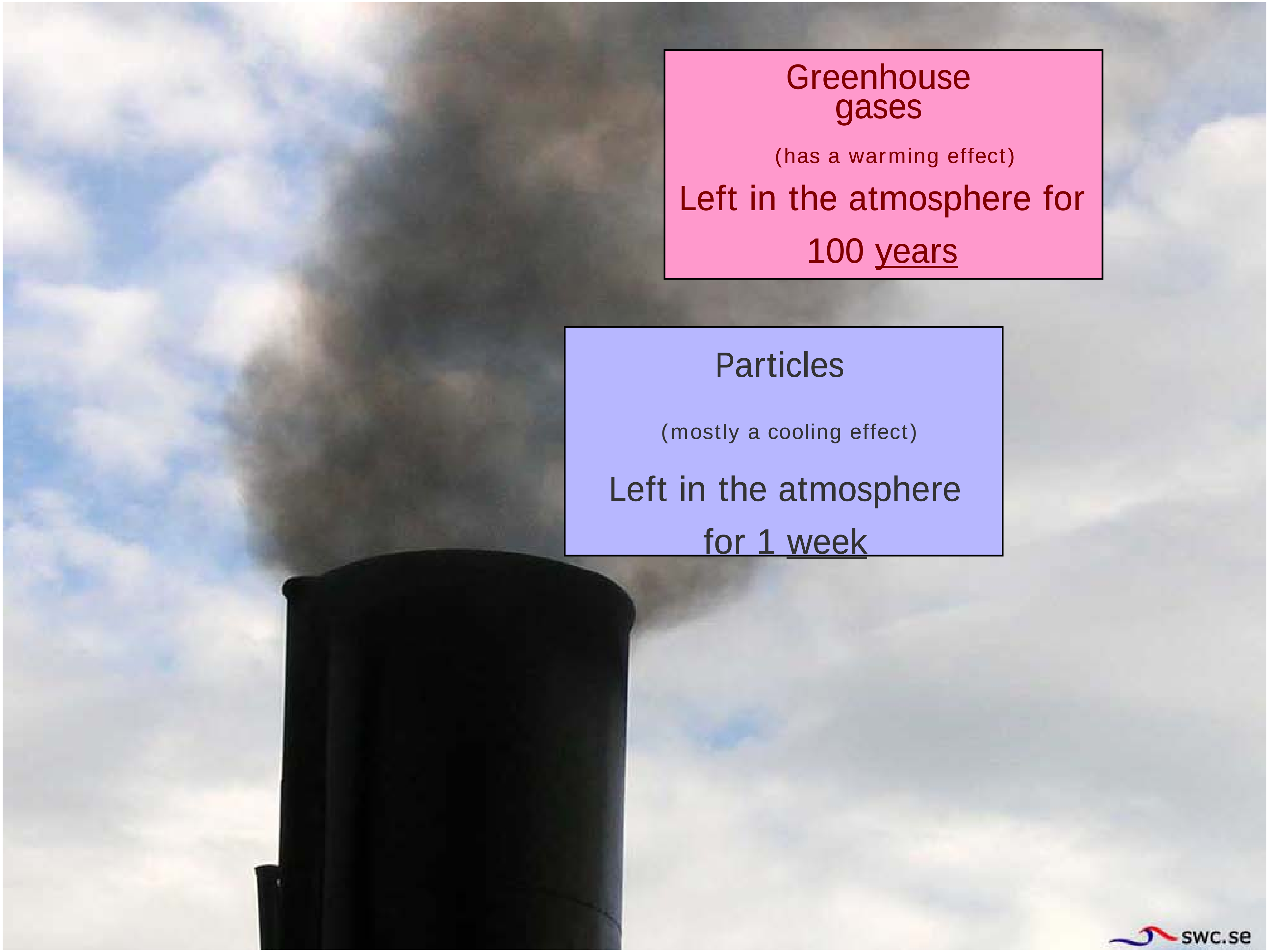
Greenhouse gases
(has a warming effect)
Left in the atmosphere for 100 years
Particles
(mostly a cooling effect)
Left in the atmosphere for 1 week
swc.se

A long term problem

- Emissions today will influence the composition of the atmosphere for hundreds of years.

- We force upon future generations an atmosphere that will take centuries to repair (if it proves necessary).

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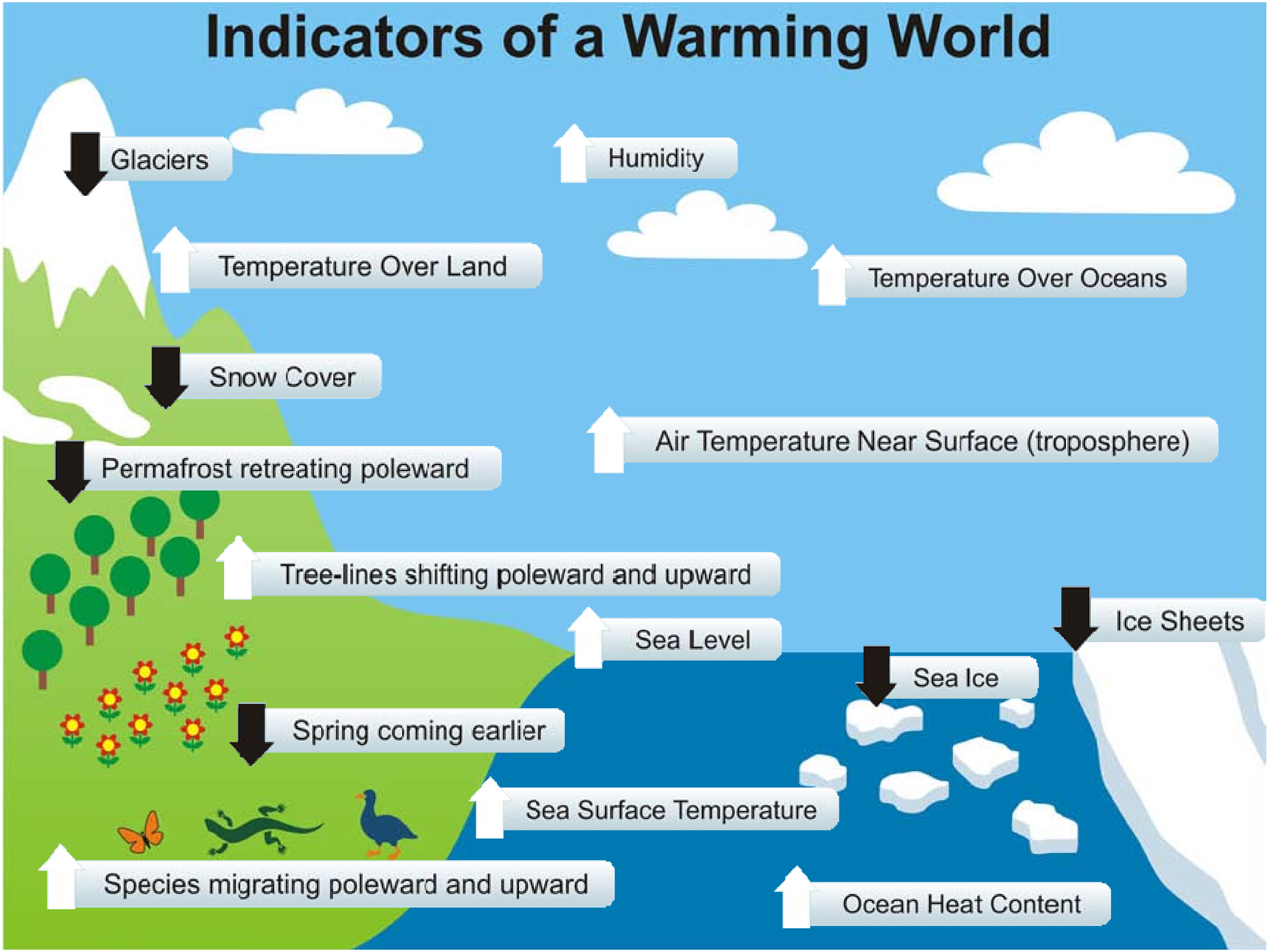

Indicators of a Warming World
Glaciers
Humidity
Temperature Over Land
Temperature Over Oceans
Snow Cover
Air Temperature Near Surface (troposphere)
Permafrost retreating poleward
Tree-lines shifting poleward and upward
Ice Sheets
Sea Level
Sea Ice
Spring coming earlier
Sea Surface Temperature
Species migrating poleward and upward
Ocean Heat Content

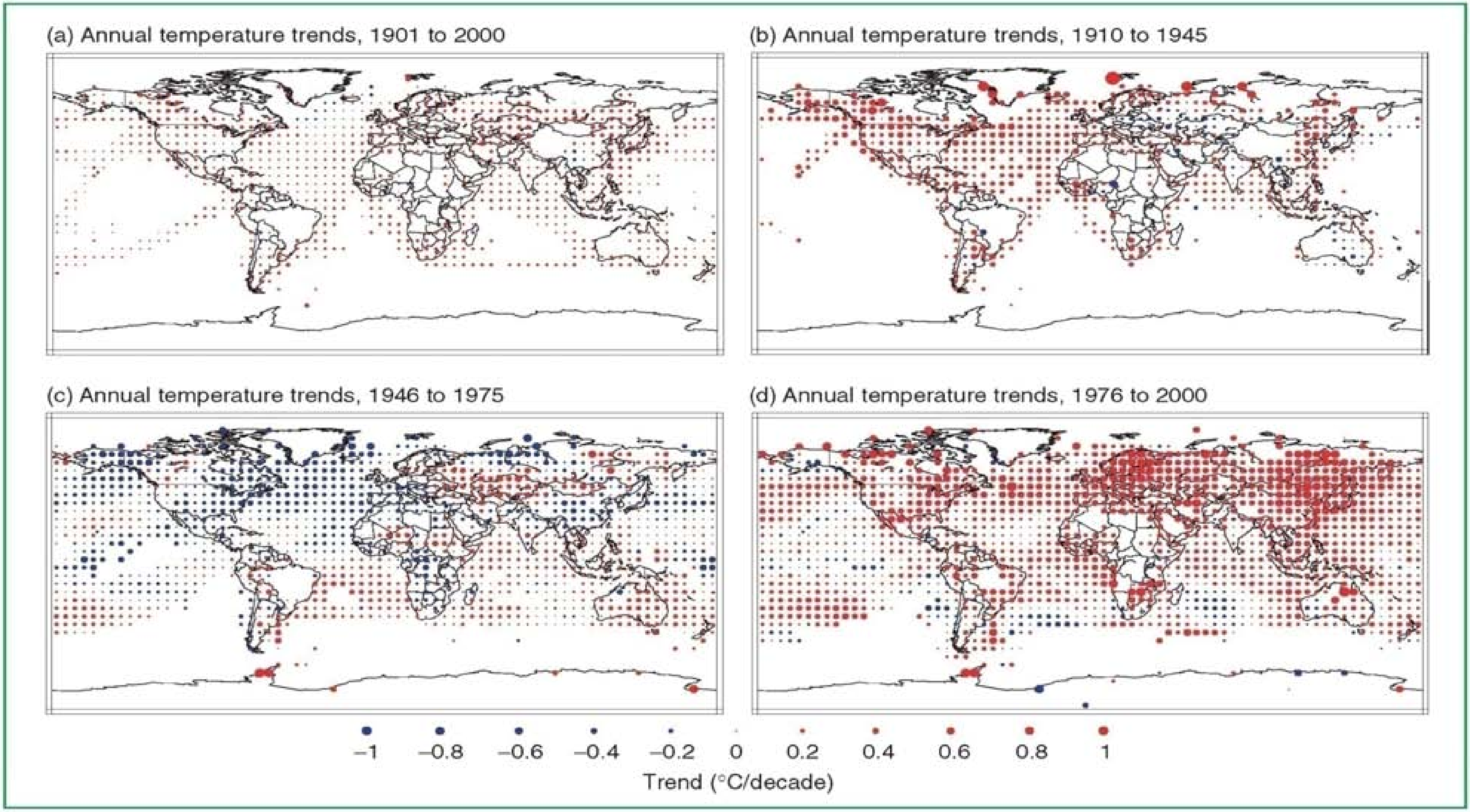
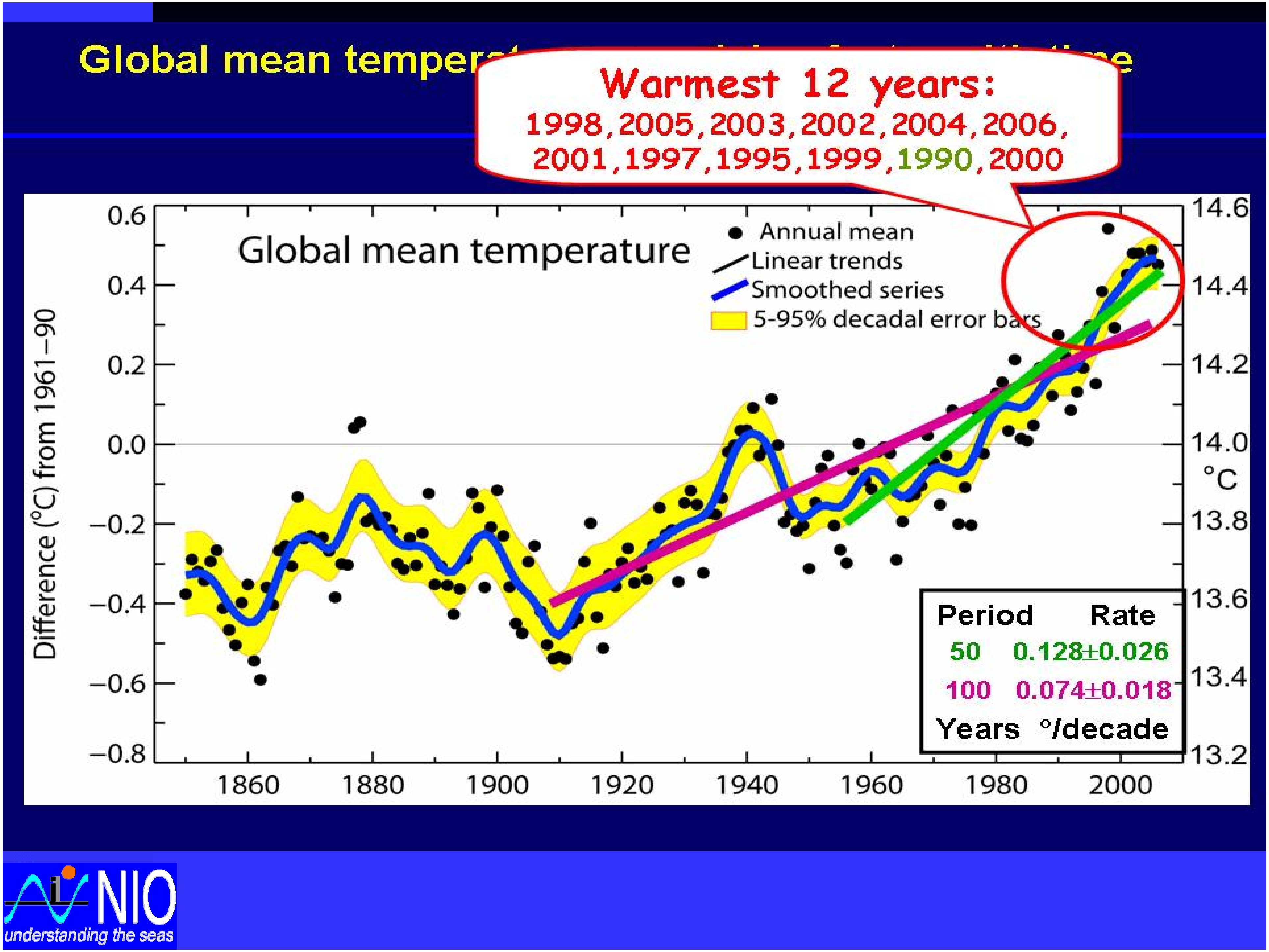


Figure 3: Annual temperature trends for the periods 1901 to 1999, 1910 to 1945, 1946 to 1975 and 1976 to 1999 respectively. Trends are represented by the area of the circle with red representing increases, blue representing decreases, and green little or no change. Trends were calculated from annually averaged gridded anomalies with the requirement that the calculation of annual anomalies include a minimum of 10 months of data. For the period 1901 to 1999, trends were calculated only for those grid boxes containing annual anomalies in at least 66 of the 100 years. The minimum number of years required for the shorter time periods (1910 to 1945, 1946 to 1975, and 1976 to 1999) was 24, 20, and 16 years respectively. [Based on Figure 2.9]


Global mean temper
Warmest 12 years:
1998,2005,2003,2002,2004,2006,
2001,1997,1995,1999,1990,2000
Global mean temperature
Annual mean
Linear trends
Smoothed series
5-95% decadal error bars
Difference (°C) from 1961–90
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
14.6
14.4
14.2
14.0
°C
13.8
13.6
13.4
13.2
1860
1880
1900
1920
1940
1960
1980
2000
Period Rate
50 0.128±0.026
100 0.074±0.018
Years °/decade
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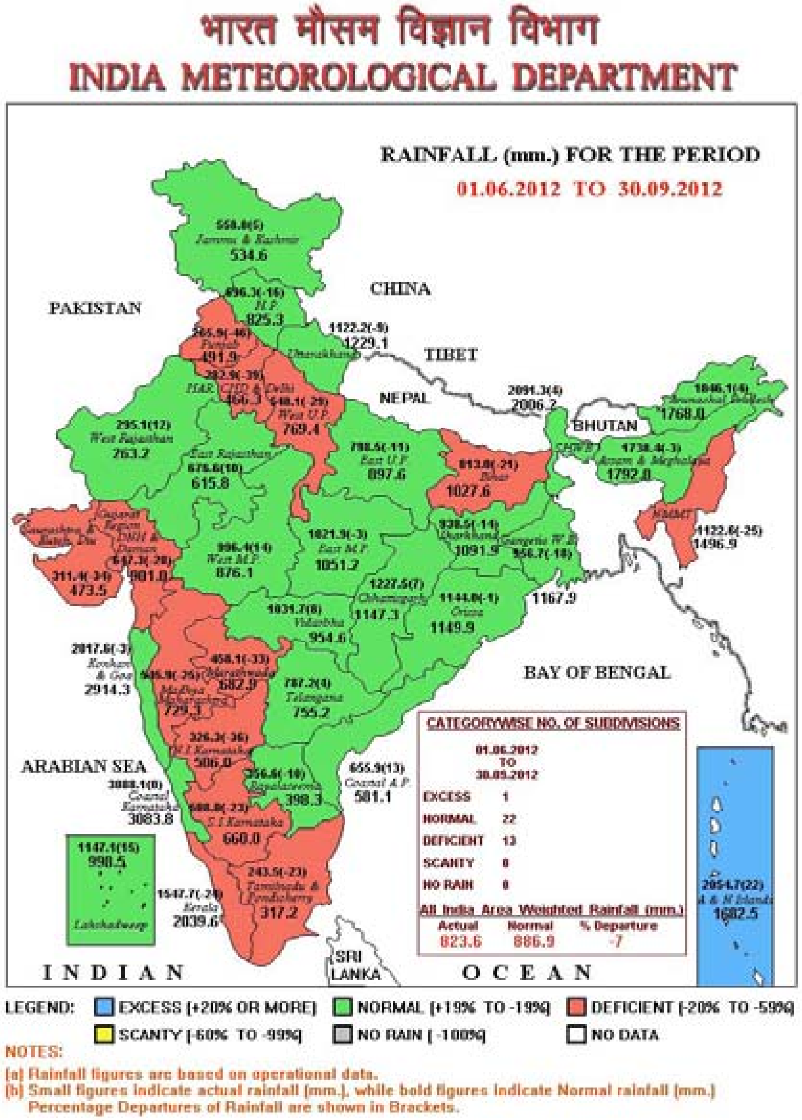
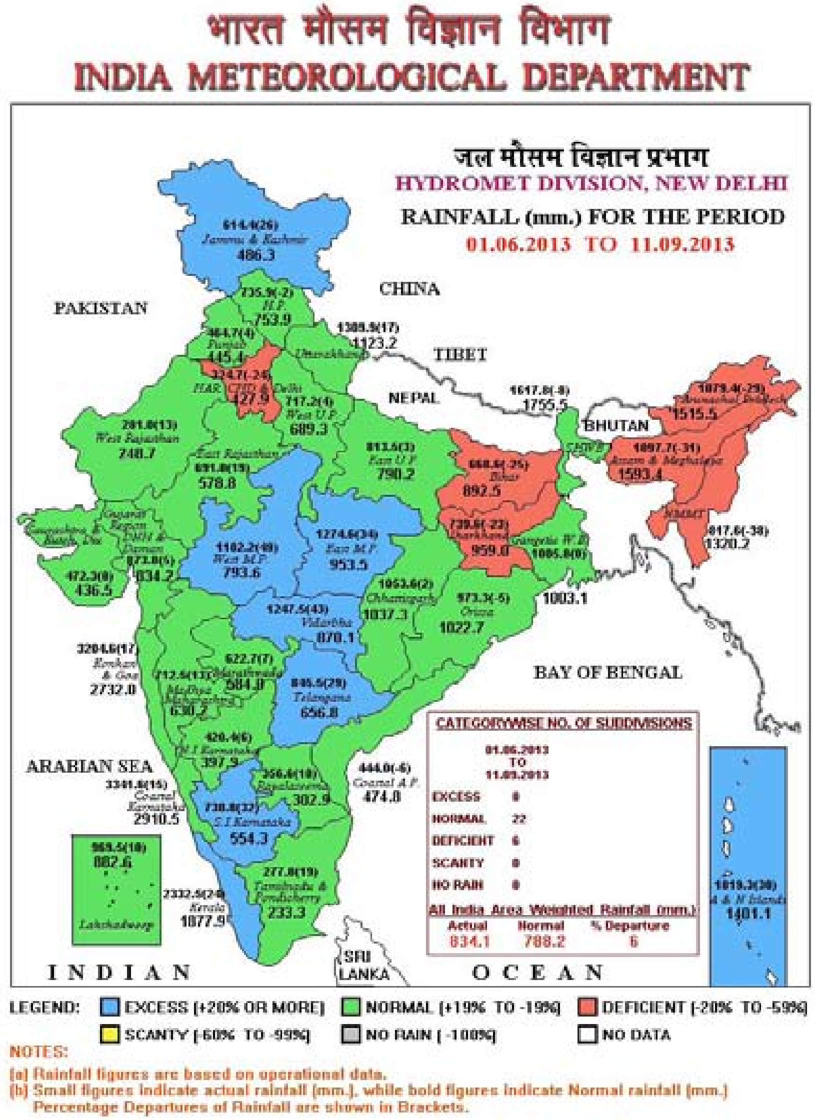
Southwest Monsoon

Monsoon Rainfall 2012 and 2013 so far ....





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IMD

SEASONS IN INDIA

1. SW Monsoon (01 June - 30 Sept.)
2. Pre-monsoon (01 March - 31 May)
3. NE Monsoon (01 Oct.- 31 Dec.)
4. Winter (01 Jan. – 28/29 Feb.)

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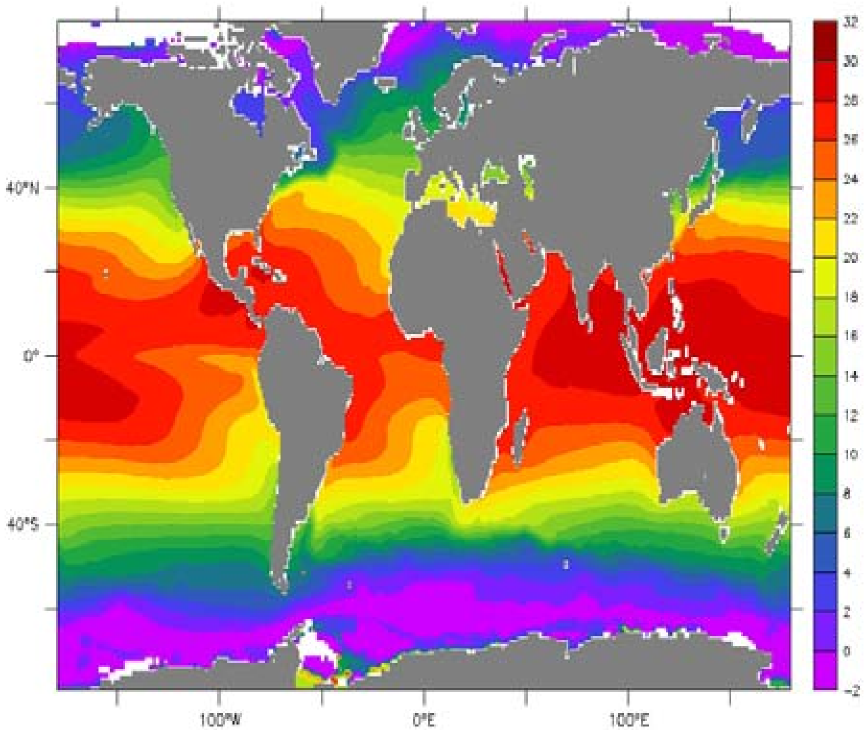

Annual Sea Surface Temperature (°C)

Unlike the Pacific and Atlantic Oceans, the Indian Ocean is landlocked to the north by the Asian continent. This geographical feature give rise to extreme thermal contrast in summer and winter seasons which is the crucial factor in the development of the most pronounced monsoon irculations over this part of the globe.

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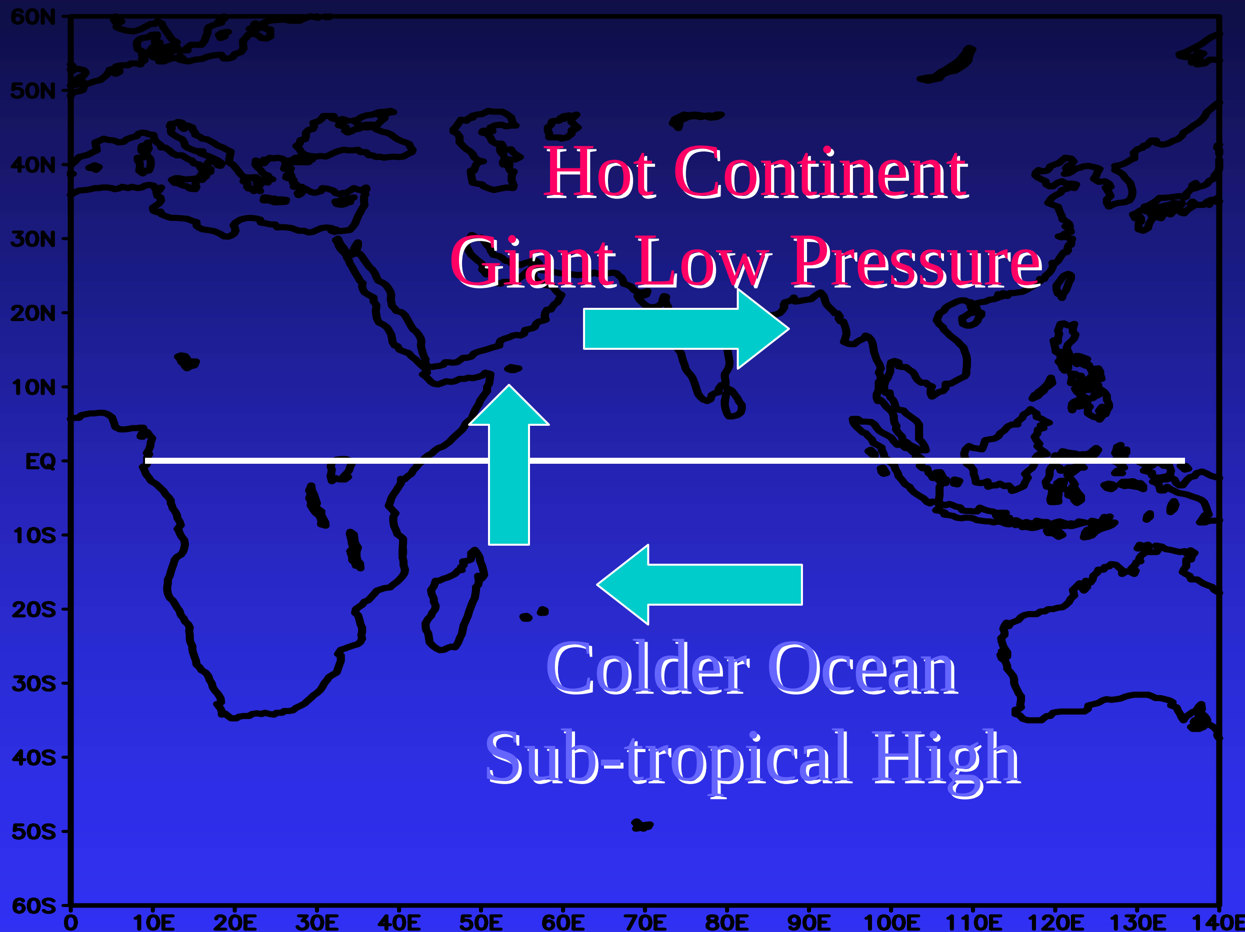
May to October



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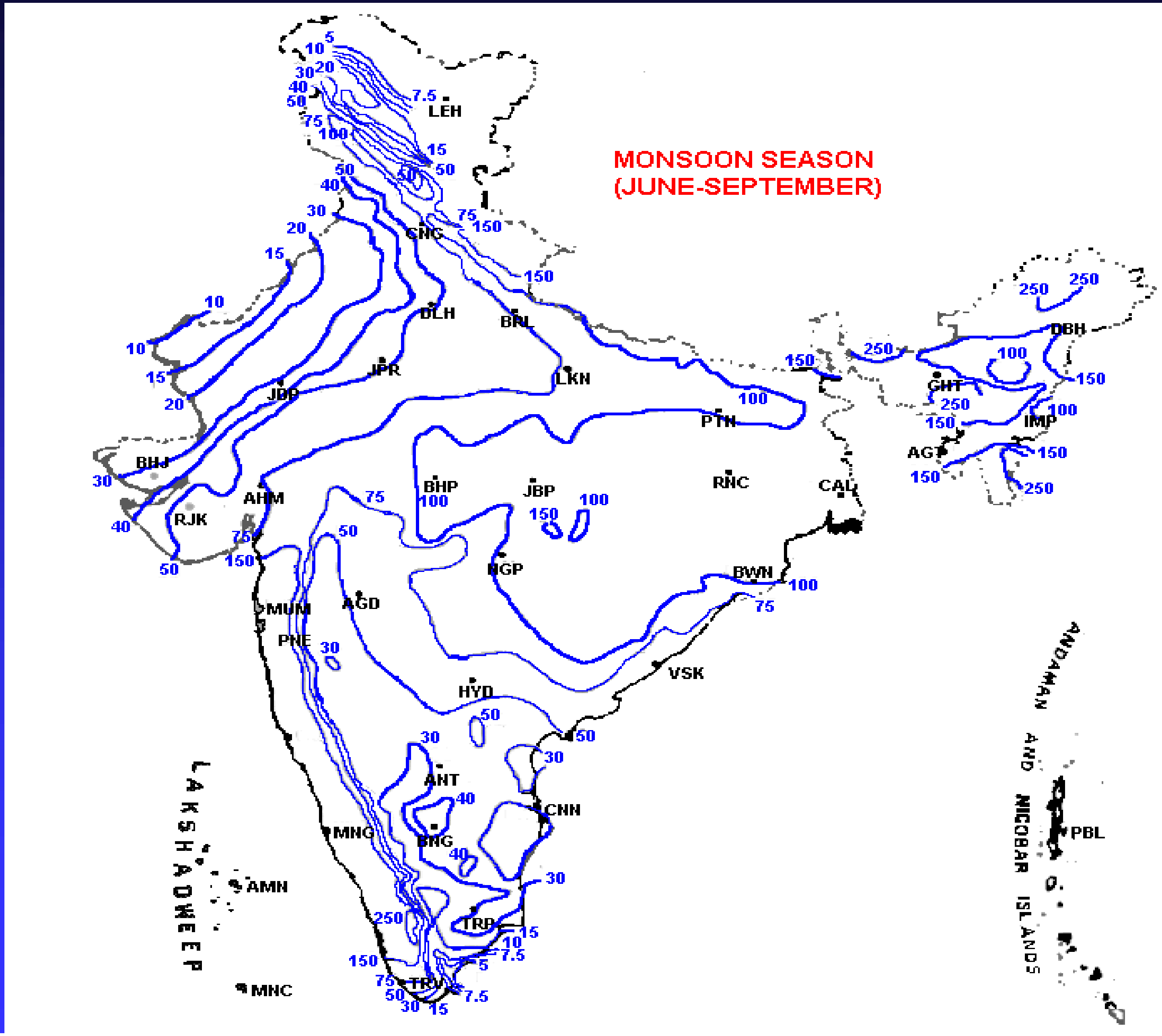
Monsoon Rainfall (cm)



Monsoon Phenomena

Monsoon Onset over Kerala Coast

Active-Break Cycle

Quantum of Monsoon Rainfall

Monsoon Onset over Kerala

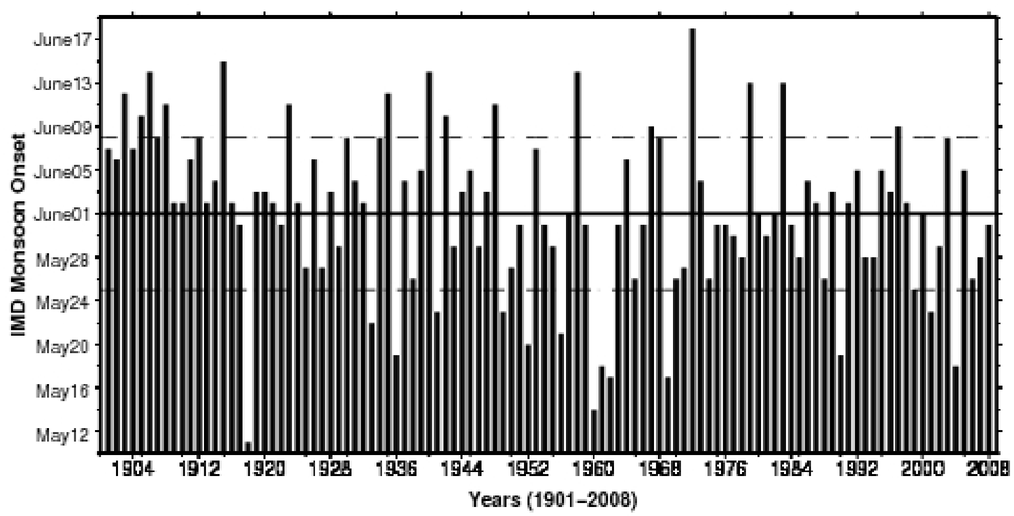
<u>MONSOON ONSET KERALA</u>

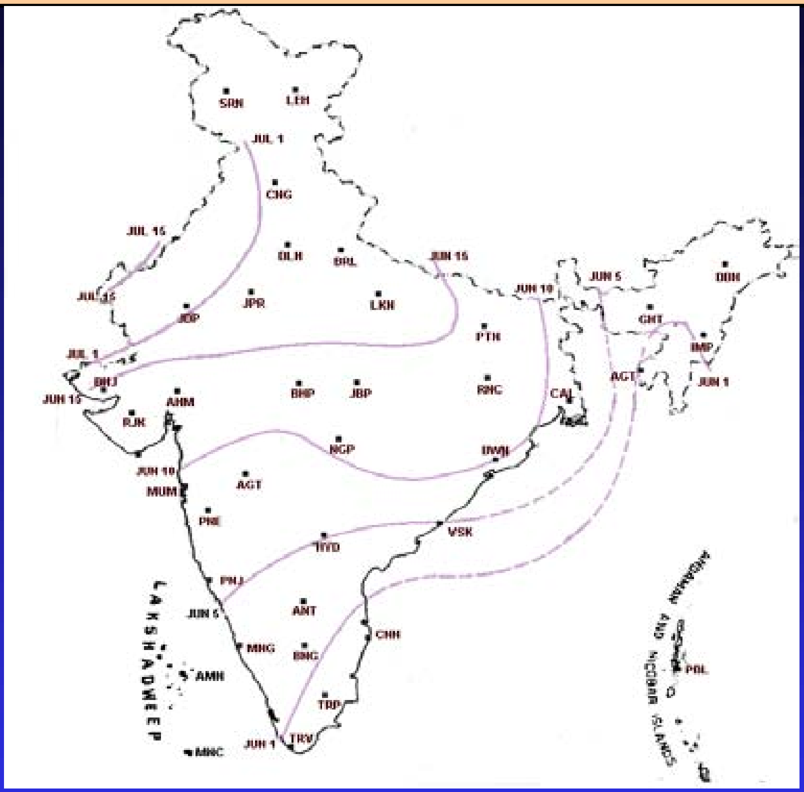
Mean Onset Date : 01 June

Earliest Onset date :11 May (1918)

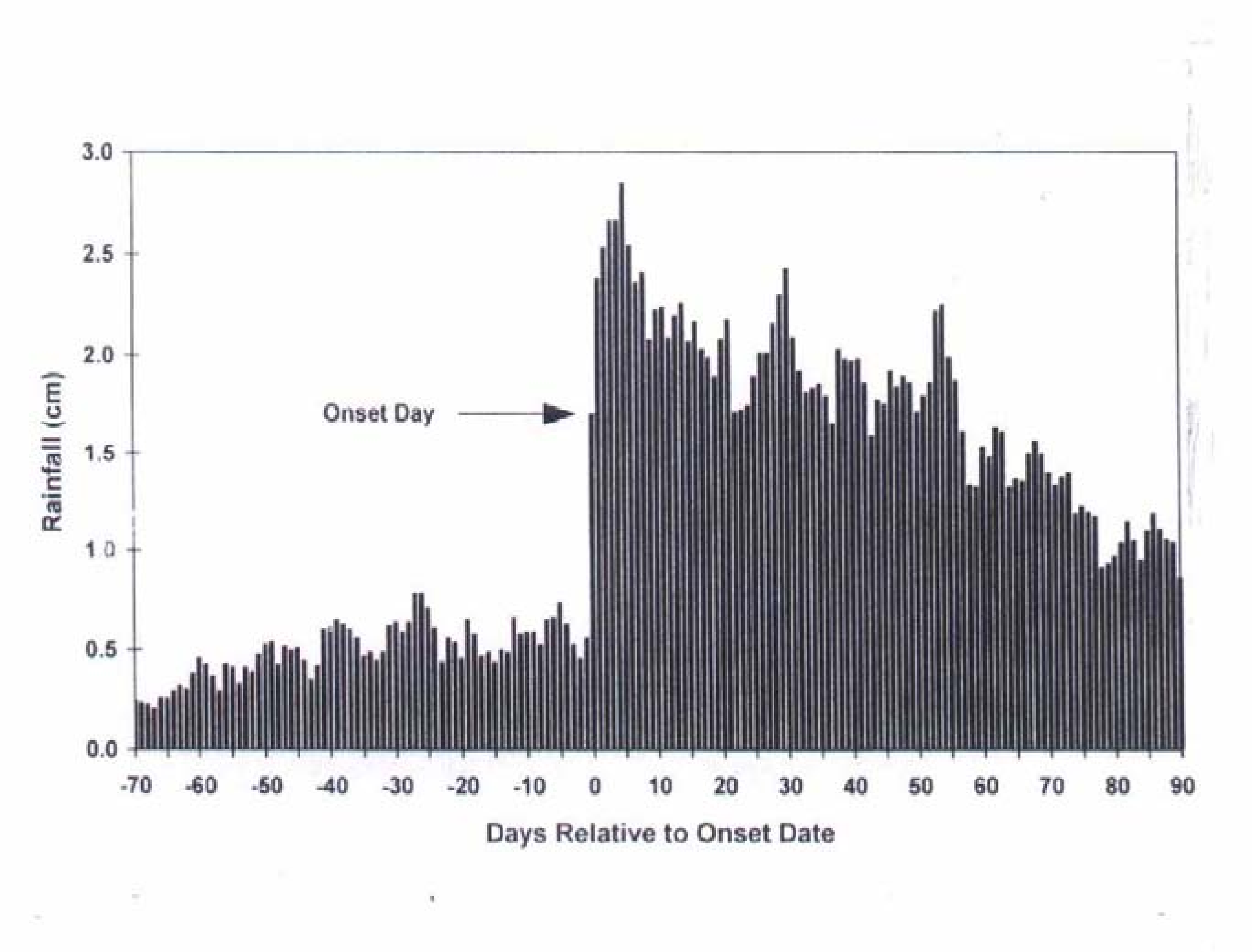
Most delayed Onset: 18 June (1972)

Standard Deviation : 8 days



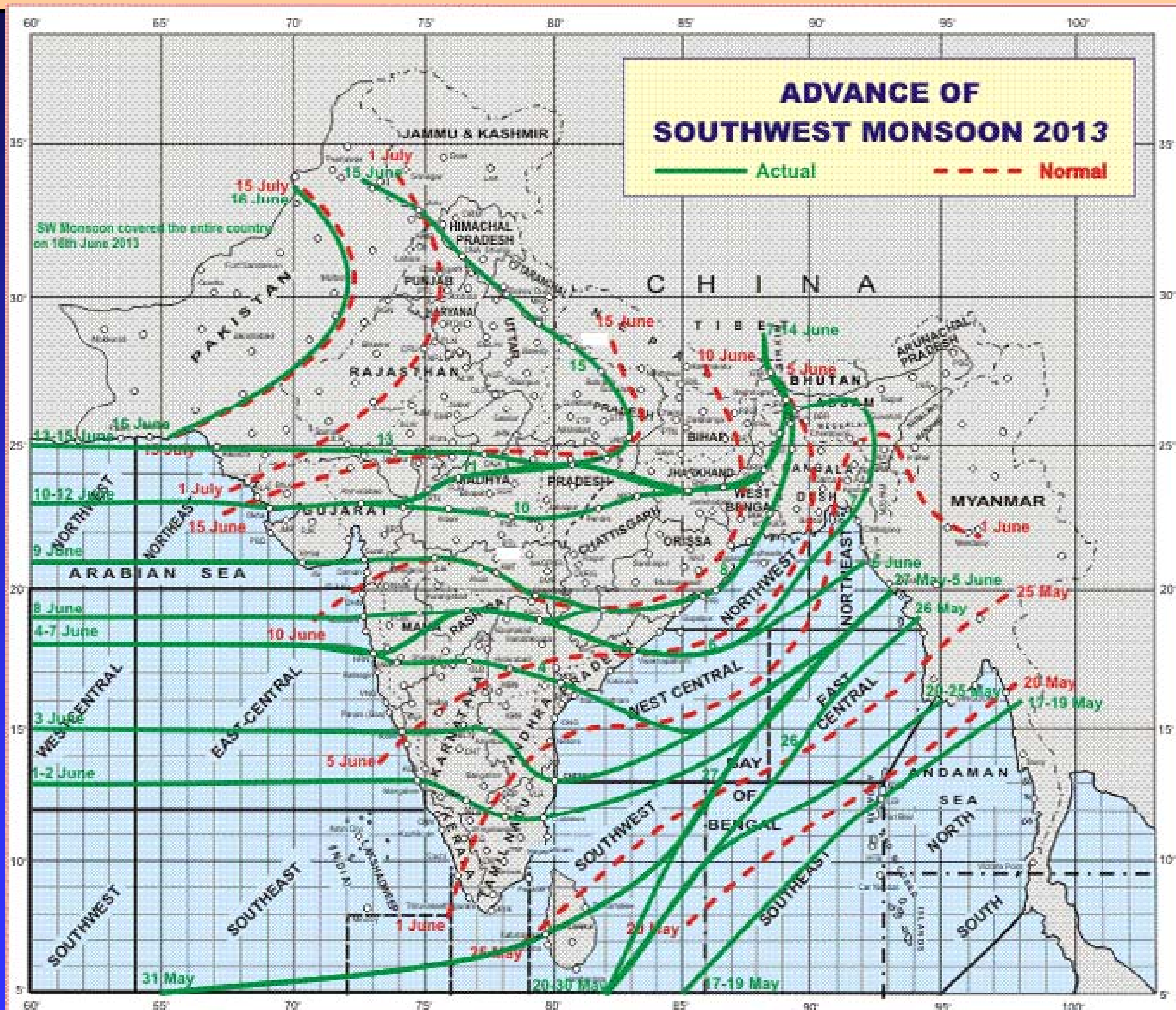


The earliest MOK was 11th May (1918) and most delayed MOK was 18th June, 1972. The normal MOK being 1st June.



Rainfall of Kerala shows sudden increase at Monsoon Onset (picture shows this as an average of 80 years, 1901-1980) - Ananthakrishnan and Soman (1988),

Onset Dates Summer Monsoon over the Indian subcontinent - 2013



IMD

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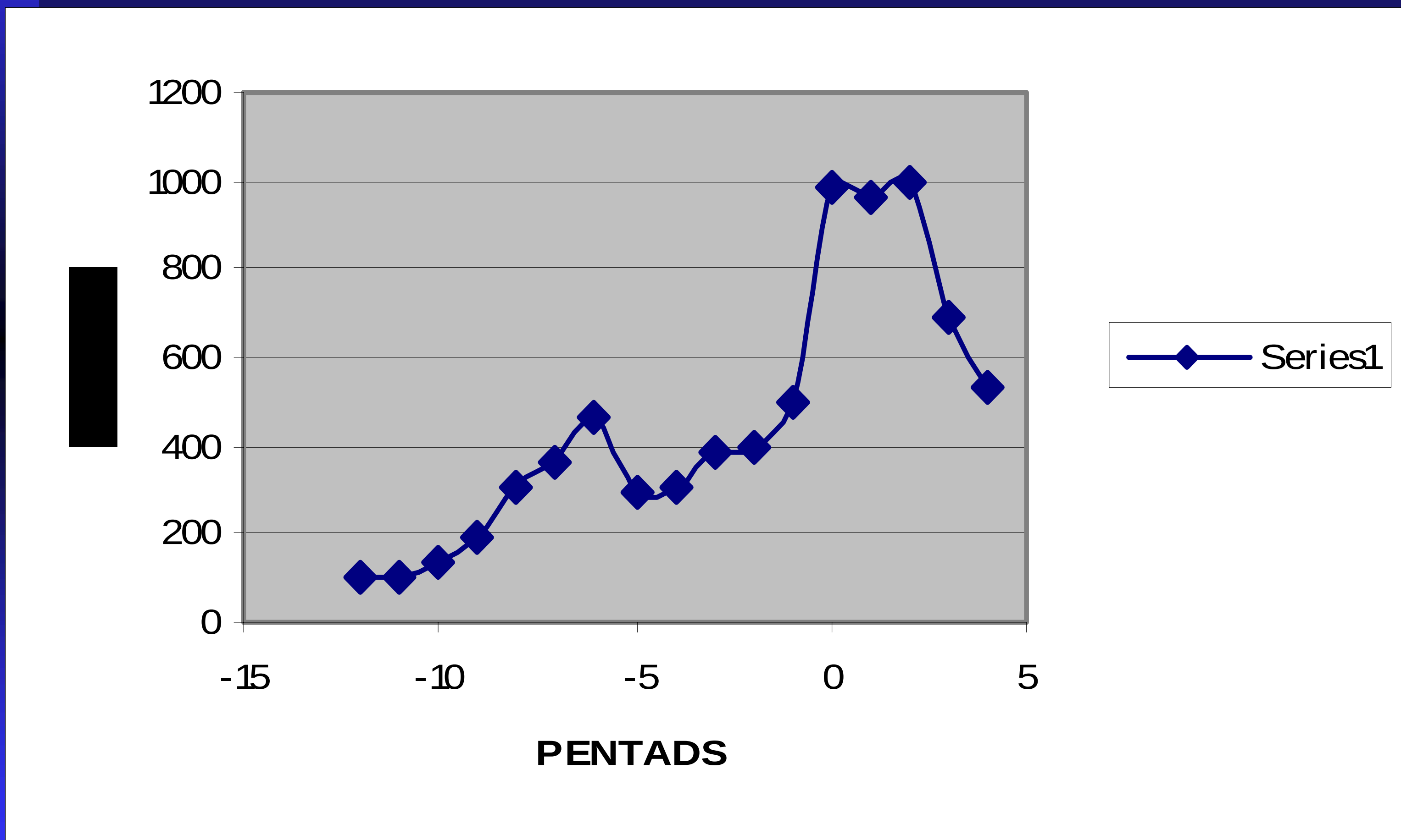
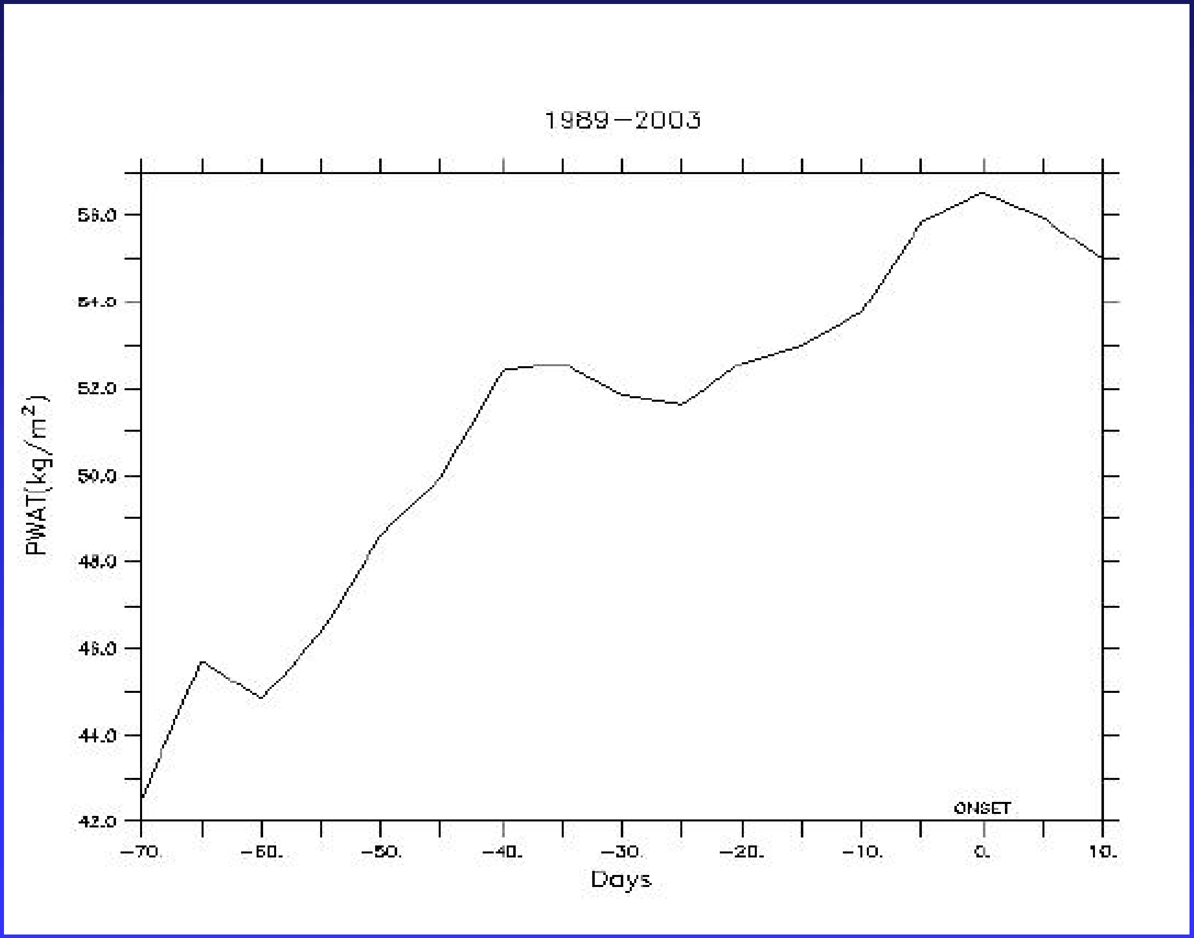
Composite of the GPCP rainfall for 23 Years (1979-2001) with the onset date coinciding with the 0 pentad. The PMRP can be clearly seen about 6 to 7 pentads before MO



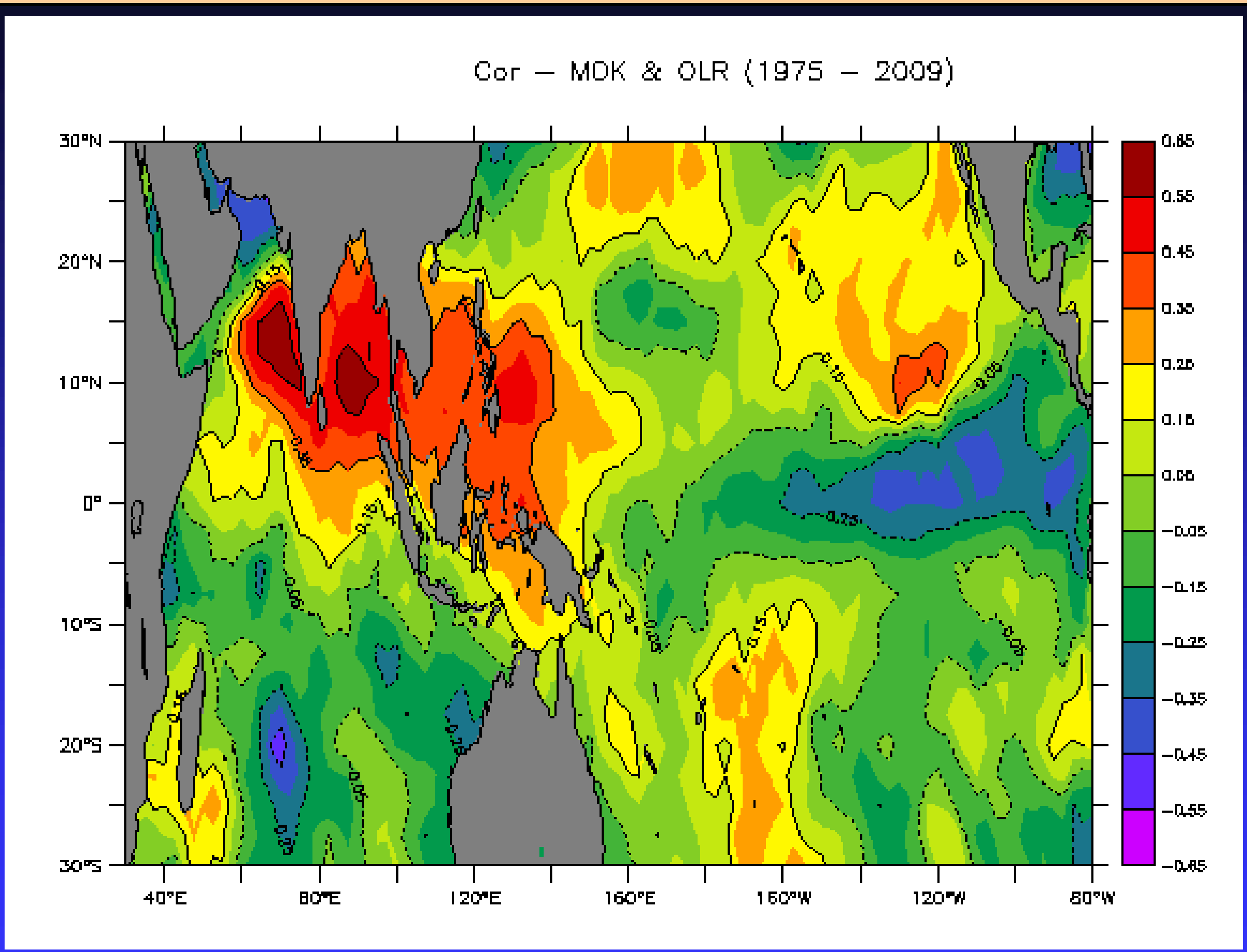
Ramesh Kumar (2004)

Composite mean IWV (in Kg/m^2) for the period 1989 to 2003 for the peninsular box [0-15 N; 70 – 95 E], with respect to MOK as 0.



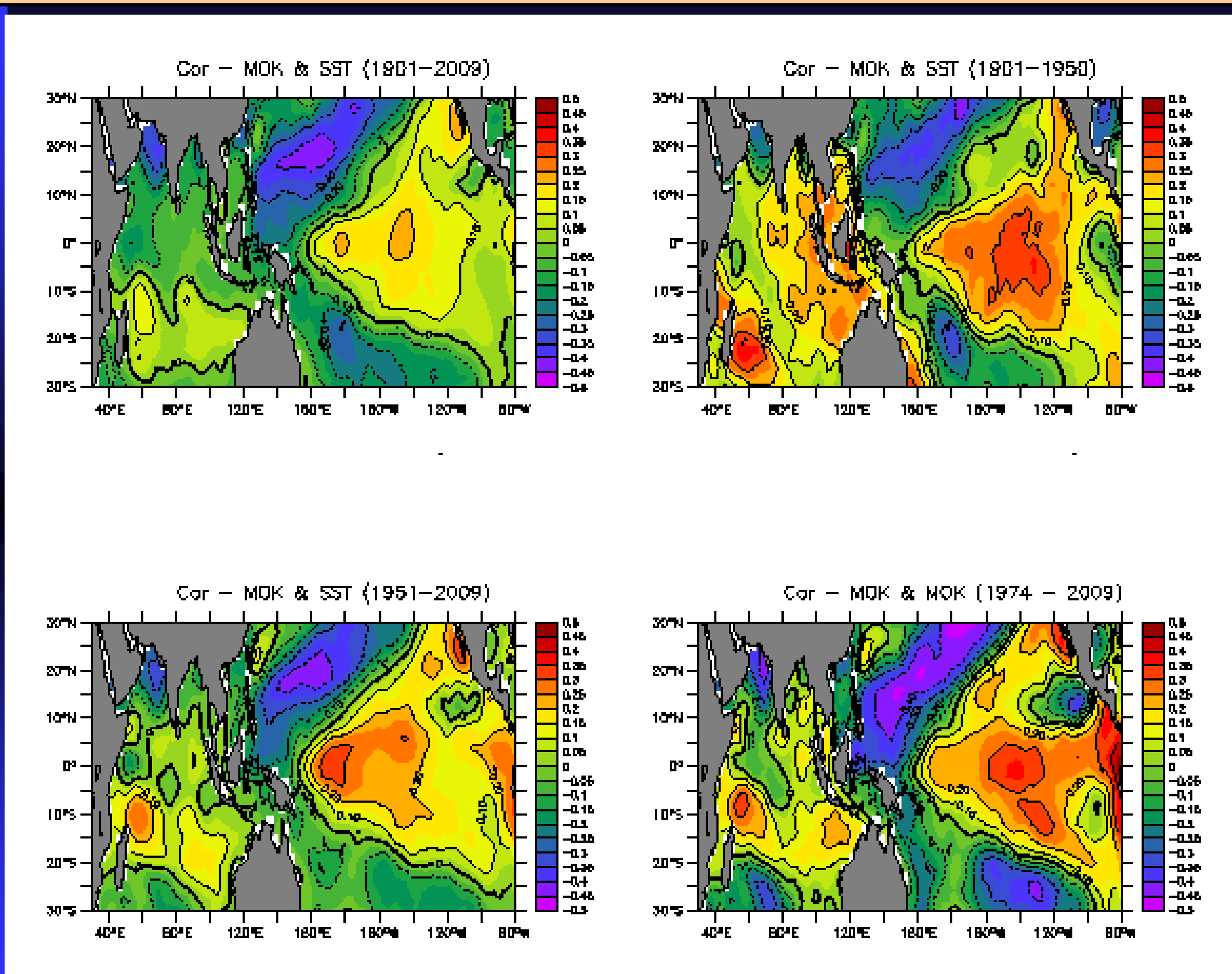
Ramesh Kumar et al., (2009a)

Correlation between Pre Monsoon OLR and MOK



Sankar et al., 2011

Correlation between SST and MOK for different epochs



Sankar et al., 2011

Synoptic Systems

The number of synoptic systems such as Lows, Depressions and Cyclonic systems were maximum in the years 1980 and 1988, there were 17 each. In addition to giving copious amount of rainfall to the various meteorological sub-divisions, they also help in the progress of the northern limit of the monsoon.

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Tracks of Systems formed in AS and BB in Monsoon

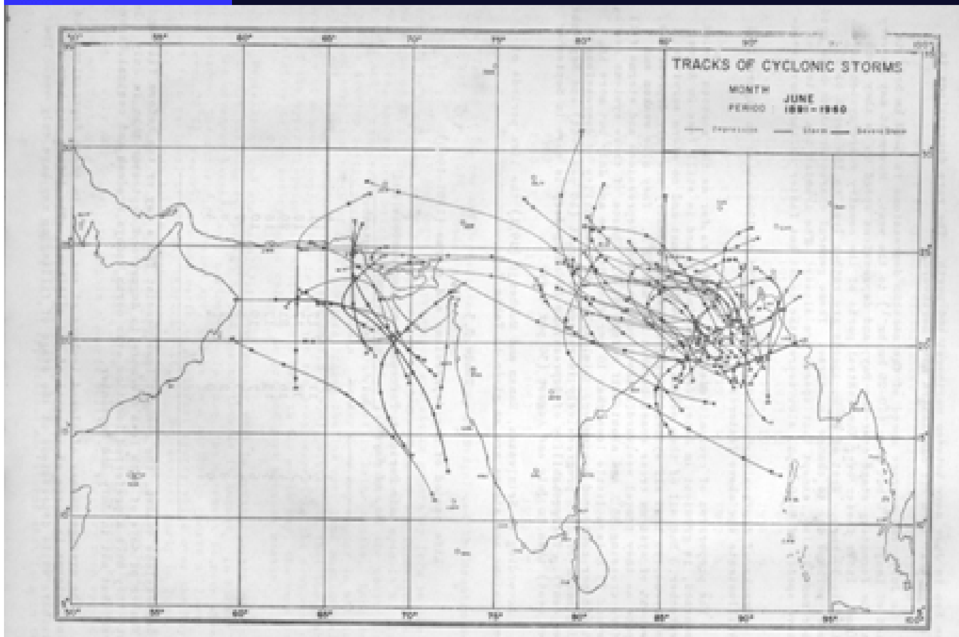
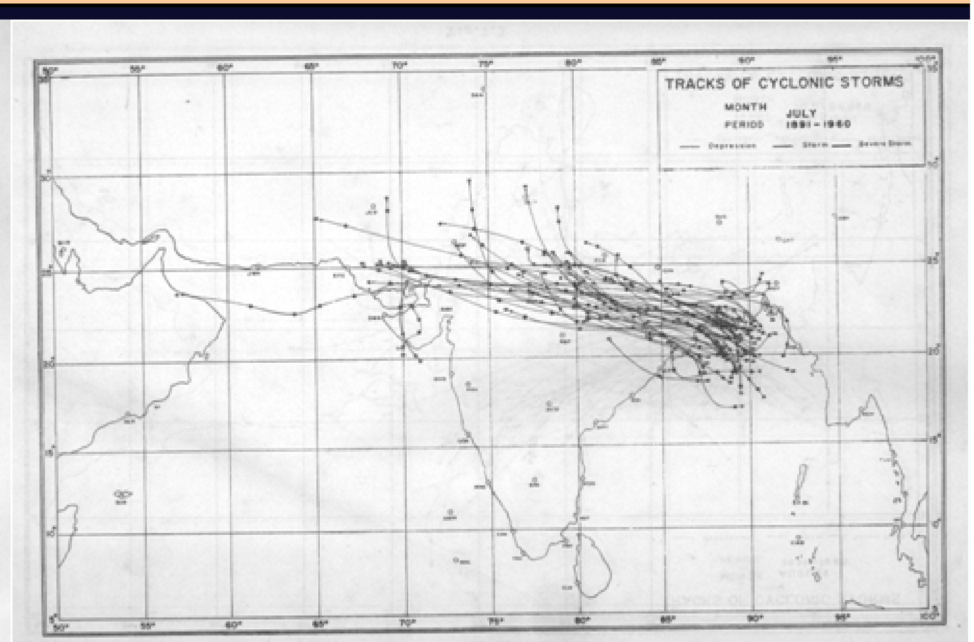
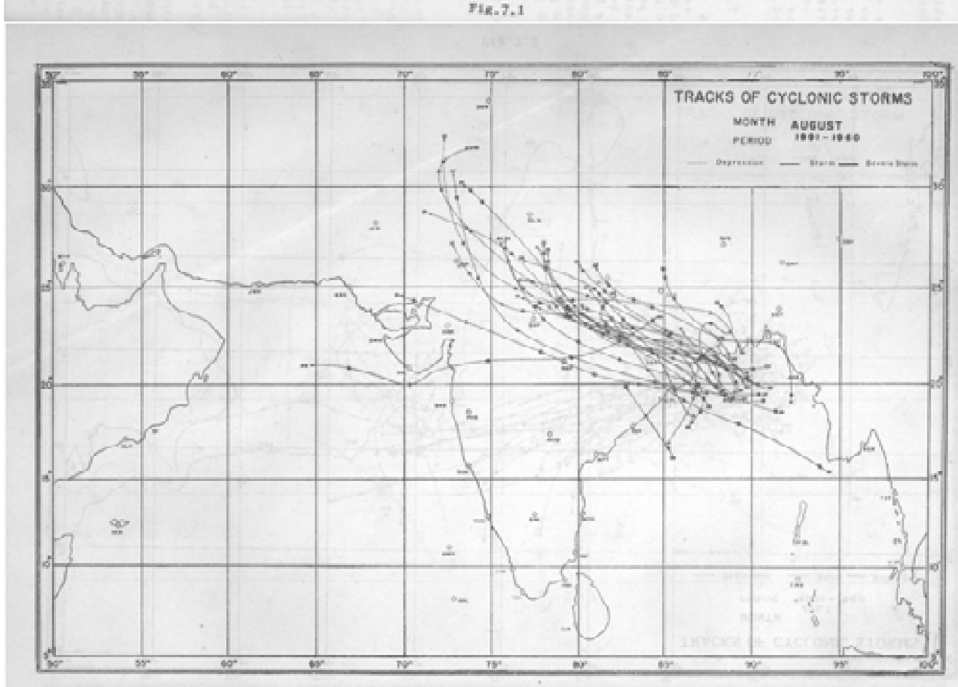


Fig.7.1





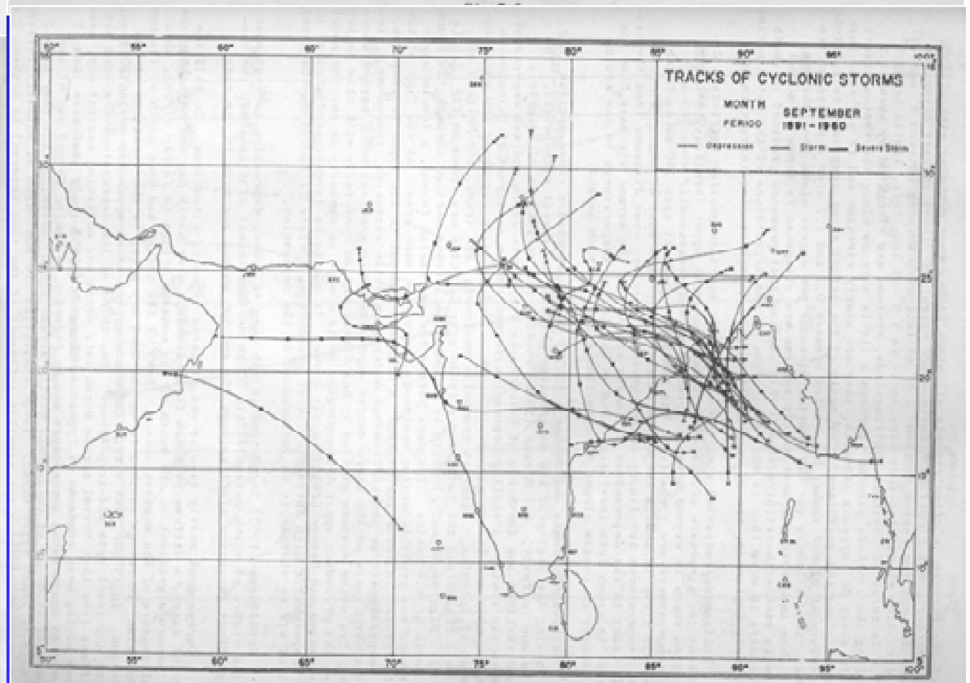
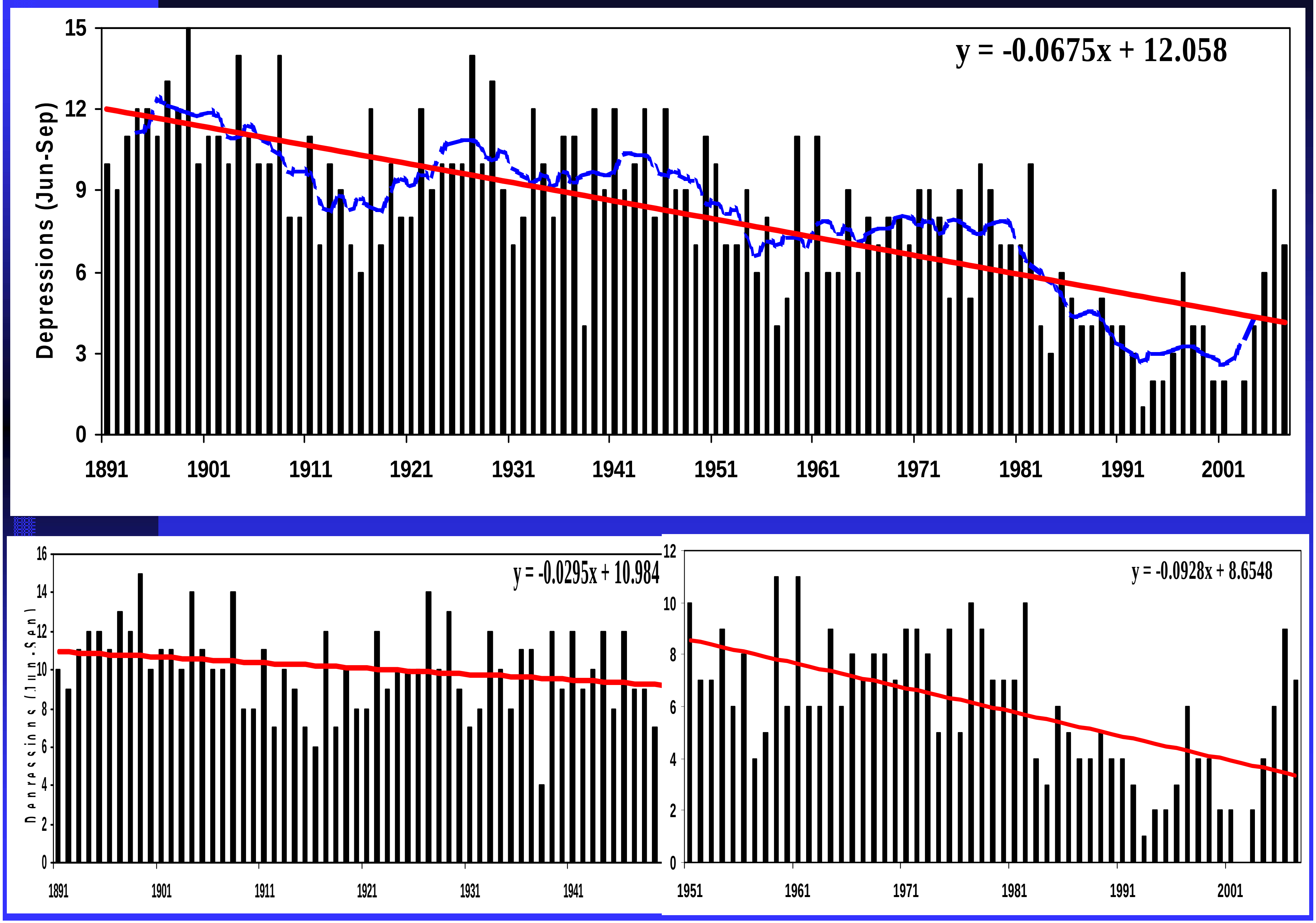


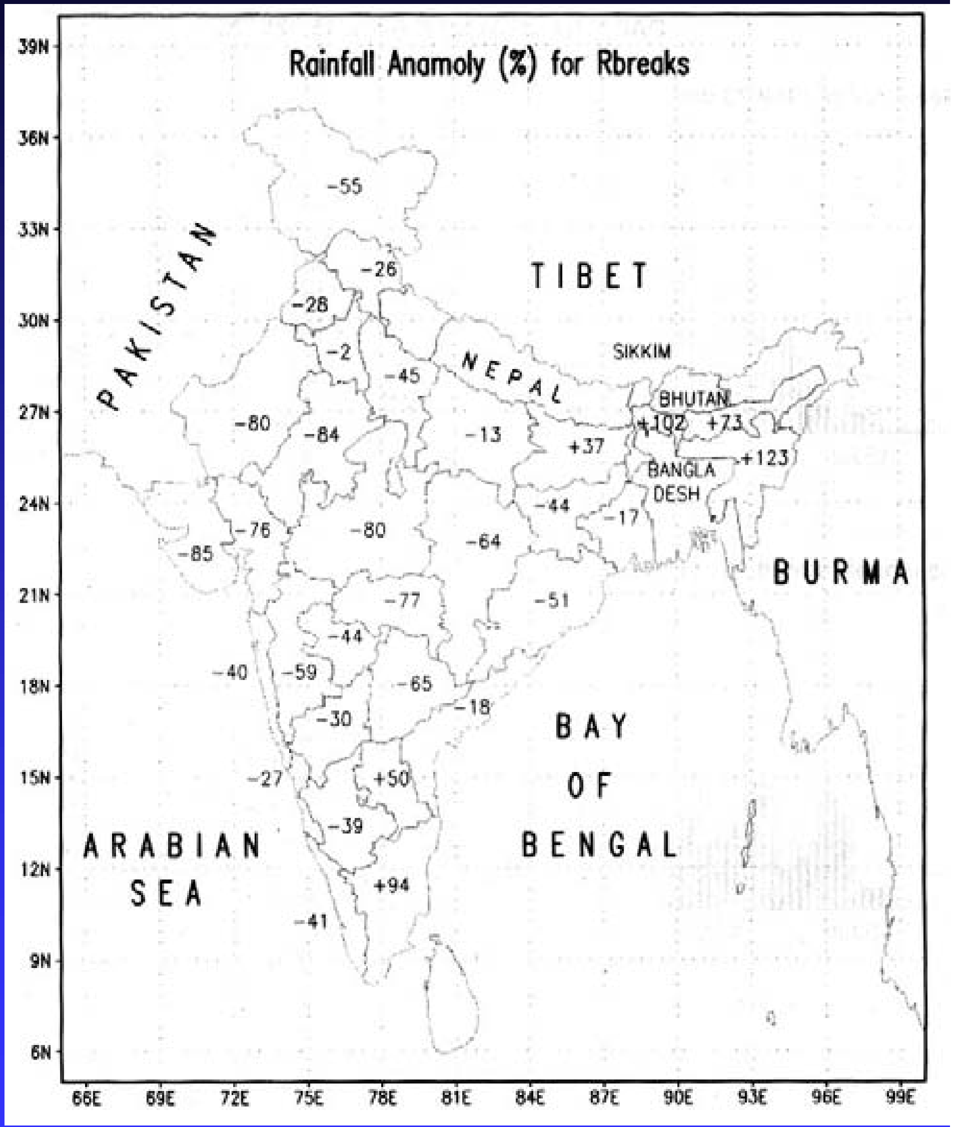
Fig.7.4

Trends in Monsoon Depression Frequency



ACTIVE BREAK CYCLE

It does not rain everyday within the monsoon life cycle of 122 days (1st June to 30th September). Some days it rains quite heavily, such days we call as active days, some days the rains are quite weak, these we call as break in monsoon conditions. During the break days, the rainfall is quite low over the entire Indian subcontinent .



Ramamurthy (1969)

Different Definitions

Ramamurthy (1969)

- The criteria used by him for a break was based on surface pressure distribution and circulation. He looked for the breaks only in the period 1st July to 31st August.

Krishnan et al. (2000)

- Breaks as days with large positive OLR anomalies for at least 4 consecutive days or more over a wide region covering the NW & C India. Breaks only in the period 15th June to 15th September were considered.

Goswami and Ajay Mohan (2001)

Breaks on the basis of the strength of the 850 hPa wind at a reference point just south of the MT (15N; 90E). The days for which the filtered zonal winds at 850 hPa are less than 1 SD are considered Breaks.

Gadgil and Joseph (2003)

- Has identified the breaks over Indian subcontinent using rainfall over the monsoon zone, which they feel is representative of the AISMR.

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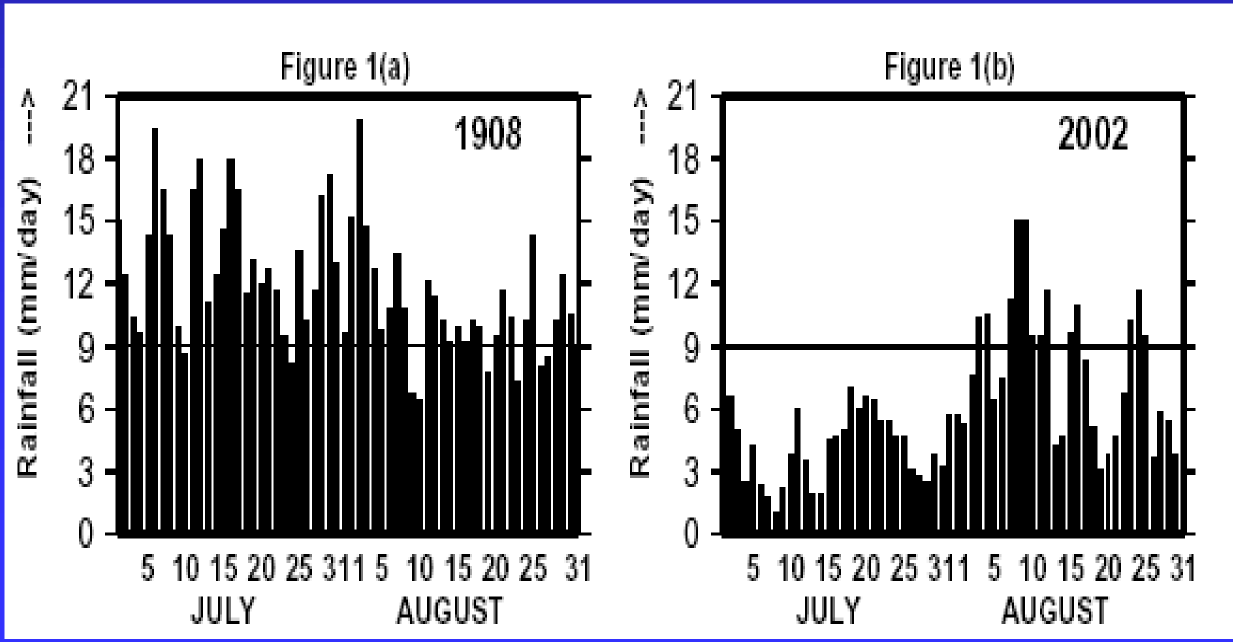
New Criteria: Ramesh Kumar and Uma (2004)

- Break : If AIR < 9mm/day & persists for a minimum of 3 days.

We looked only for breaks during the peak monsoon months of July and August because
a) a delayed onset or an early withdrawal of the monsoon can create an artificial break if we consider the months of June and September respectively
b) the monsoon months of July and August, together contribute to about 60% of the seasonal total.

The year 2002 had the longest spell of 34 days (1st July to 3rd August) and the year 1908 on the other hand had no breaks at all.



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Comparison of the % of duration of the breaks with earlier studies.

Duration of Breaks (Days)	Ramamurthy (1969)	Gadgil & Joseph (2003)	Ramesh & Uma (2004)
3-4	49.5	44.8	45.4
5-6	19.8	22.8	23.2
7-8	16.2	14.3	11.7
9-10	6.3	6.7	6.1
11-12	4.5	4.8	3.6
13-14	1.0	3.8	3.4
>15	2.7	2.8	2.2

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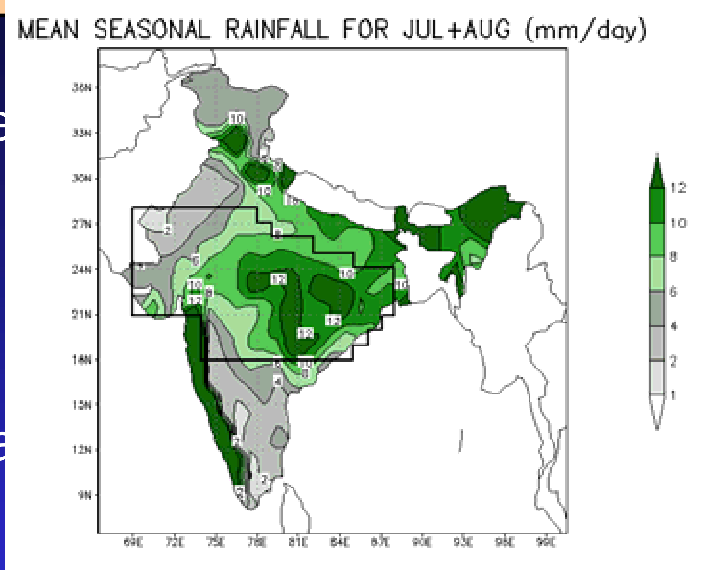
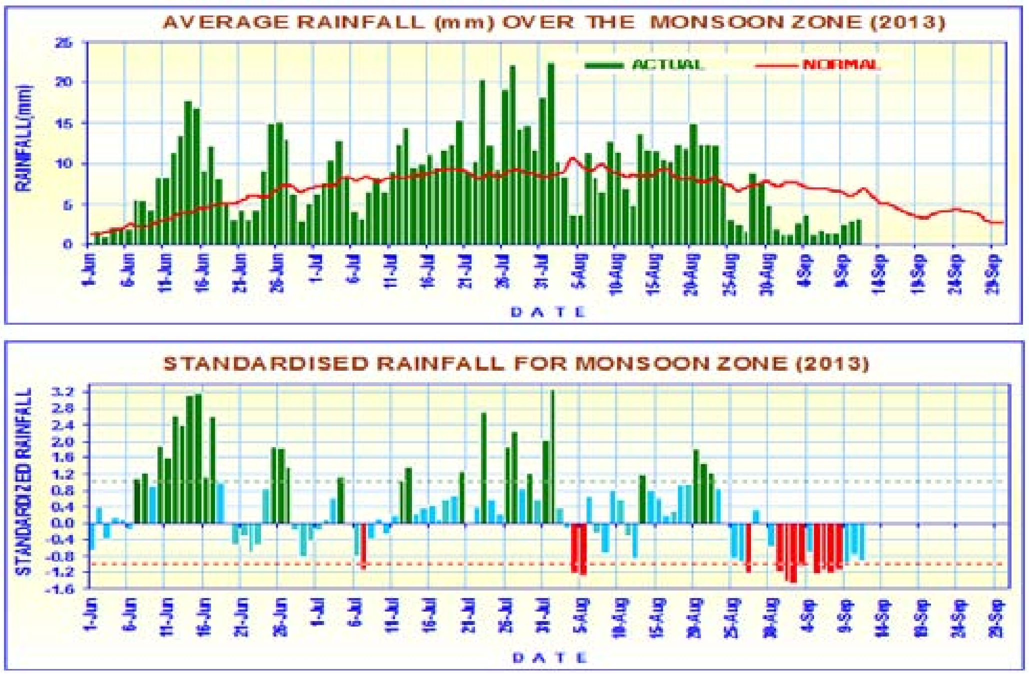
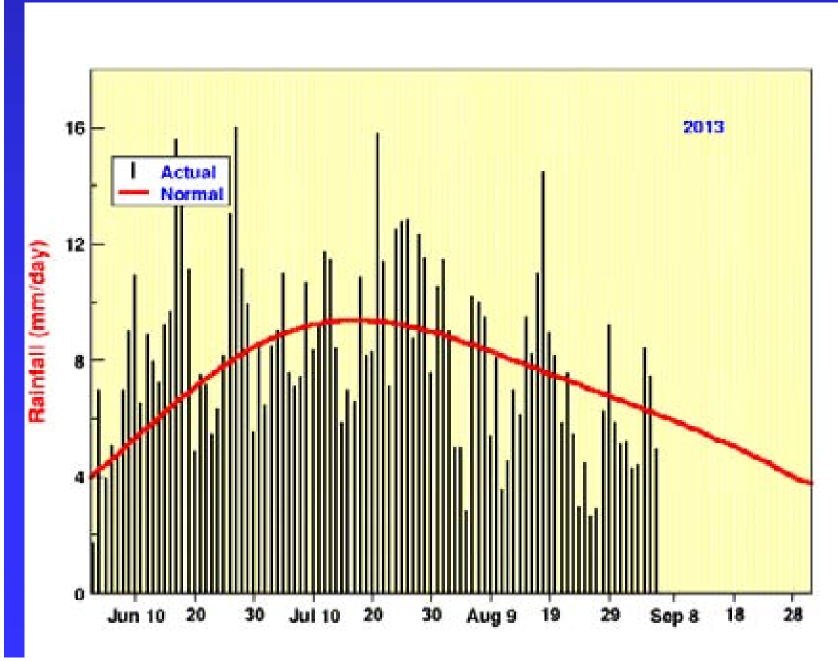
Ramesh Kumar and Uma (2004)

Daily Rainfall over MZ (IMD) and All India (IITM, Pune) - 2013

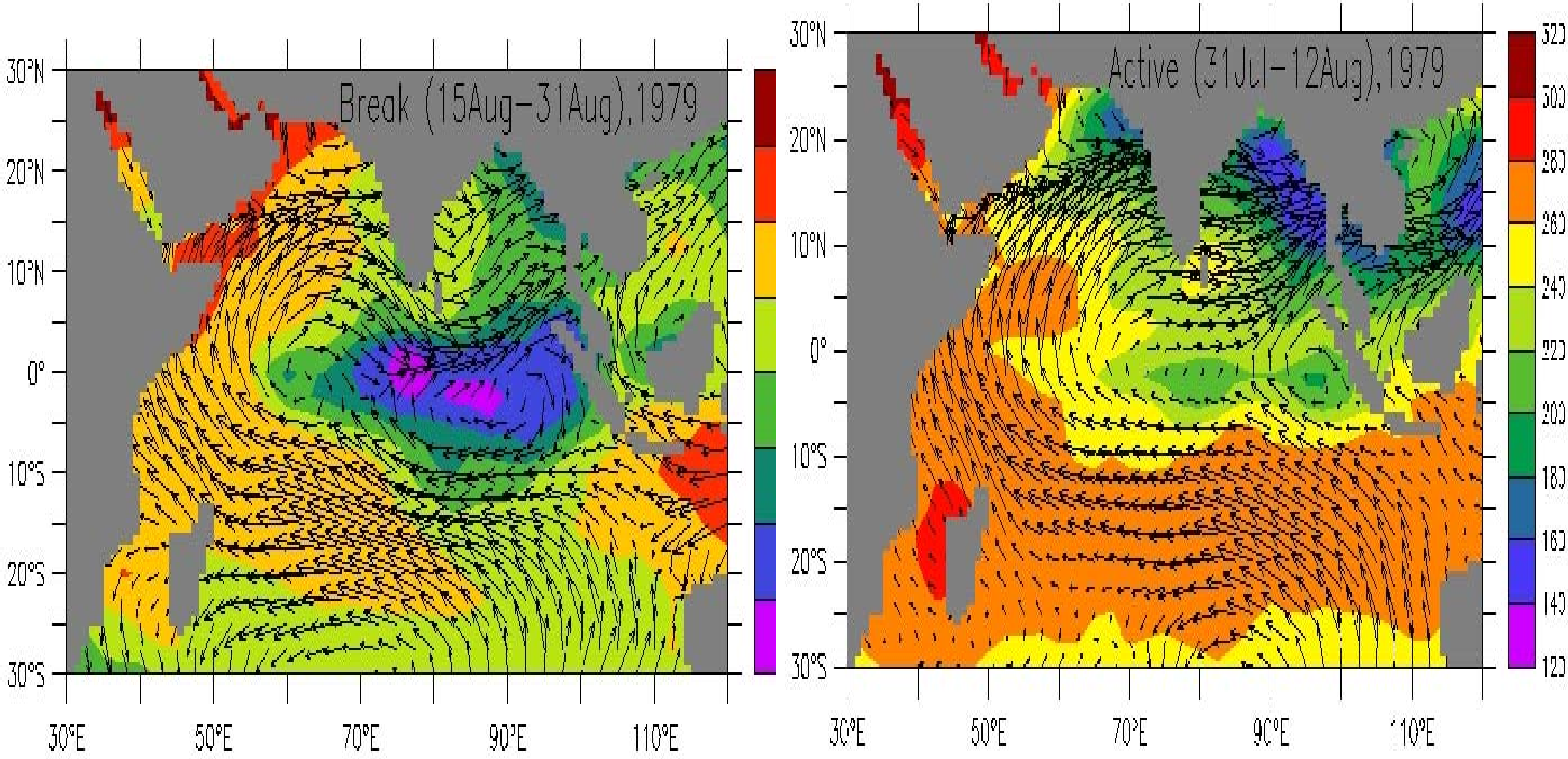
Active and break events are identified from the average rainfall data over a critical area, called the core monsoon zone (MZ) within which the MT/ CTCZ normally fluctuates. Events are defined as periods in which the normalized anomaly of the rainfall over the MZ exceeds 1 or is less than -1.0 respectively, provided the criterion is satisfied for at least 3 consecutive days.







Convection (OLR) and LLJ (850 hPa) over IO during break and active monsoon conditions.



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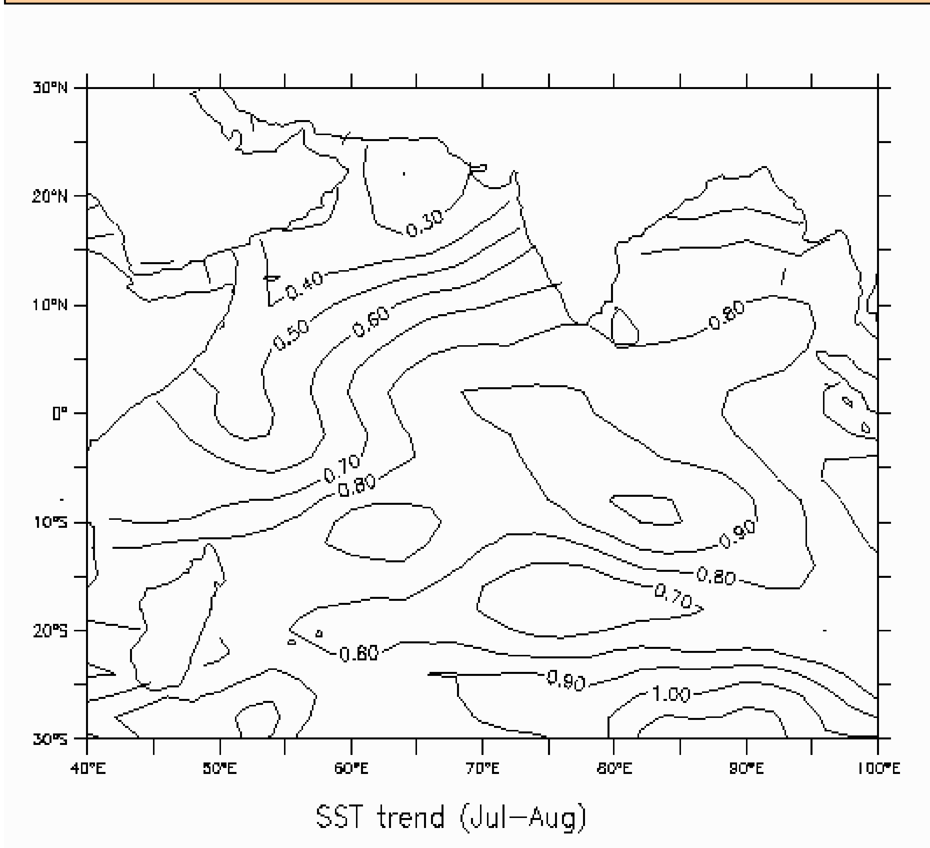
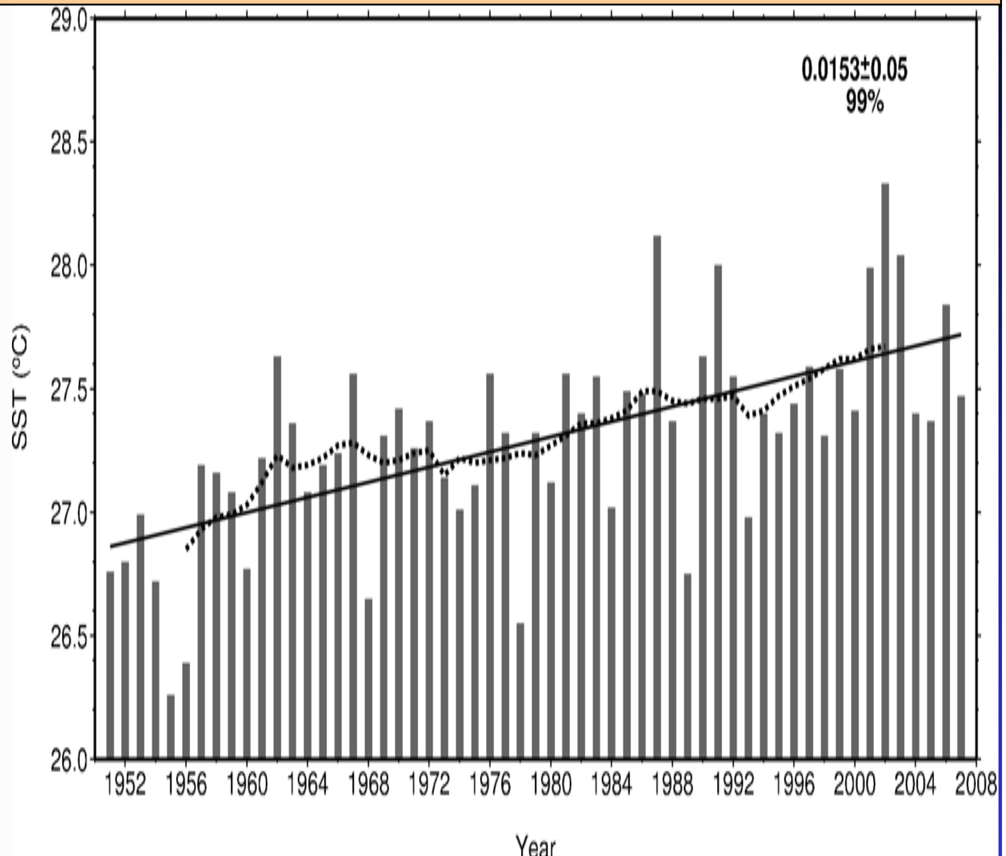
Swapna and Ramesh Kumar (2002)

Warming of the EEIO (1951-2008)





During the period (1951 – 2008) the SST of EEIO (0 – 10 S; 70 E – 90 E) has warmed much more than the Arabian Sea and Bay of Bengal by about 1 ^{0} C during this period.

Ramesh Kumar et al (2009a)

Breaks over India during 1951-2007

Decade	Type I			Type II			Total No. of Breaks	% of Type II to the total
	J	A	T	J	A	T		
1951-1960	15	21	36	3	4	7	43	16
1961-1970	14	12	26	3	6	9	35	26
1971-1980	14	18	32	2	5	7	39	18
1981-1990	15	19	34	3	6	9	43	21
1991-2000	9	30	39	7	7	14	43	33
2001-2007	7	12	19	5	4	9	28	32

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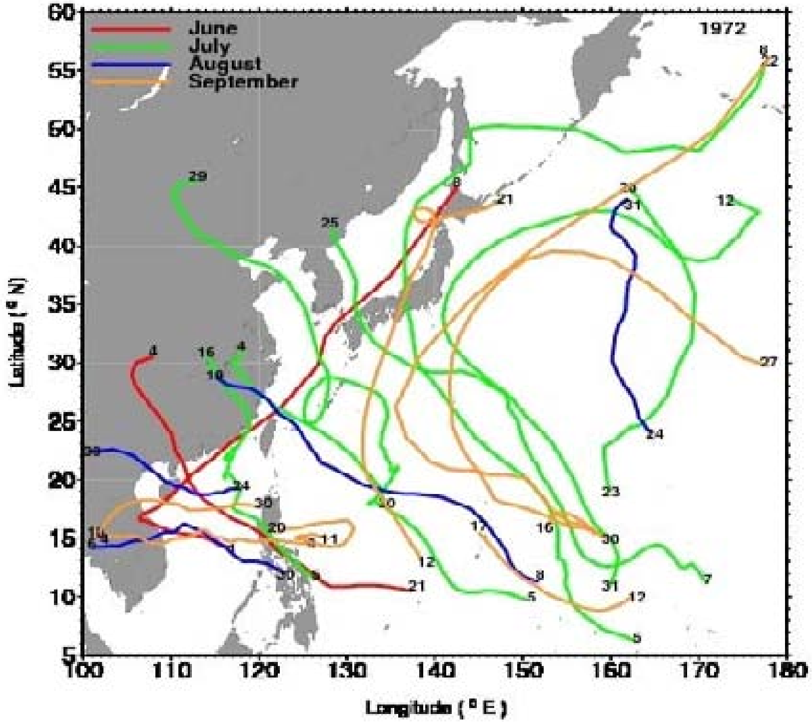
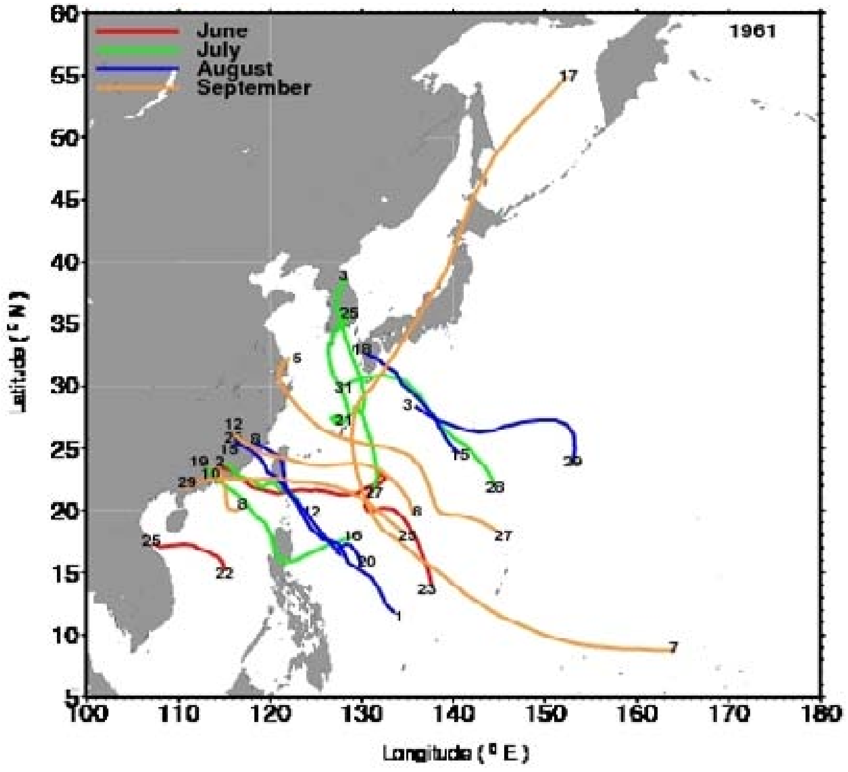
Ramesh Kumar et al (2009a)

Tracks of Convective Systems over SCS and NWP for two contrasting monsoon years

1961(E) : MR: 1020.1 mm

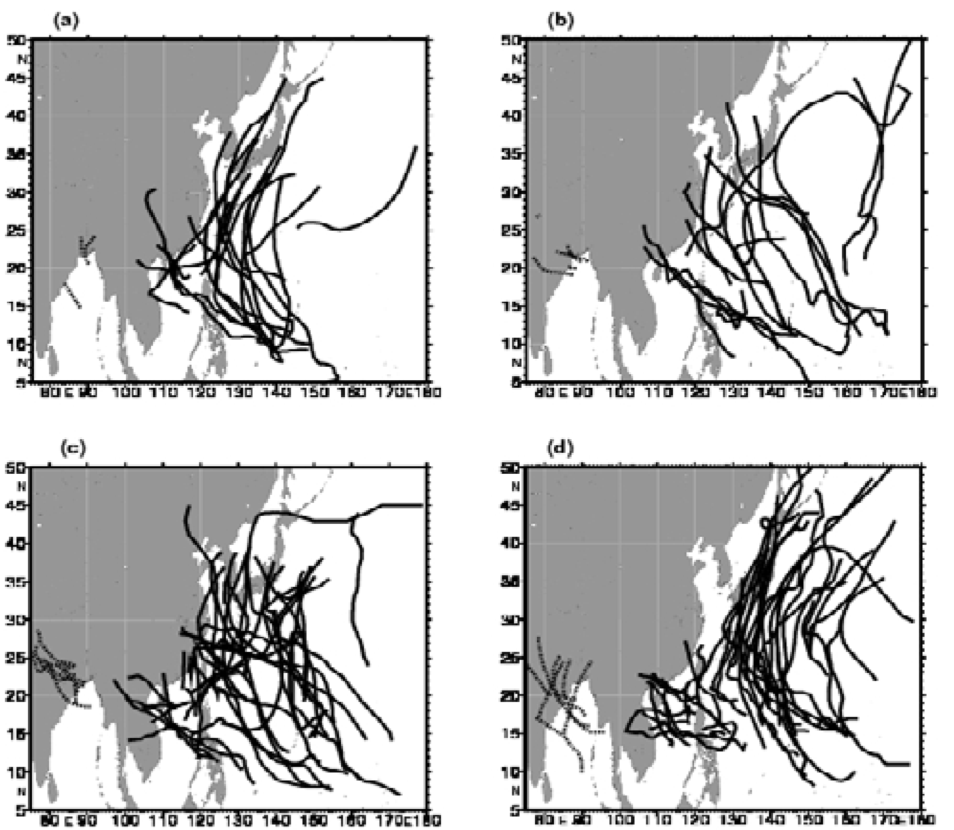




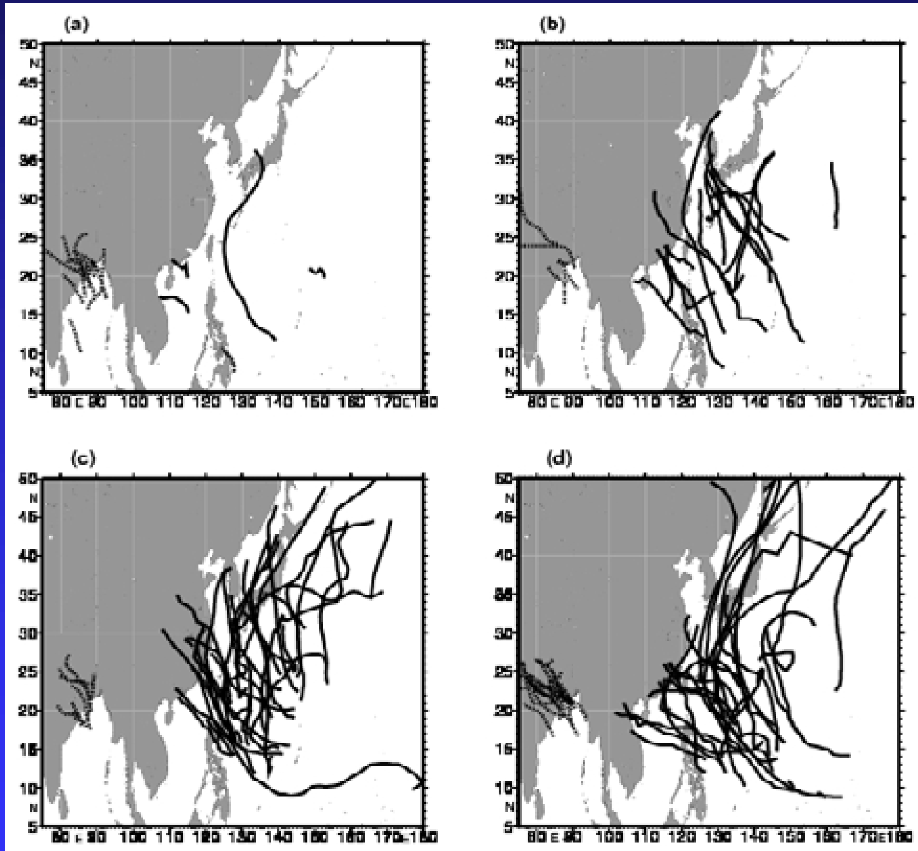
1972 (D):MR： 736.4 mm

Tracks of Convective Systems in Bay of Bengal and NWP during Deficit and Excess monsoon composites in Recent Decades

Deficit



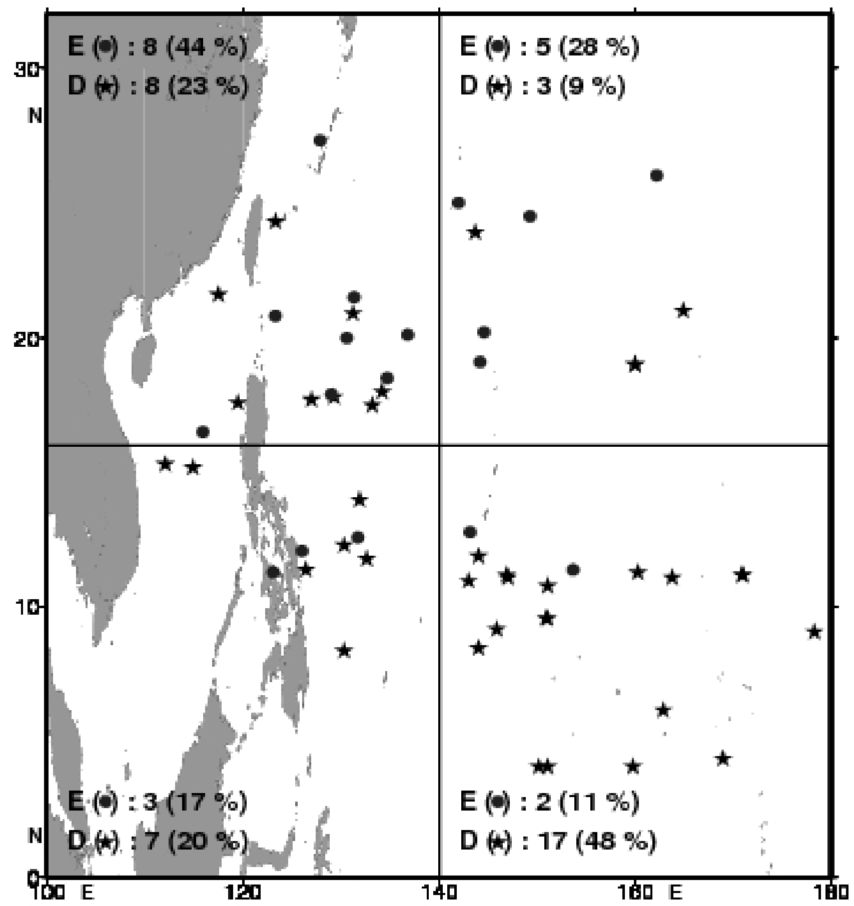
Excess



The number of systems was 1.83 times more over the NWP as compared to over the BB during deficit monsoon years.

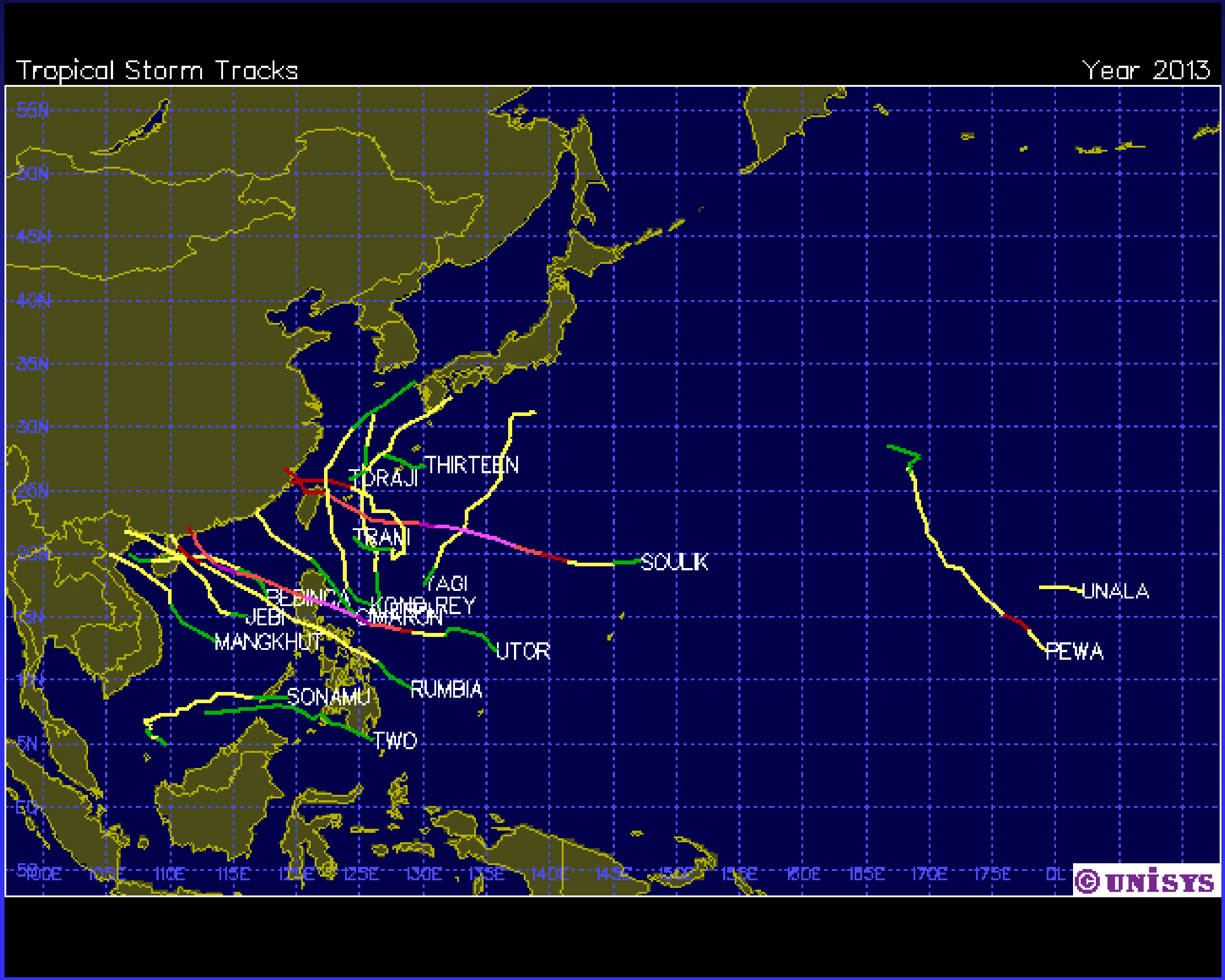
Composite picture of the systems (represented by stars and circles) formed during the excess (circle) and deficit (star) monsoon years for the peak monsoon month of July

During Deficit monsoon years and prolonged Breaks, the majority of NWP systems formed further south than in the case of excess monsoon years. The correlation between the number of break days and the number of systems that formed in NWP was positive and statistically significant (r = 0.73).



Ramesh Kumar et al (2009b)

Convective systems in the Northwestern Pacific Ocean 2013



Convective Systems over WP 2013

No.	Name	Date	Wind	Cat
1	Tropical Storm SONAMU	03-08 JAN	45	-
2	Tropical Depression TWO	19-21 FEB	25	-
3	Tropical Storm YAGI	08-12 JUN	55	-
4	Tropical Storm LEEPI	17-20 JUN	35	-
5	Tropical Storm BEBINCA	20-23 JUN	35	-
6	Typhoon-1 RUMBIA	28 JUN-02 JUL	65	1
7	Super Typhoon-4 SOULIK	07-13 JUL	125	4
8	Tropical Storm CIMARON	15-18 JUL	40	-
9	Tropical Storm JEBI	31 JUL-03 AUG	60	-
10	Tropical Storm MANGKHUT	05-07 AUG	40	-
11	Super Typhoon-4 UTOR	08-14 AUG	130	4
12	Tropical Depression THIRTE	17-17 AUG	25	-
13	Typhoon-1 TRAMI	17-21 AUG	75	1
14	Typhoon-1 PEWA	18-25 AUG	65	1
15	Tropical Storm UNALA	19-19 AUG	35	-
16	Tropical Storm KONG_REY	26-31 AUG	55	-
17	Tropical Storm TORAJI	01-04 SEP	50	

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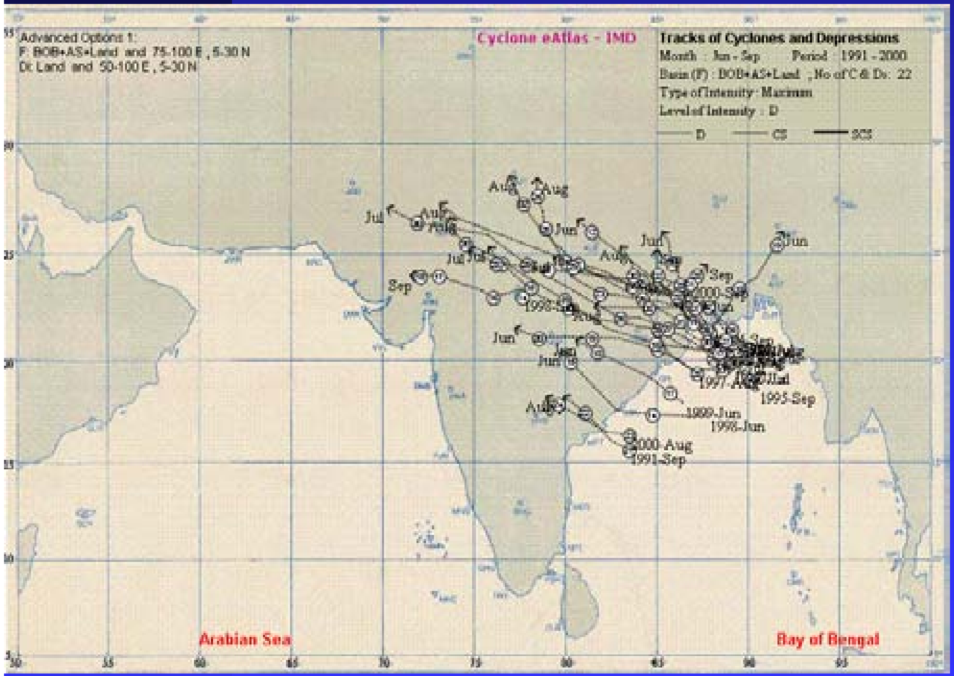
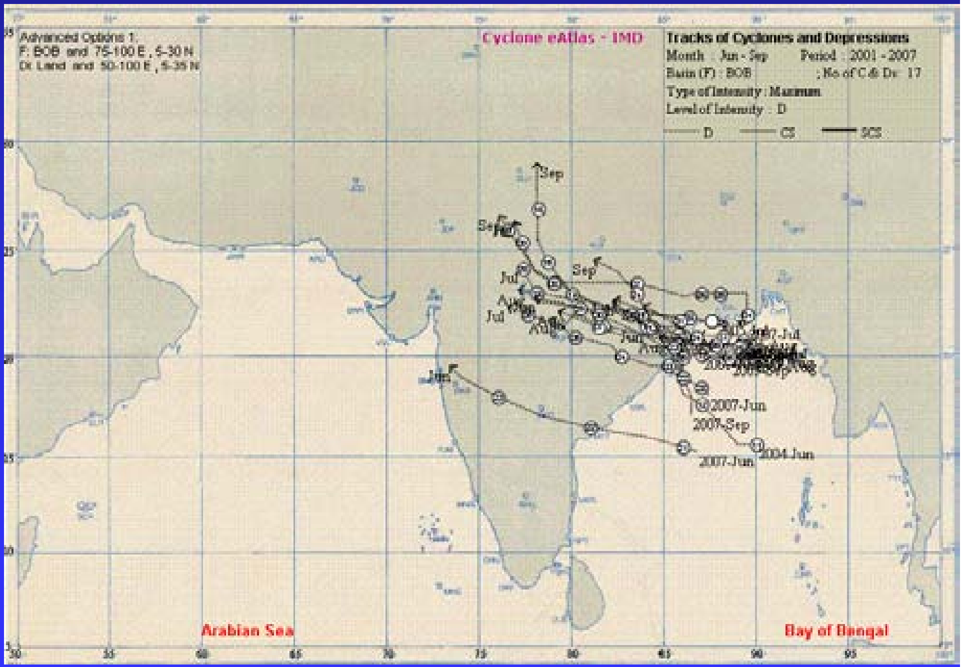
Tracks of MD in BB for recent decades

Monsoon depressions are disturbances that form over the North Indian Ocean during the Monsoon season and giving copious amounts of rainfall over the Indian sub continent.





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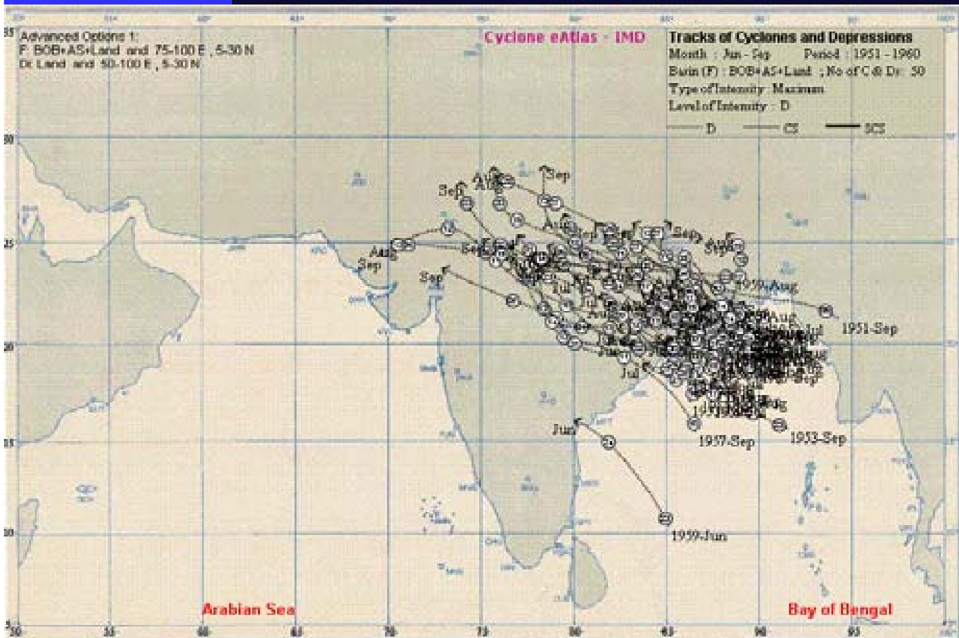
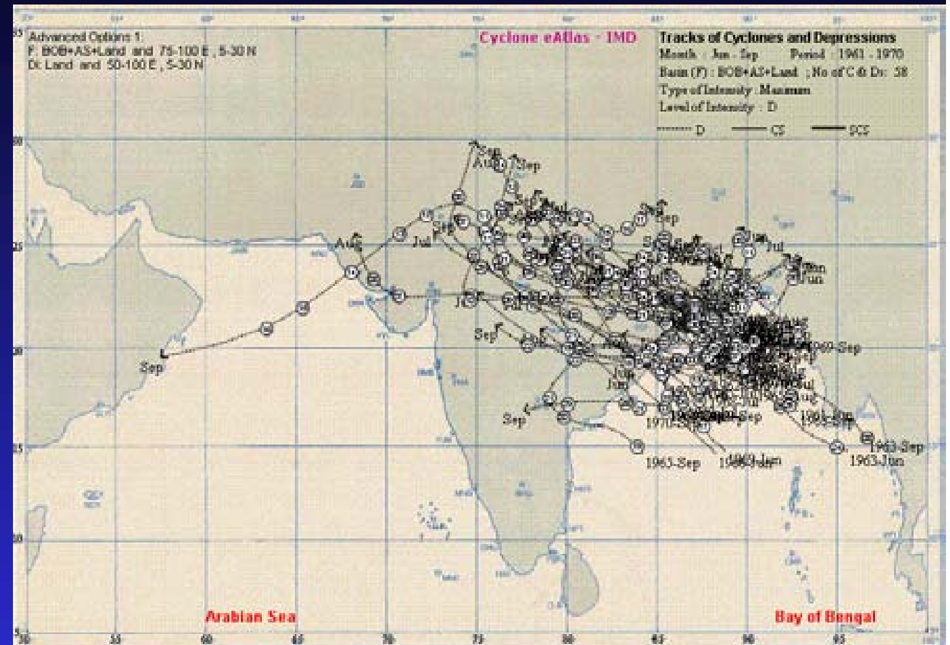
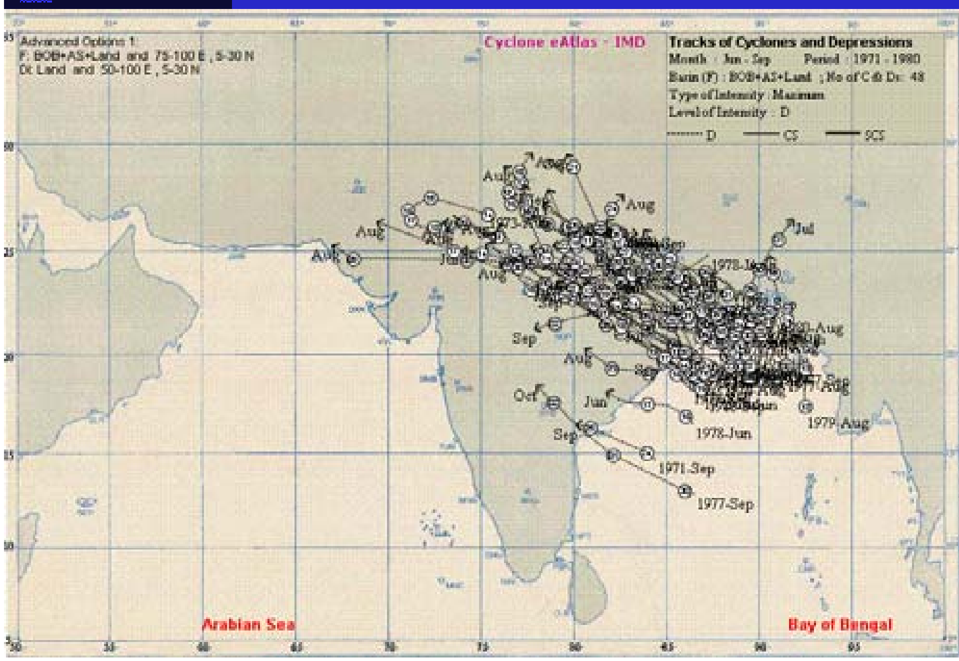
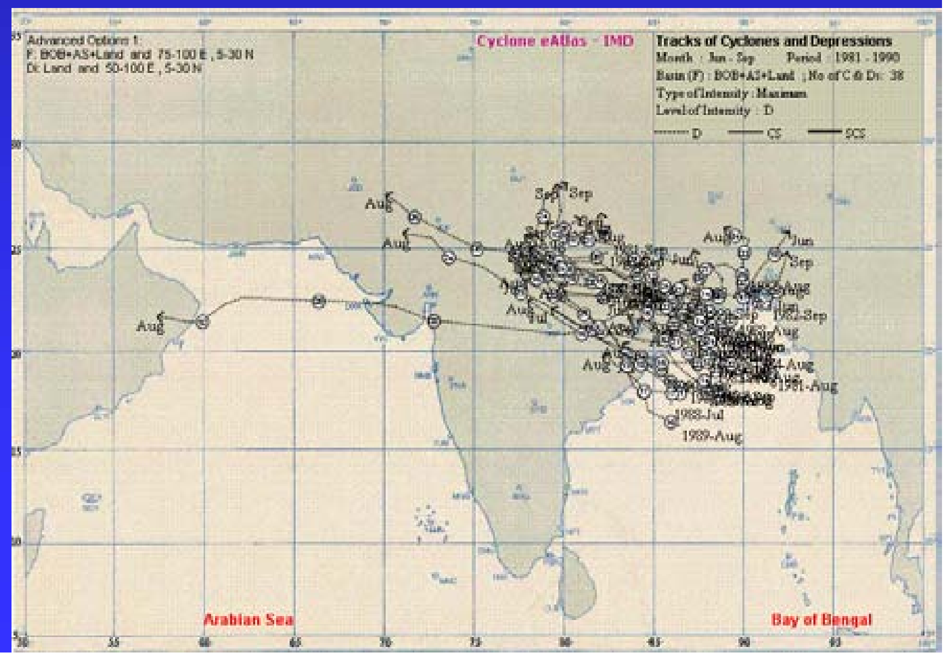
Tracks of MD in BB for different decades

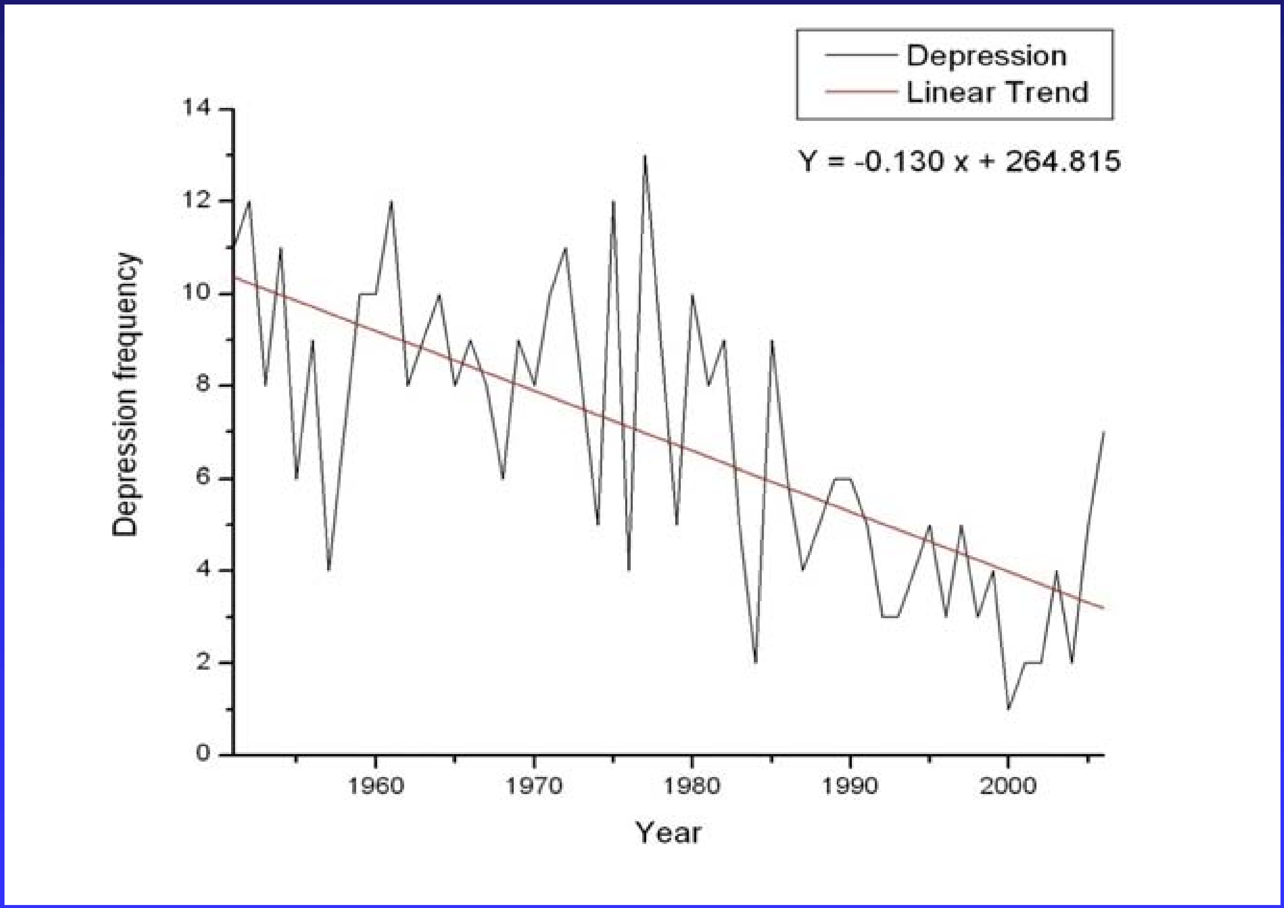








Trend of Monsoon Depressions In Bay of Bengal for 1951-2007



Monthly location of the systems (Latitude (^{0} N), Longitude (^{0} E)) over NWP during deficit and excess monsoon composites and the difference between them

Month	Excess		Deficit		Difference	
	Lat	Long	Lat	Long	Lat	Long
June	14.70	131.13	13.97	133.95	0.73	-2.82
July	18.75	136.94	13.32	143.80	5.43	-6.86
Aug	19.27	138.25	16.78	138.92	2.49	-0.67
Sep	15.74	141.30	16.23	141.69	-0.49	-0.39

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Ramesh Kumar et al., (2009a)

Quantum of Monsoon Rainfall

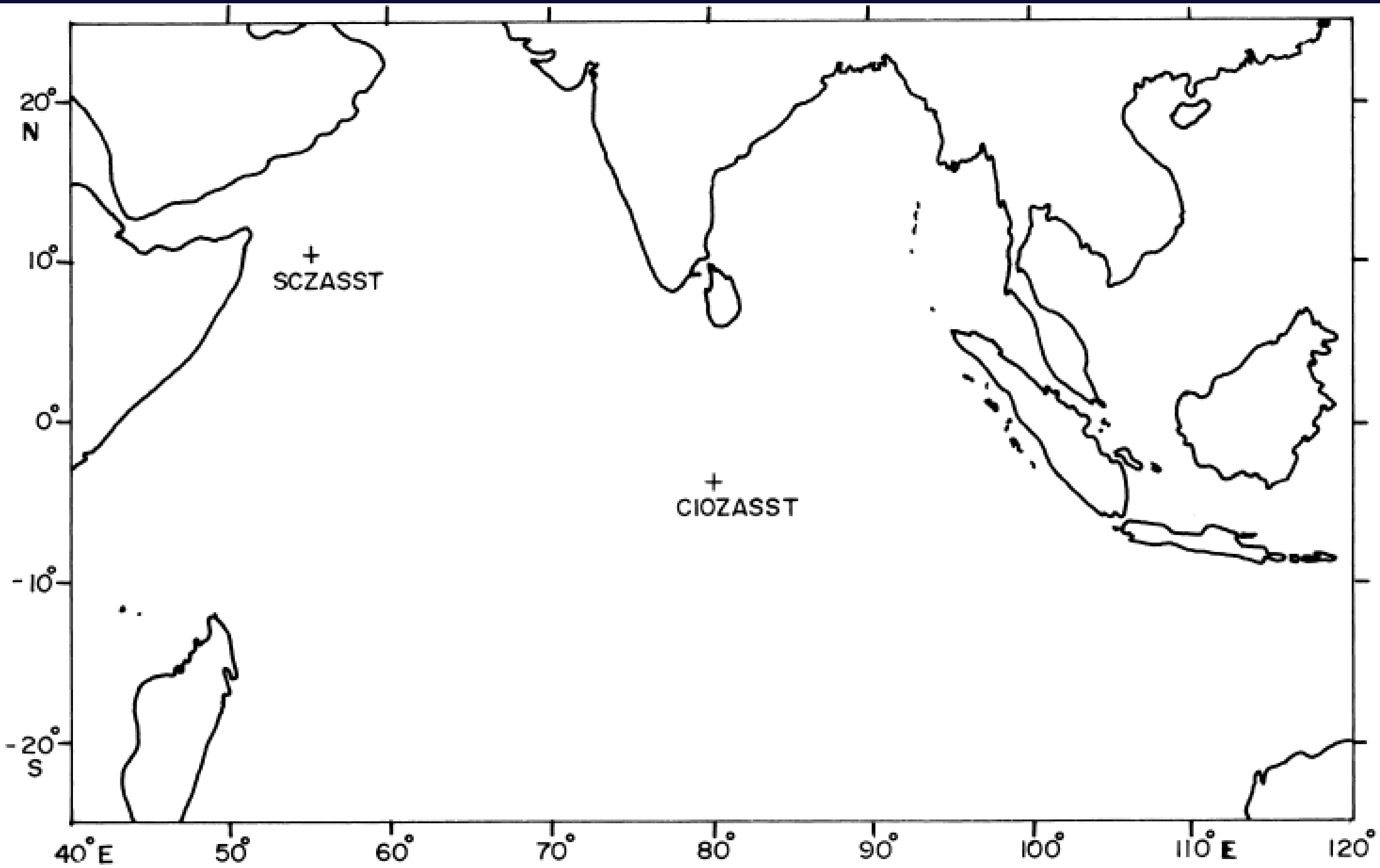

Figure 3. Map showing the regions used for computation of SCZASST and CIOZASST.

Ramesh Kumar et al., 1986

CC between SCZASST and weekly subdivisional Monsoon Rainfall

Subdivision	0	1	2	3
Kerala	----	----	----	-0.57
Konkan & Goa	-0.55	----	----	----
W. Rajasthan	-0.42	----	----	----
E. Rajasthan	-0.56	----	----	----
W.M.P.	-0.60	-0.45	----	----
E.M.P.	-0.64	-0.55	-0.48	-0.38
Marthawada	----	----	-0.44	----
Vidarbha	-0.54	----	----	----

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Ramesh Kumar et al., (1986)

CC between CIOZASST and weekly subdivisional rainfall

Subdivision	0	1	2	3
Kerala	0.43	----	----	----
Konkan & Goa	0.54	0.38	----	----
E. Rajasthan	0.44	----	----	----
W.M.P	0.63	----	----	----
E.M.P.	0.66	0.52	----	----
Marthwada	0.51	0.47	----	----
Vidarbha	0.56	0.52	----	----
Coastal A.P	----	----	----	-0.54

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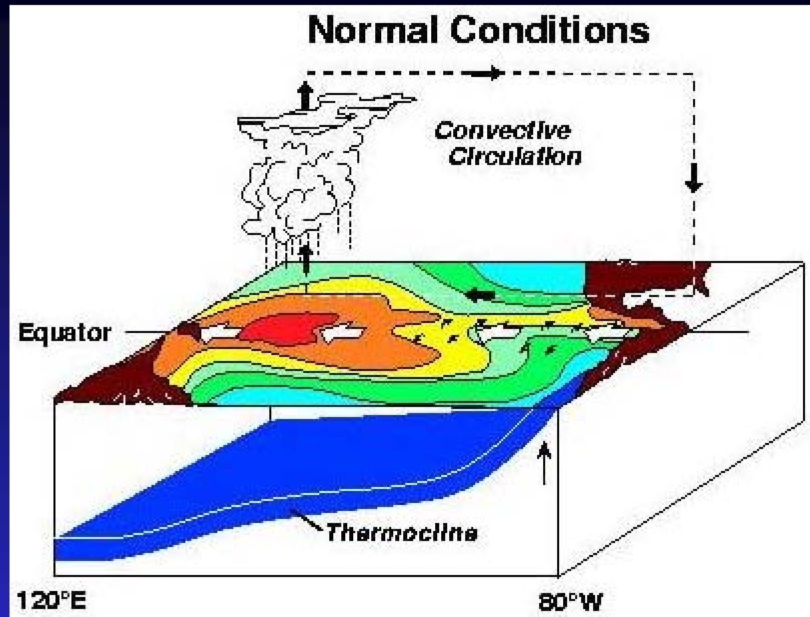
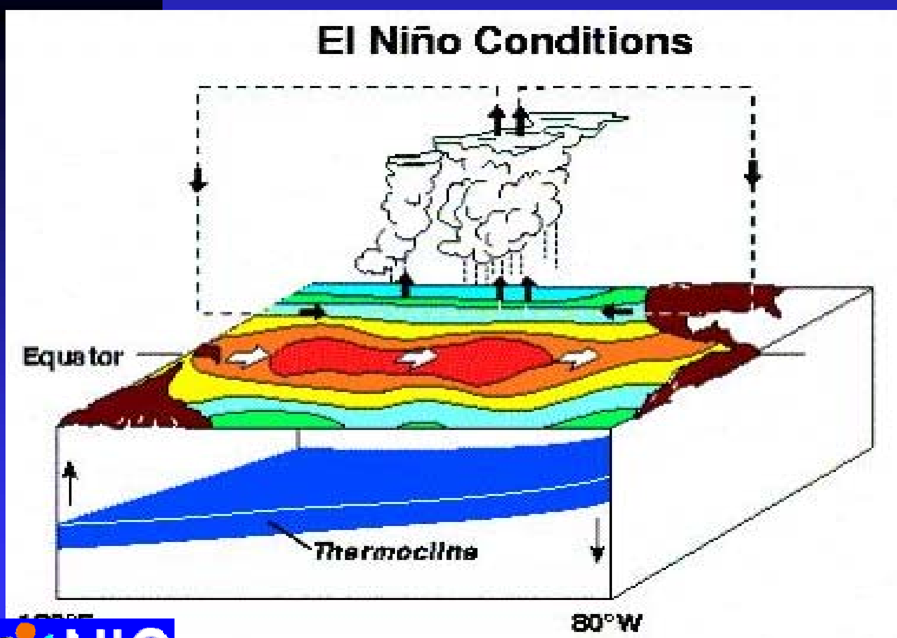
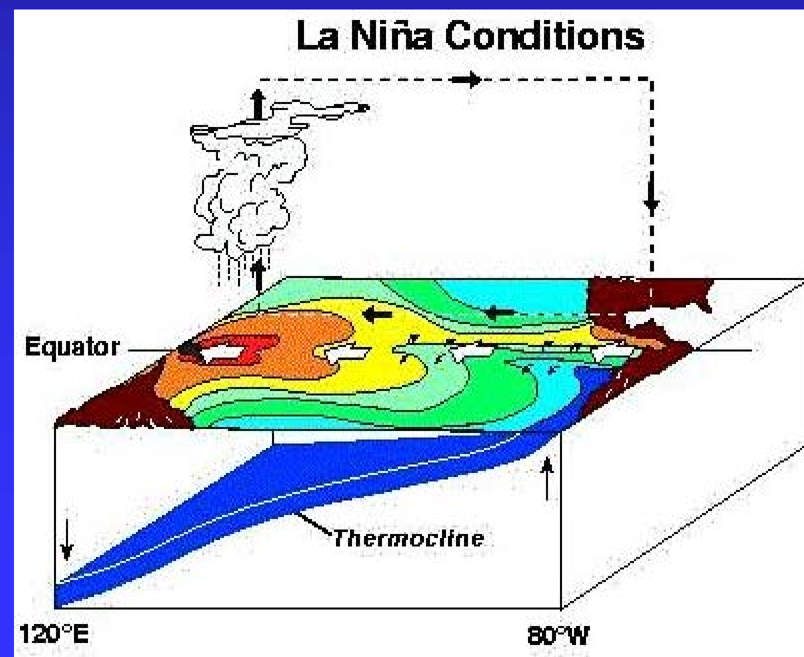
Ramesh Kumar et al., (1986)







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ISMR anomalies during El Nino and La Nina years

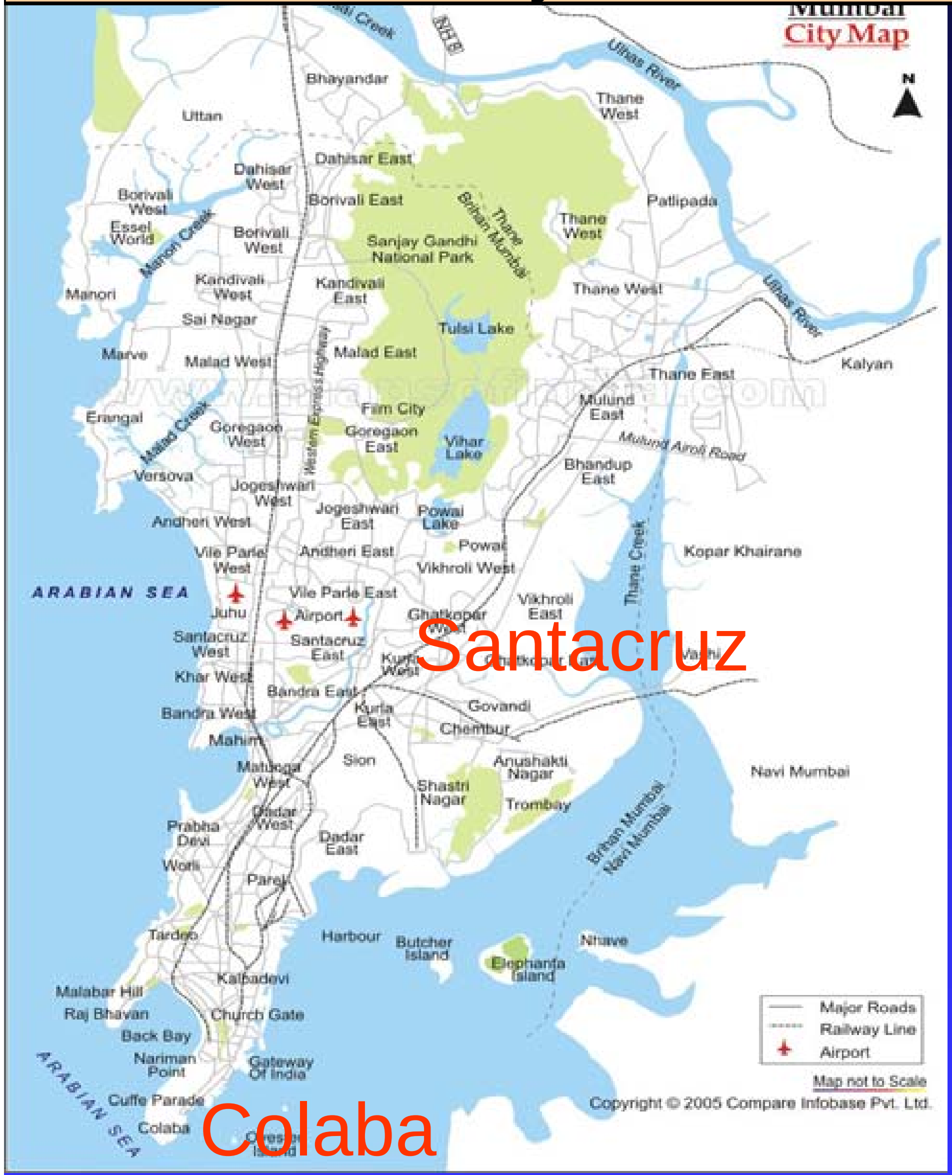
Number of years with	Deficient monsoon Deficit>10%	Normal monsoon (-ve)	Normal monsoon (+ve)	Excess monsoon excess>10%	Total
El Nino	11	11	4	0	26
La Nina	0	1	9	8	18
Other	11	23	42	11	87
Total	22	35	55	19	131

P.S: Most interesting aspect is that there are equal numbe
Of deficit years without El Nino too !!!

Rupakumar et al., (2002)

Intense Rainfall Events

Intense Rainfall Events. We consider an event as IRE if the daily rainfall is more than 10 cm/day.



24 hour Rainfall recorded at 0830IST

on 02 July 1984

Colaba - 54cm

Santacruz - 24cm

24 hour Rainfall recorded at 0830IST

on 27 July 2005

Colaba - 7cm

Santacruz - 94cm

Changes in the Frequency Distribution of Extremes during 1951-1970 and 1980-2000

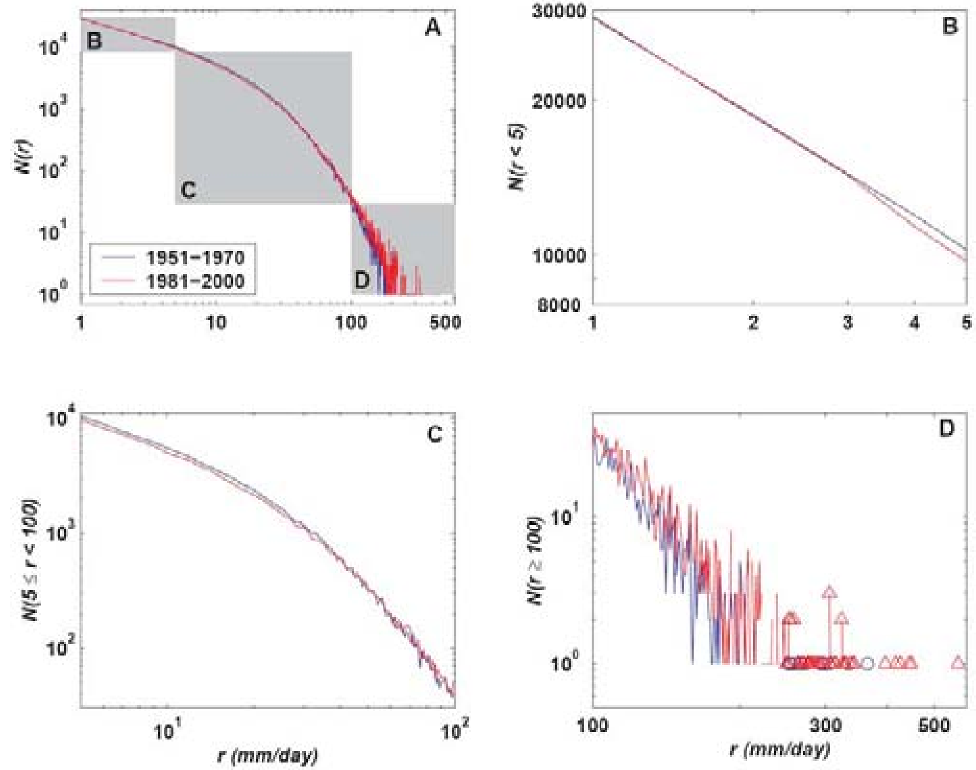
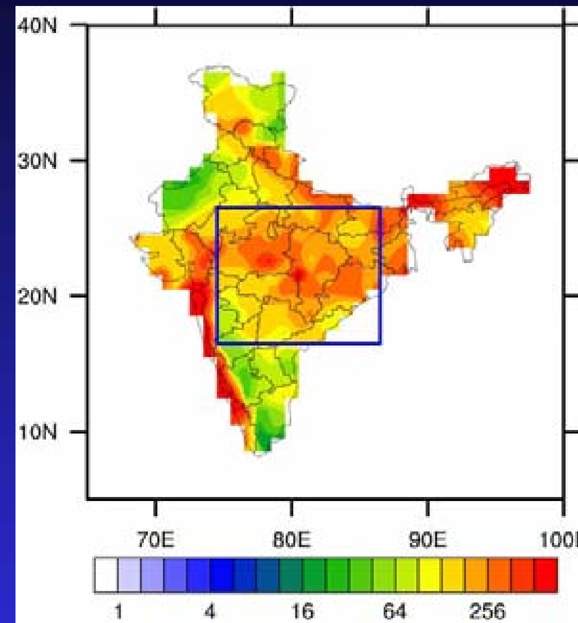


Fig. S2: (A) Frequency Histogram of daily rainfall over CI during summer monsoon for two periods, 1950-1970 and 1980-2000. The regions marked by the shaded rectangles in A are magnified in B, C, and D. For the sake of clarity, rain intensities larger than 250 mm/day have been shown by symbols (blue circles and red triangles) in panel (D).



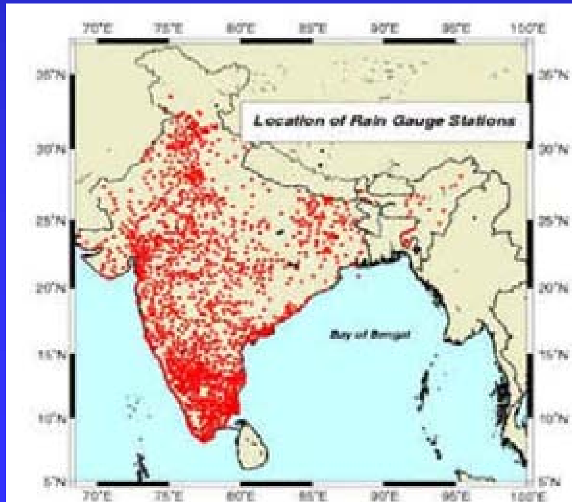


Figure 1. Location of 1803 rain gauge stations.

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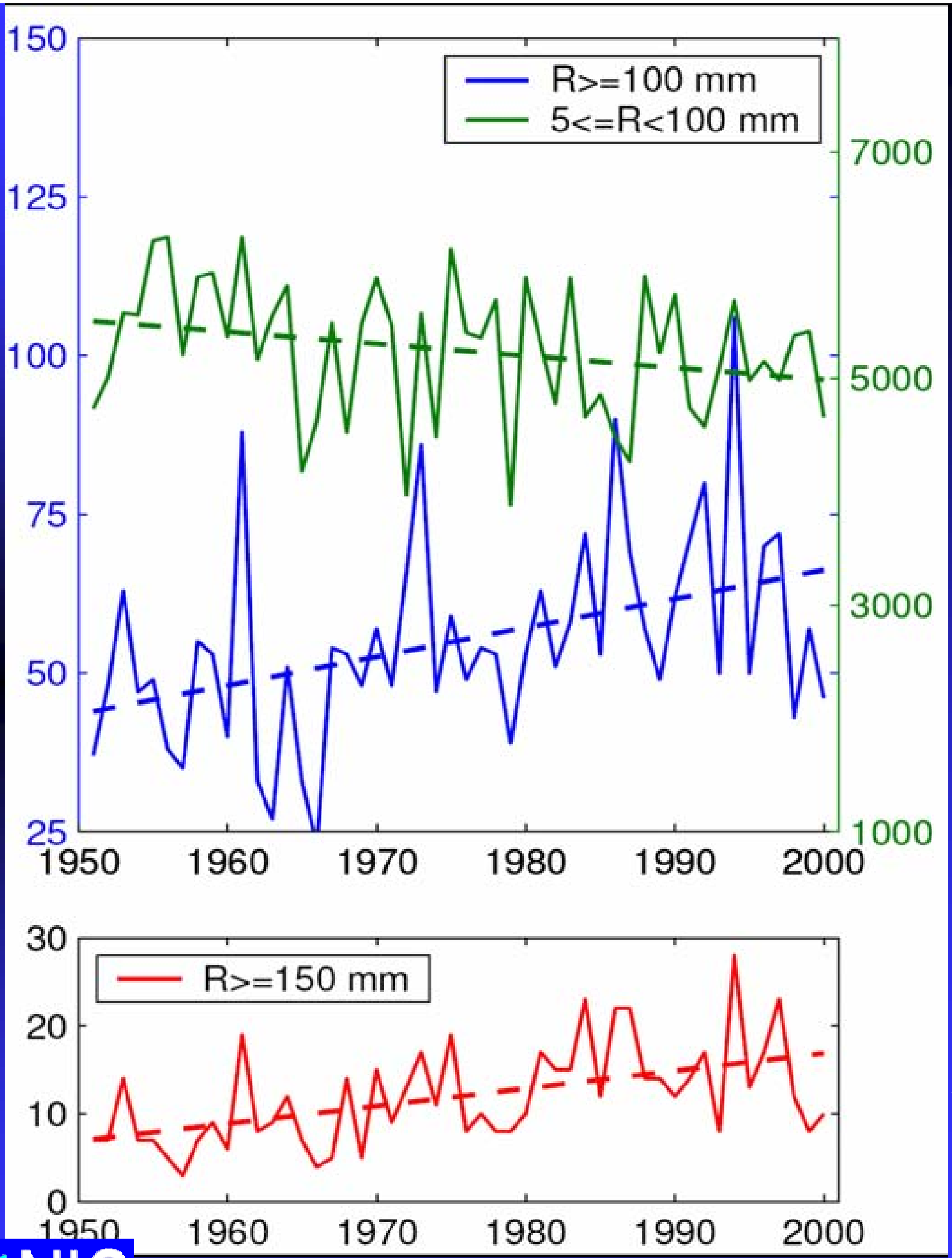
Goswami et al ., (2006)

Time series of count over CI



Low & Moderate events

Heavy events (>10cm)

V. Heavy events (>15cm)

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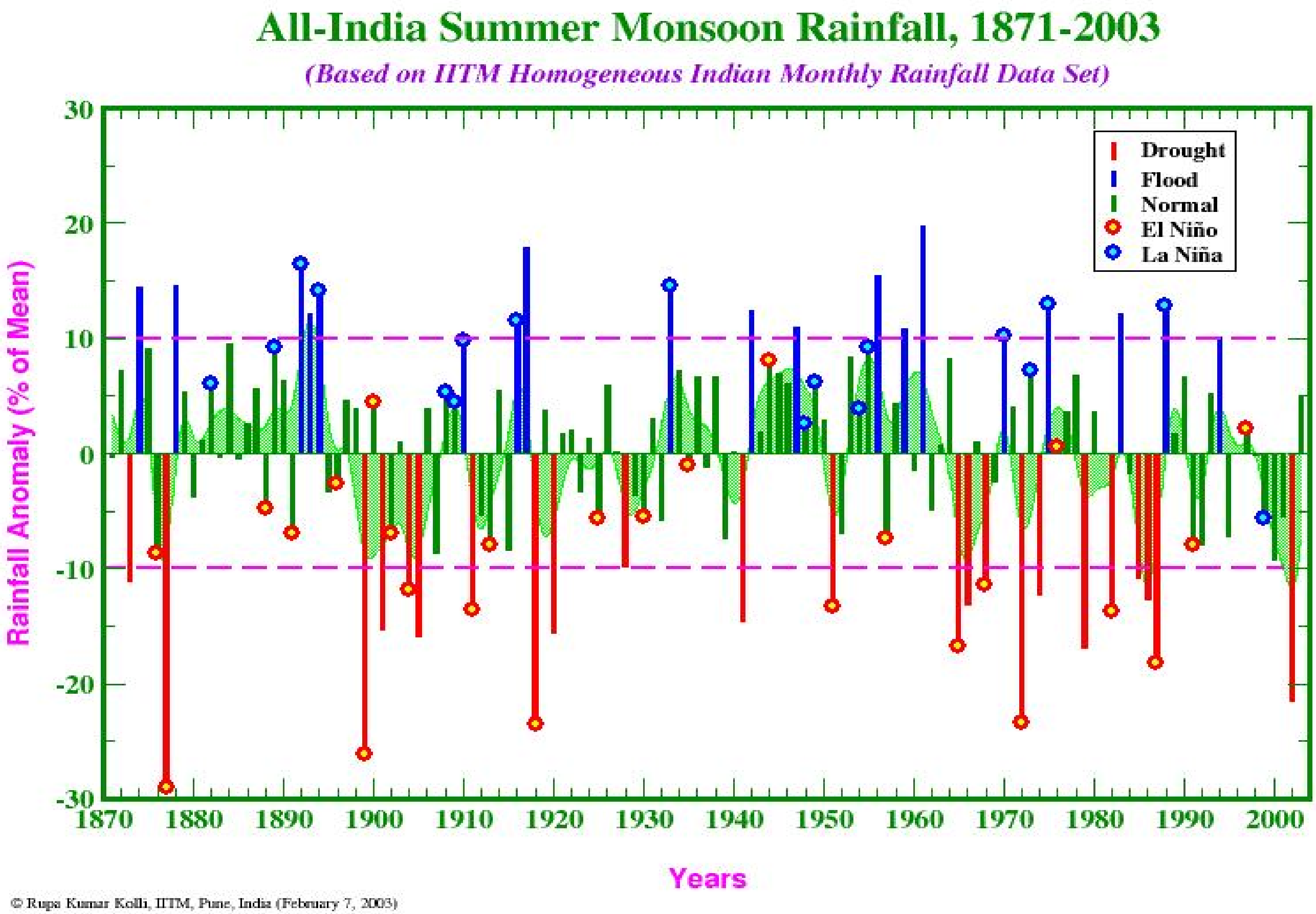
Goswami et al ., (2006)


All-India Summer Monsoon Rainfall, 1871-2003
(Based on IITM Homogeneous Indian Monthly Rainfall Data Set)
Drought
Flood
Normal
El Niño
La Niña
Rainfall Anomaly (% of Mean)
30
20
10
0
-10
-20
-30
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Years
© Rupa Kumar Kolli, IITM, Pune, India (February 7, 2003)
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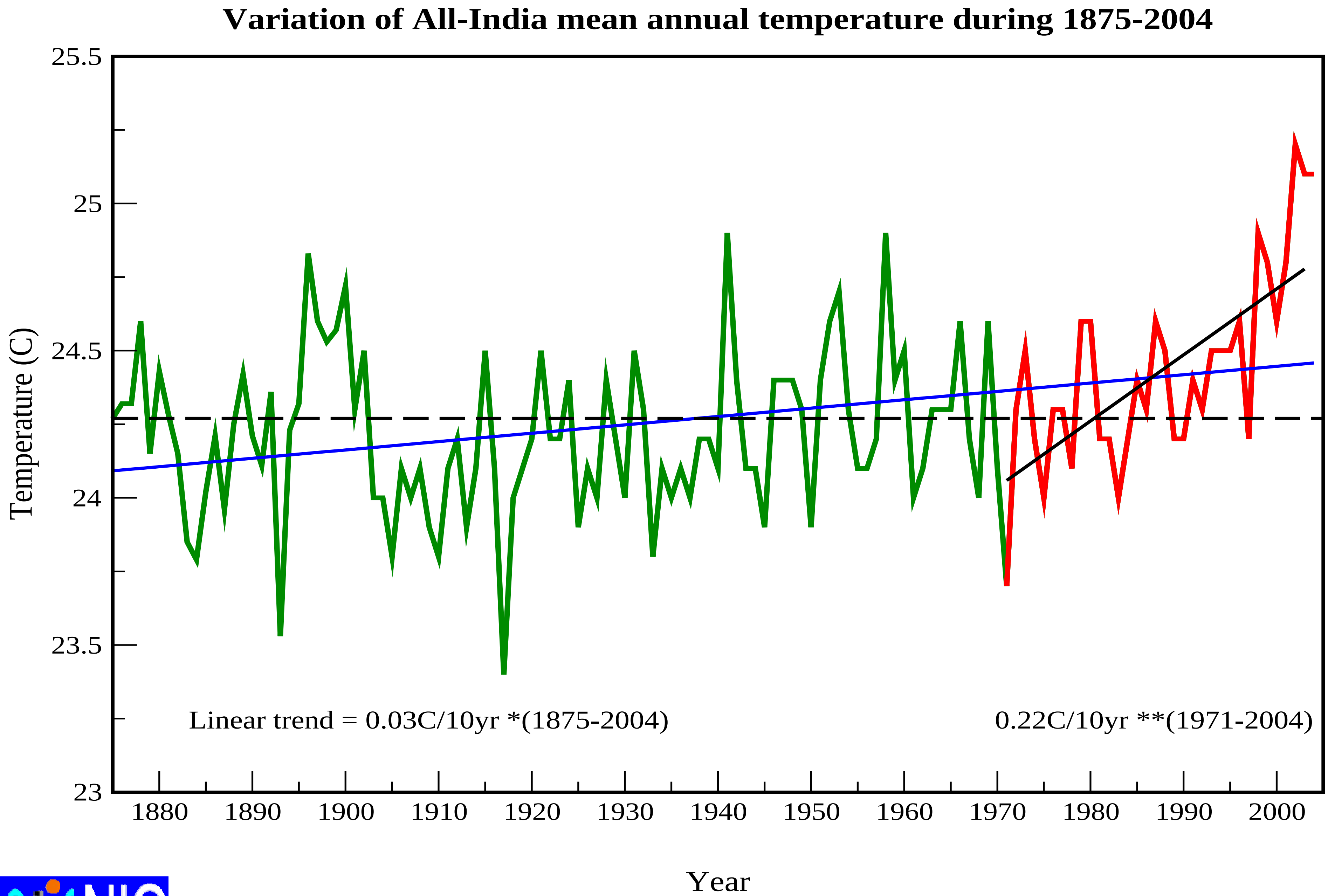
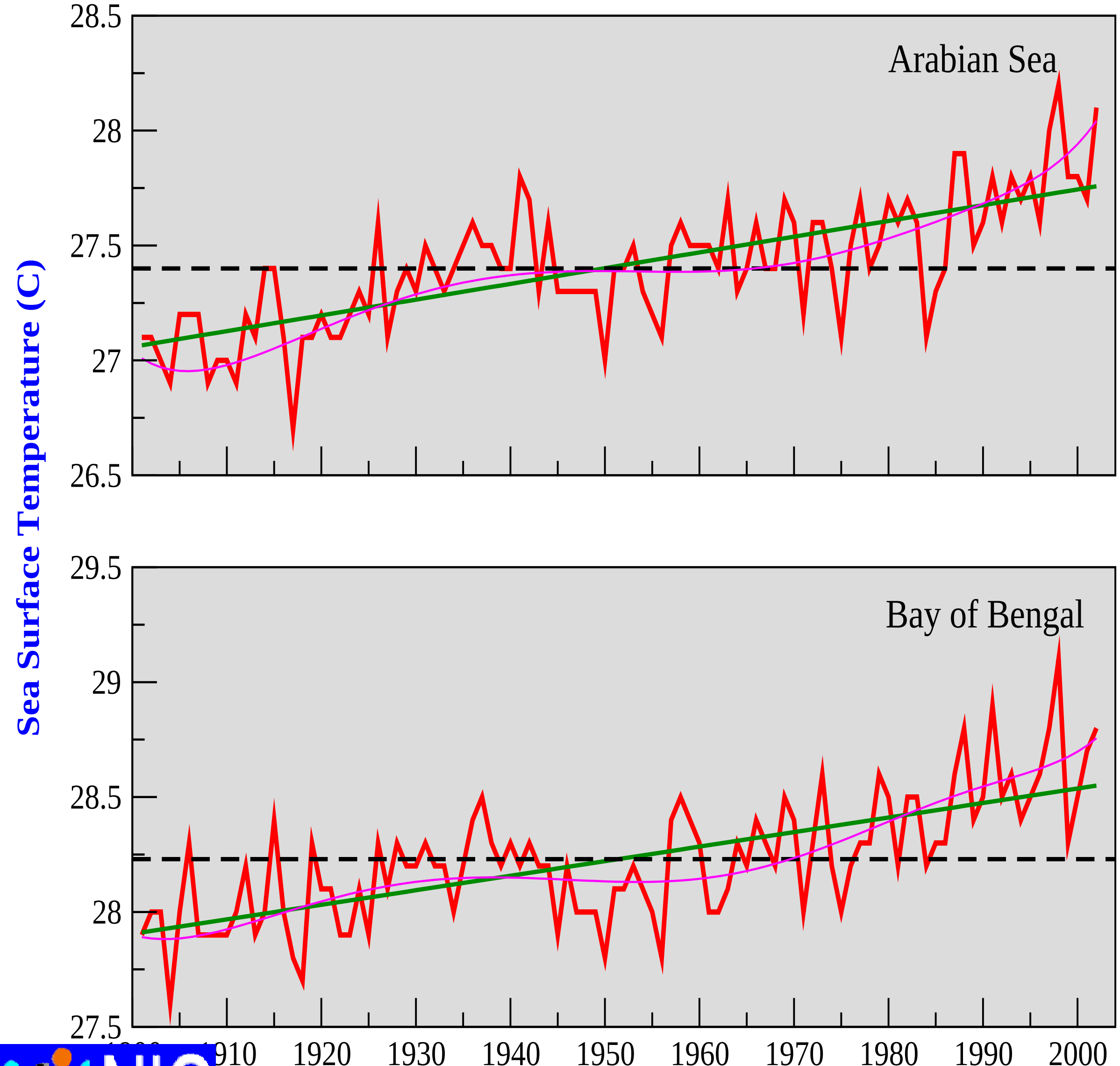
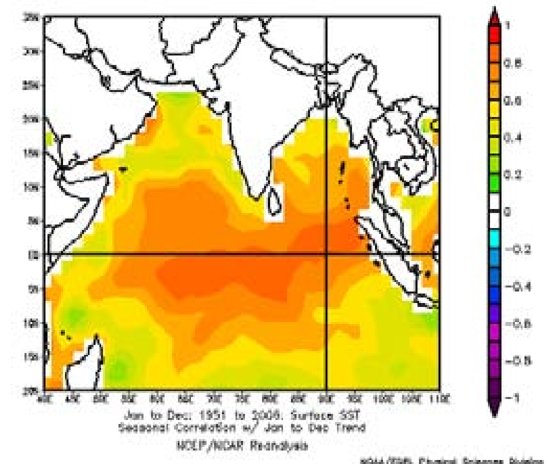

Variation of All-India mean annual temperature during 1875-2004
25.5
25
24.5
24
23.5
23
Temperature (C)
Linear trend = 0.03C/10yr *(1875-2004)
0.22C/10yr **(1971-2004)
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Year

Sea Surface Temperature Variations in the Indian Ocean





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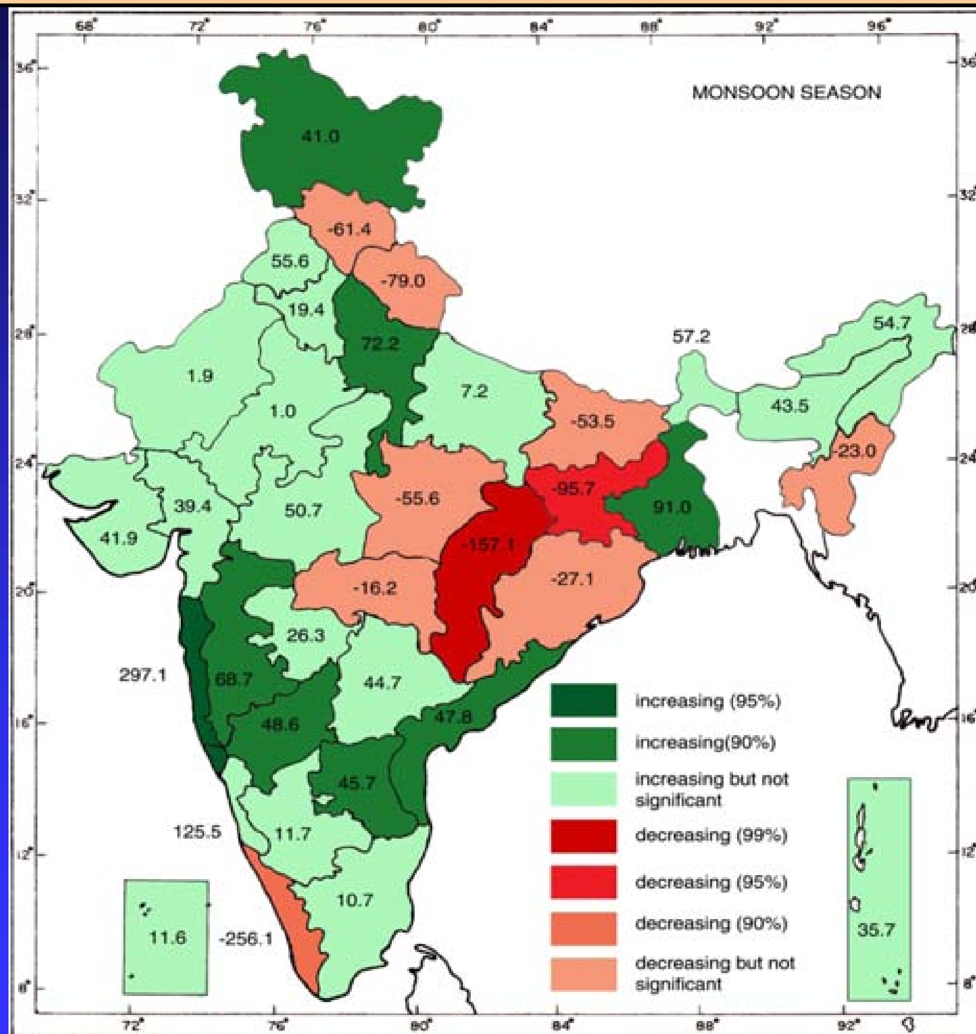
INCREASE/DECREASE IN RAINFALL (MM) IN 100 YEARS ALONG WITH THE SIGNIFICANCE LEVEL FOR THE SOUTH WEST MONSOON SEASON



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Guha Thakurtha P. and Rajeevan M (2008

Summary

During Recent Decades

- The convection over SHET and SST over EEIO has increased substantially.
- The VIMT to Peninsular India has shown a decreasing trend.
- TEJ over I.O. has also shown a decreasing trend.
- Monsoon depressions over BB is showing a decreasing trend.
- More systems formed over the NWP during deficit monsoon years and prolonged breaks.

The combined effect of all these Ocean Atmosphere phenomena has been to increase the prolonged “Breaks” in recent decades over India.

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Extreme Weather Events

Extreme Weather Events

- Cold Wave, Fog, Snow Storms
- Hailstorm, Thunderstorm, Dust storm.
- Heat Wave.
- Tropical Cyclones and Tidal waves
- Floods, Heavy Rain, land slides
- Droughts

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Cold Wave

- Occurrences of extreme low temperature in association with incursion of dry cold winds from north into the sub continent are known as cold waves. The northern parts of India specially the hilly regions and the adjoining plains are influenced by transient disturbances which often have weak frontal characteristics, known as western disturbances. They occur maximum over Jammu & Kashmir, Rajasthan and Uttar Pradesh.

Number of Cold Waves

State	1901-10	1911-67	1968-77	1978-99	1901-99
West Bengal	2	14	3	28	47
Bihar	7	27	8	67	109
Punjab	3	34	4	19	60
U.P	21	51	8	47	127
Rajasthan	11	124	7	53	198
J & K	1	189	6	15	211
M.P.	9	88	7	12	116

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Fog

- Immediately after the passage of a Western Disturbance a lot of moisture is available in the atmosphere and the regional and synoptic scale conditions provide the trigger for the formation of fog. This has an effect on all forms of transport and in particular to aviation. This has indirect effect on the economy of aircraft operations and air passenger inconvenience. Airports in north India show a significant increasing trend in visibility during the winter season amounting to 90%.

Heat Wave

- Extreme positive departures from the normal maximum temperature result in heat wave during the summer season. They occur maximum over Uttar Pradesh. Bihar, Rajasthan, West Bengal etc.

- In recent years the heat wave has increased in both in intensity as well as duration.

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Number of Heat Waves

State	1901-10	1911-67	1968-77	1978-99	1901-99
West Bengal		31	2	28	61
Bihar		76	9	28	113
Punjab		---	1	---	1
U.P		105	6	23	134
Rajasthan		43	1	7	51
J & K		26	5	35	66
M.P.		32	4	15	51

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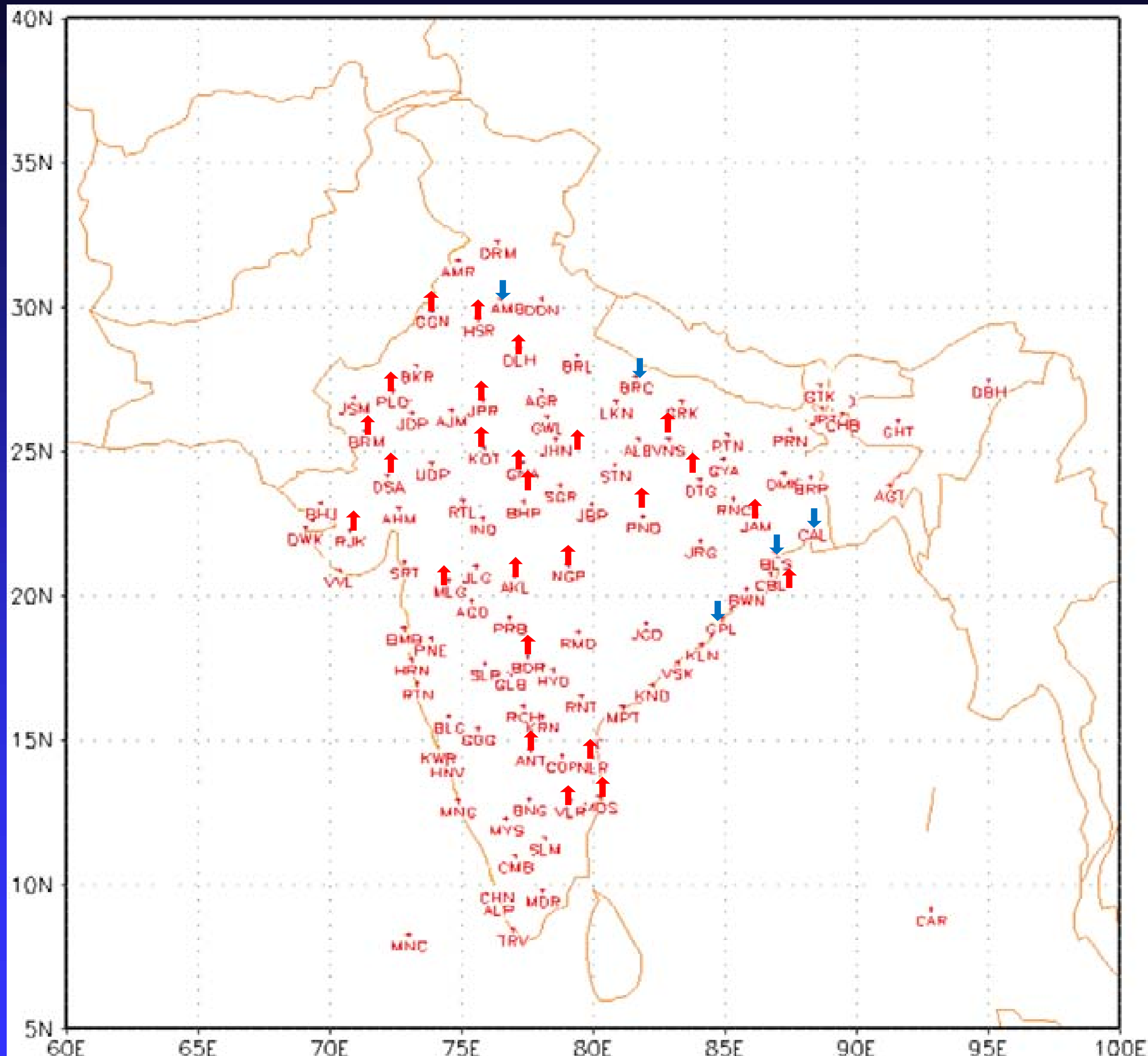
Trends in Heat Waves over India (1961-2010)



IMD

Tropical Cyclones
of
Indian Seas

Genesis of Cyclones

There are two seasons for cyclone formation in the north Indian Ocean :

- Pre Monsoon - (March to May)
- Post Monsoon - (October to December)

Objectives

To study whether there is any significant influence of climate change on the frequency and intensity of cyclonic storms over the north Indian Ocean during these seasons.

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Cyclogenesis Parameters

- Low level Relative Vorticity
- Inverse of the Vertical shear of the horizontal wind between lower and upper troposphere.
- Ocean thermal energy , SST> 26°C upto a depth of 60 m
- MTRH (500 hPa).

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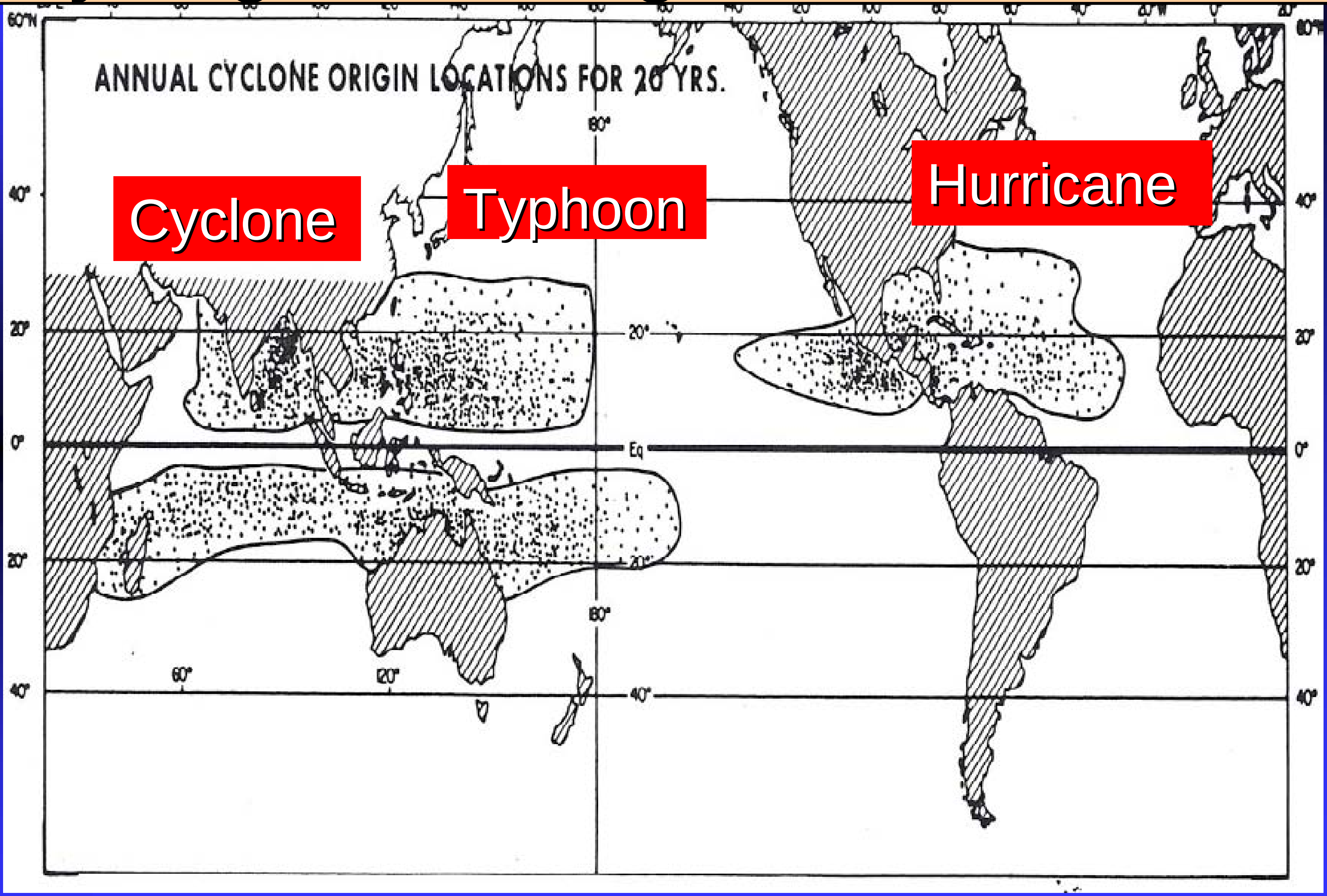
Cyclogenesis regions over Globe



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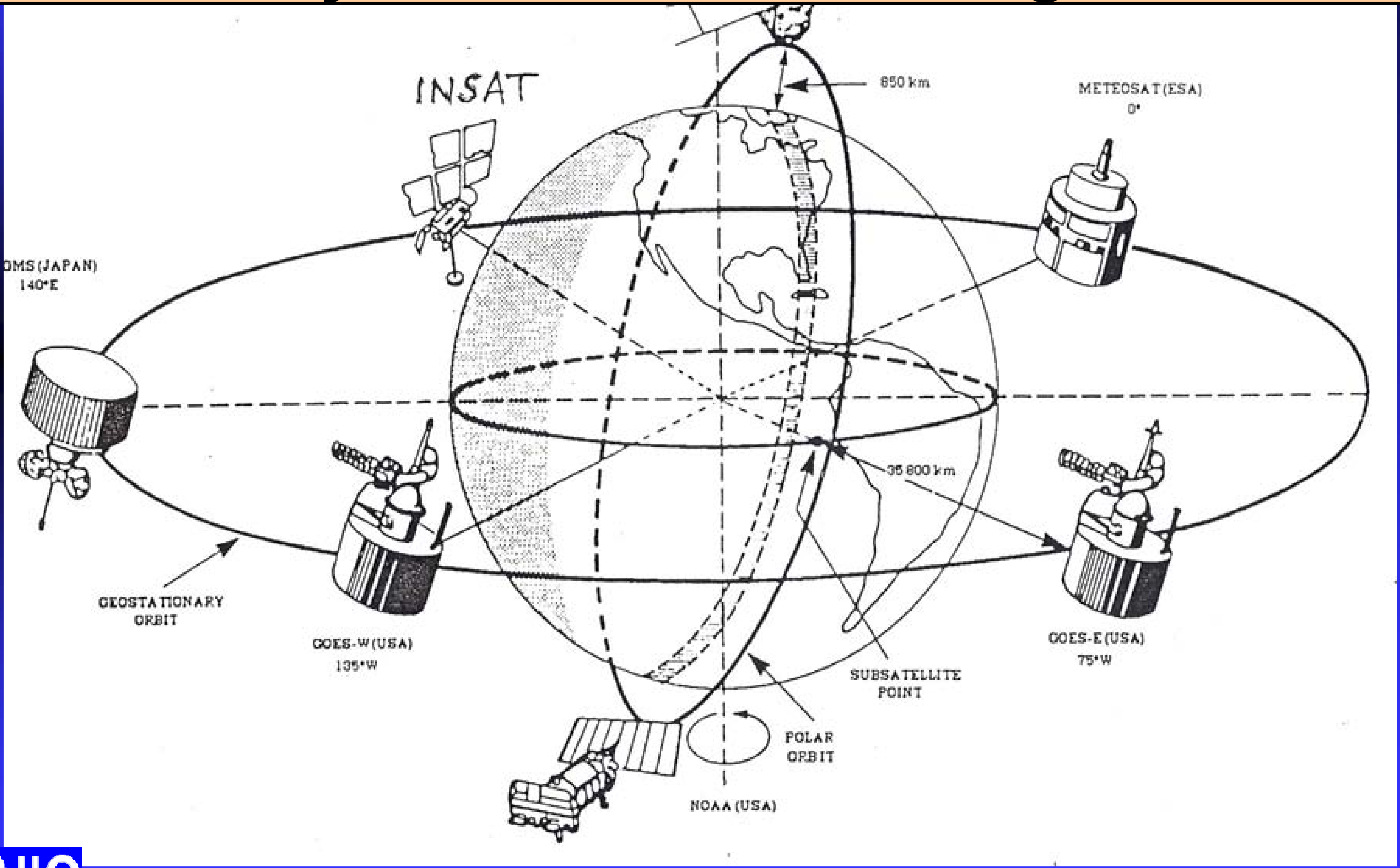
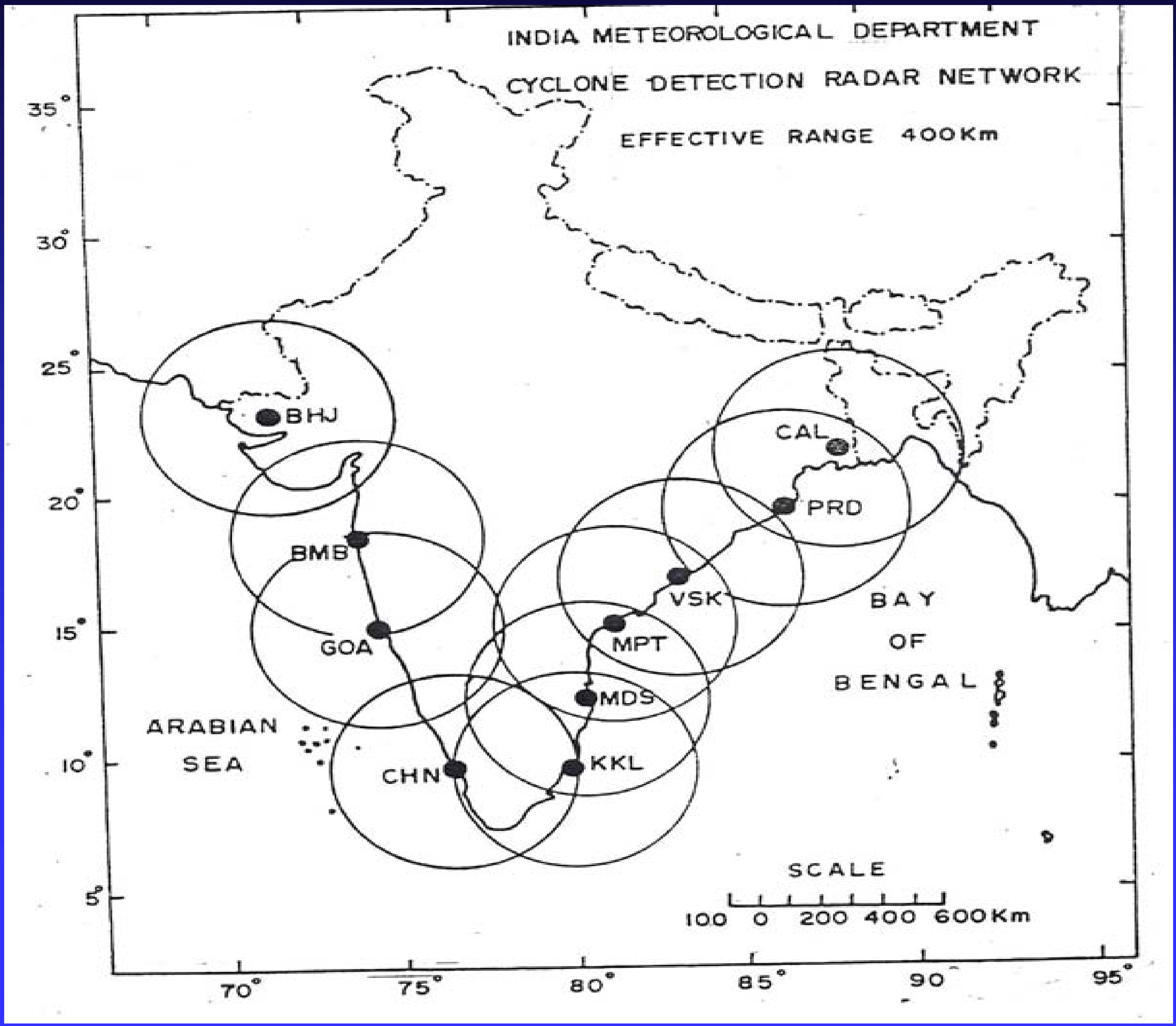
Geostationary satellite network for Cyclone monitoring



Cyclone Detection Radars in India



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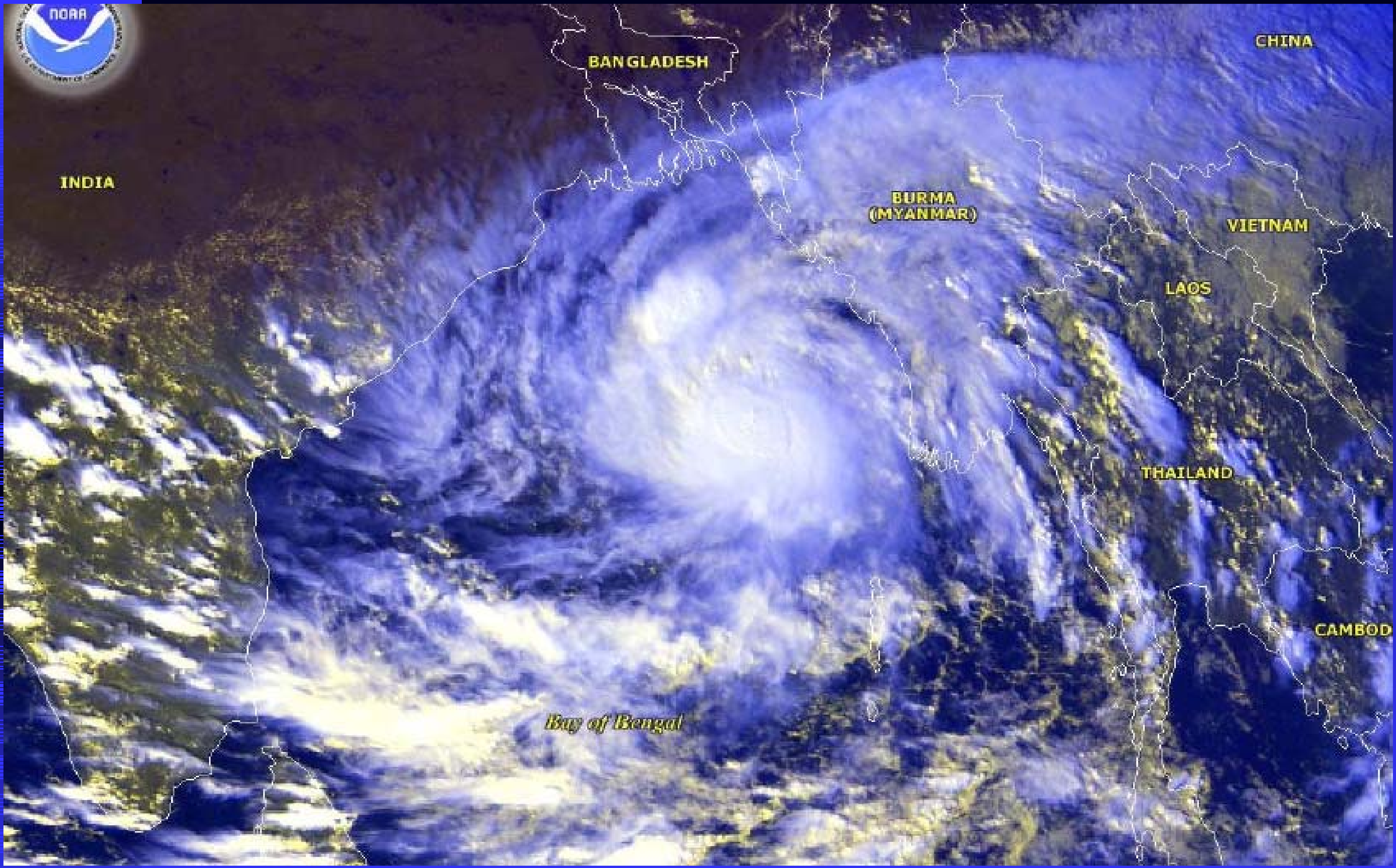
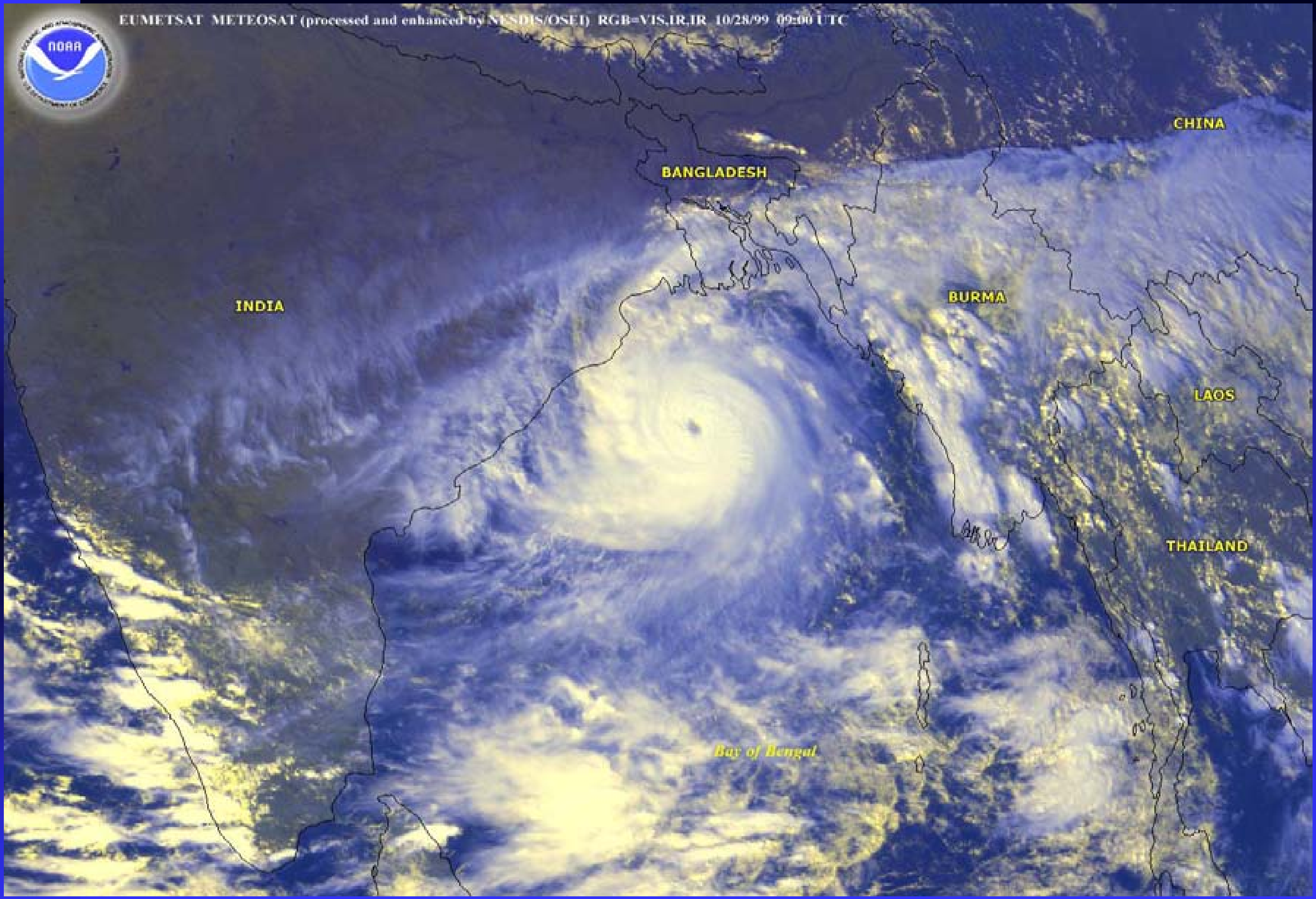
Tropical Cyclones

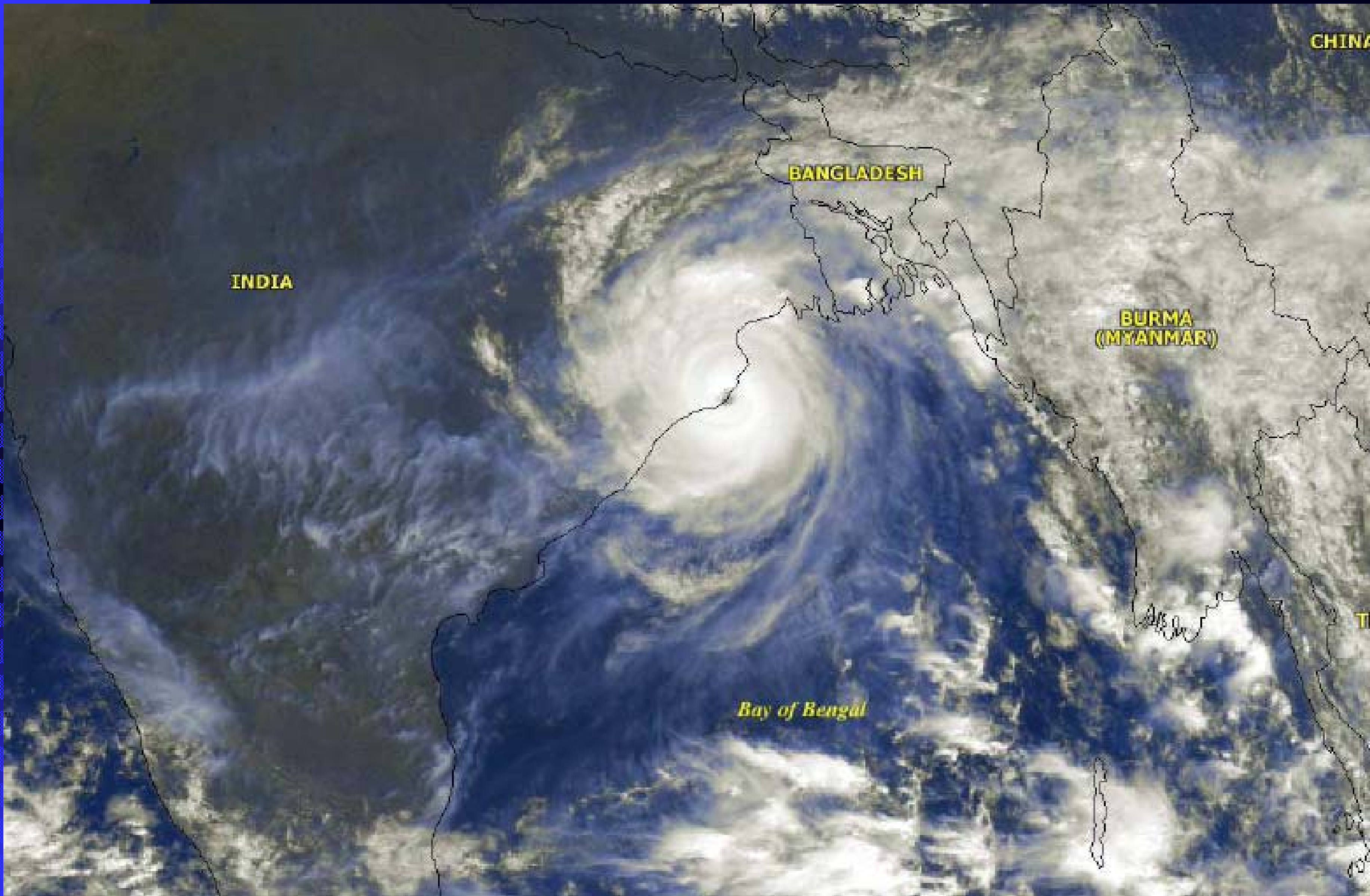
A severe Super Cyclonic Storm with winds of upto 250 km/h, crossed the coast in Orissa on October 29, 1999. This may prove to have been the worst cyclone of the century in the Orissa region and is responsible for as many as 10,000 deaths, for rendering millions homeless and for extensive damage . Over the past decades the frequency of tropical cyclones in the north Indian ocean has registered significant increasing trends (20% per hundred years) during November and May which account for maximum number of intense cyclones .



ORISSA SUPER CYCLONE ON 27 OCTOBER 1999

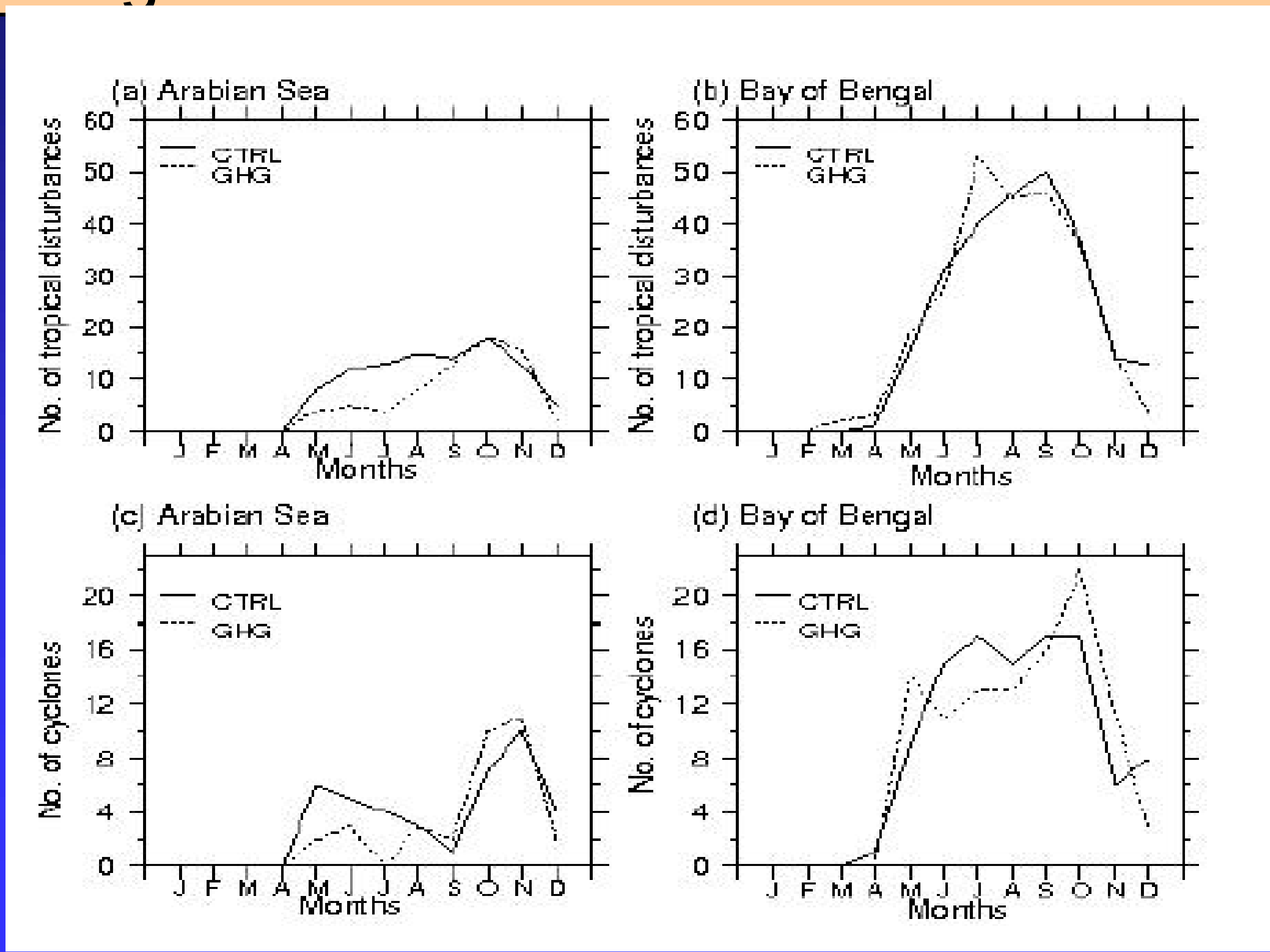


ORISSA SUPER CYCLONE ON 28 OCTOBER 1999



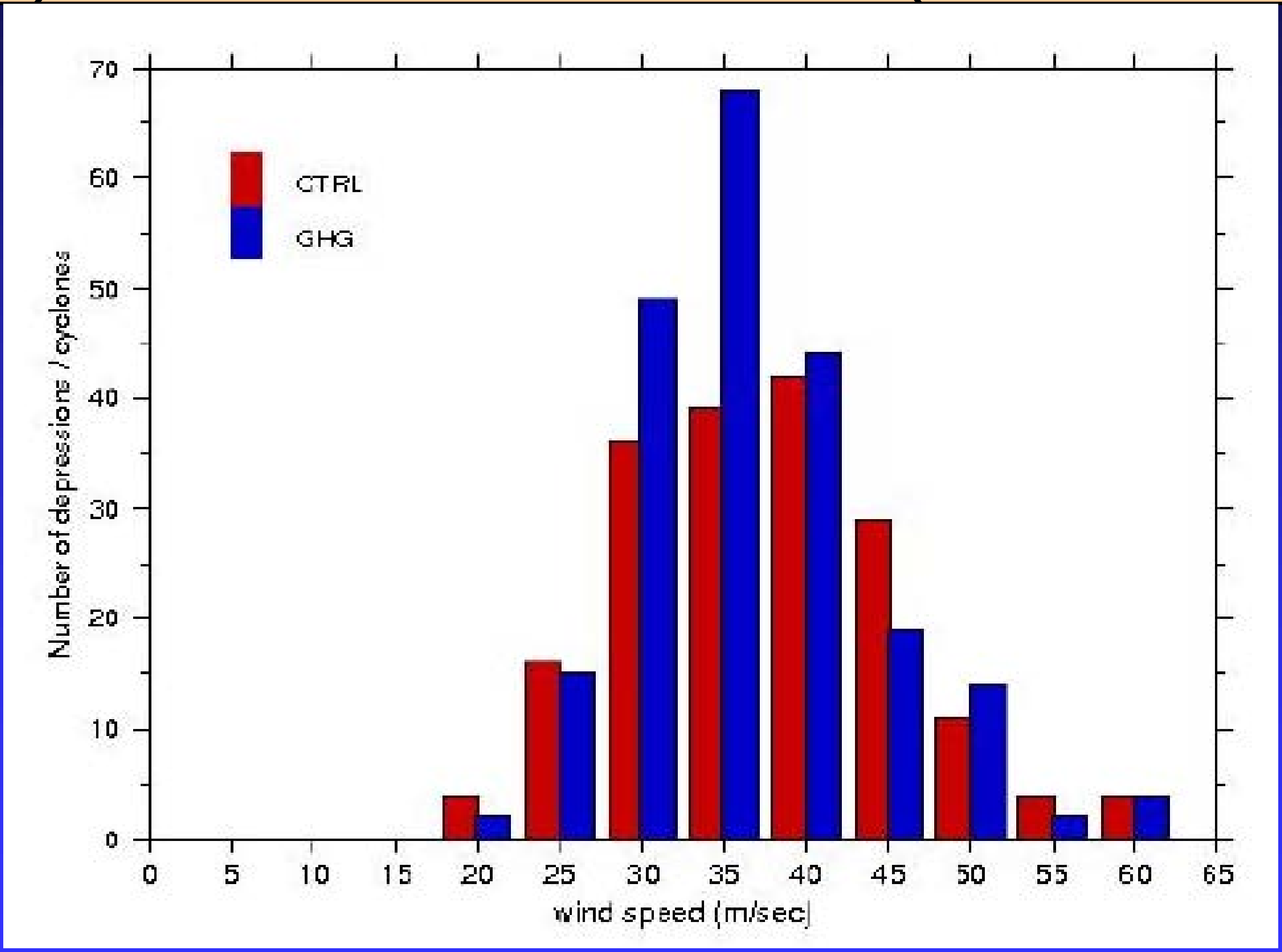
ORISSA SUPER CYCLONE ON 29 OCTOBER 1999

Frequency distribution of all tropical disturbances and that of intense events (cyclones) as simulated by the regional climate model HadRM2 in CTRL run (1990) and in the increased GHG run (2050) over Arabian Sea and the Bay of Bengal .



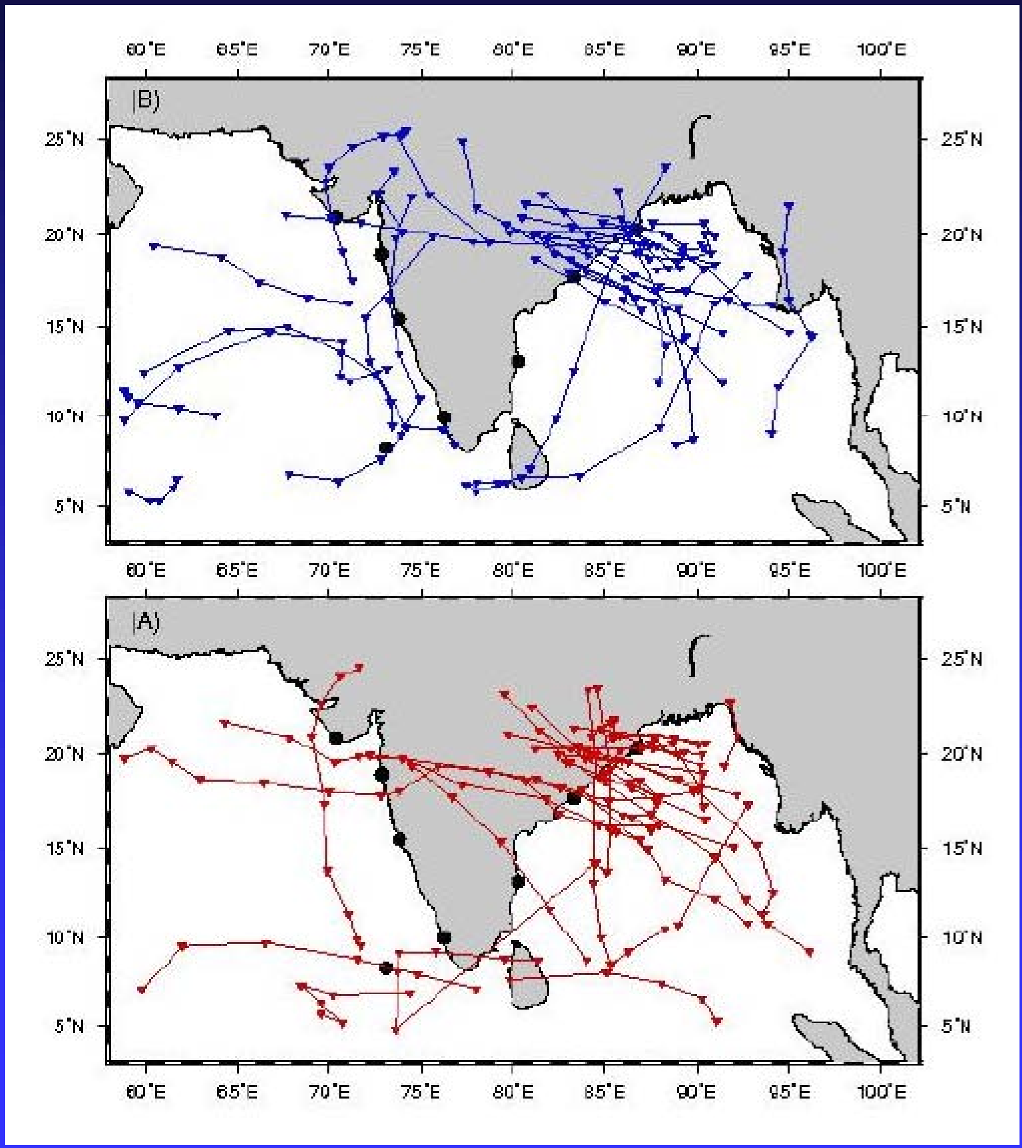
Unnikrishnan et al., (2006)

Frequency distribution of maximum wind speeds associated with cyclones in HadRM2 for CTRL run (1990, red colour) and in increased GHG run (2050, blue colour).



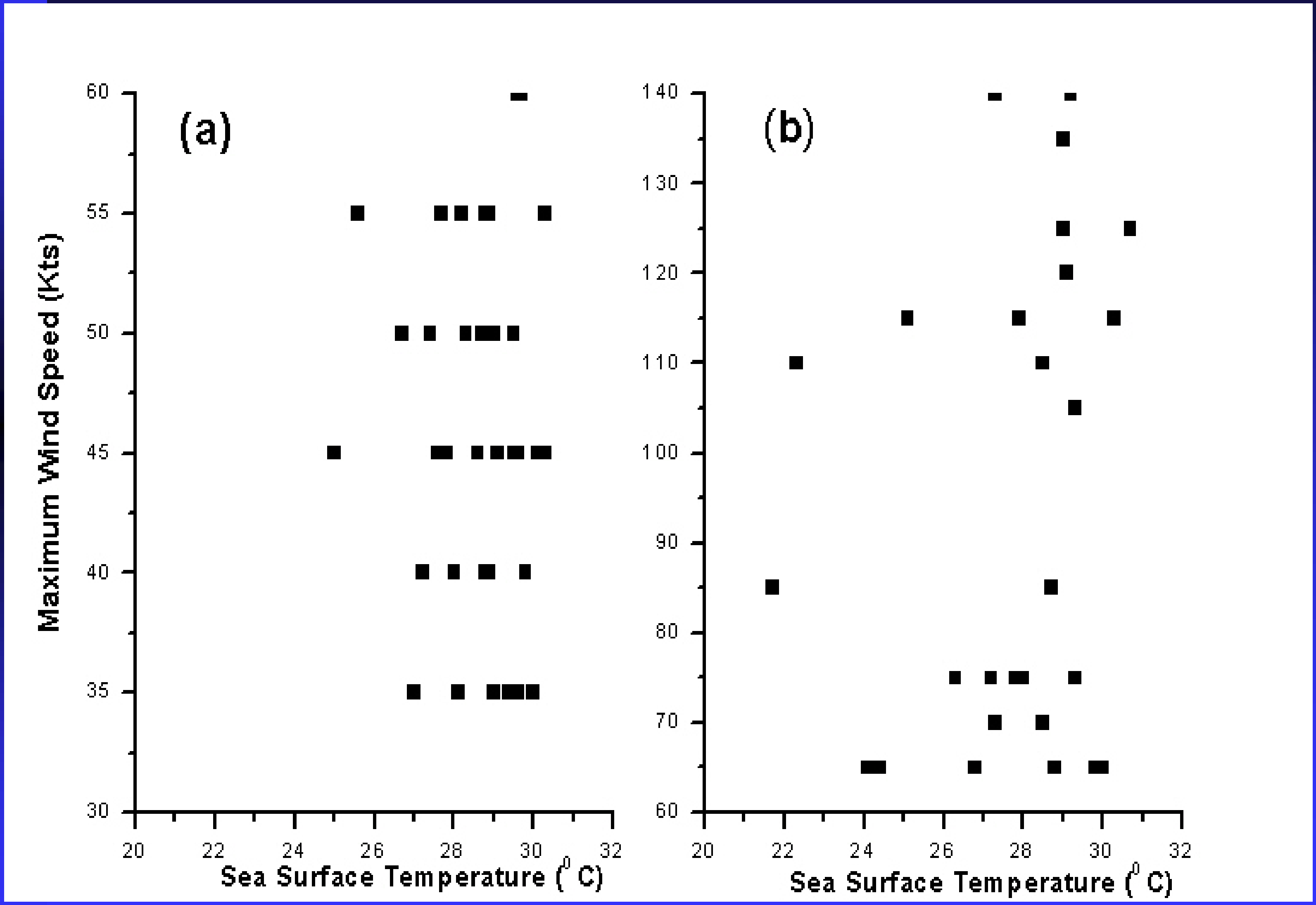
Unnikrishnan et al., (2011)

Tracks of cyclones from HadRM2 during the first five years of (a) CTRL run (b) in increased GHG run .



Unnikrishnan et al., (2011

Scatter diagram of SST a) CS b) SCS in Bay of Bengal.



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Ramesh Kumar and Syam (2010)

The occurrence of the CS and SCS over BB for different SST

SST (º C)	Cyclonic Storms	Severe Cyclonic Storms	Total systems	% of SCS
25.0 – 25.9	2	1	3	33.3
26.0 – 26.9	1	2	3	66.7
27.0 – 27.9	7	6	13	46.2
28.0 – 28.9	11	5	16	31.3
29.0 – 29.9	13	8	21	38.1
30.0 – 30.9	4	3	7	42.9

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Ramesh Kumar and Syam (2010)

Major Cyclones of India and Neighbourhood regions

Year	Area affected (Maximum Wind Speed)	No. of Deaths/ Damage
1920 (6-14 Jun)	Veraval (153 kmph)	Rs 32 lakhs damage and 7700 cattle perished
1927 (29 oct- 3 Nov)	Nellore (79 Kmph)	300 lives lost, 6000 cattle perished
1940 (9-20 Oct)	Colaba (121 kmph)	Heavy loss of live and Rs 25 lakhs
1942 (14-18 Oct)	Midnapore (109 kmph)	19,000 lives lost, Several lakhs of rupees damage, 60,000 cattle perished.
1948 (15-23 Nov)	Bombay (151 kmph)	Heavy loss of life,several lakhs of rupees damage
1949 (23 – 23 Oct)	Masulipatnam (130 kmph)	750 lives lost, several crores of rupees, 30, 000 cattle perished
1952 (26 Nov- 1 Dec)	Nagapatinam (241 kmph)	400 lives lost, Rs 6 crore damage, 30,000 catlle perished

Major Cyclones of India and Neighbourhood regions

Year	Area affected (MWS)	No. of Deaths/ Damage	Storm surge (height in ft)
1970 (8-13 Nov)	Bangladesh (185 kmph)	2,00,000. 2 lakh cattle perished and crop damage of Rs 47 crore.	13-17
1971	Paradeep,Orissa	10,000 lives of lost	7-20
1977	Chirala, Andhra Pradesh (200 kmph)	10,000. Damage worth Rs 350 crores	16-18
1990	Andhra Pradesh	990 lives lost	13-17
1991	Bangladesh	1,38,000 lives lost	7-20
1998 (4-10 Jun)	Porbander	1173 lives lost	---
1999	Paradeep,Orissa	9,885. Damage to crops over I lakh hectare land	30

Summary

- The relationship between SST over the BB and the maximum wind speed of the CS is complex.
- Study indicates that warm SST's and heat content in the surface to 50 m alone are not sufficient for initiation of convective systems over Bay of Bengal, and their intensification to storms or SCS.
- Environmental parameters such as low-level vorticity, MTRH and VWS, all play an equally important role in their genesis and intensification

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Floods and Droughts

- Floods and droughts are two important aspects of the weather associated with the abundance or deficit of monsoon rainfall. During the last 125 years phenomenal droughts on all India scale were only four, namely, 1877, 1899, 1918 and 1972. In these years, the seasonal rainfall deficiencies were more than -26% below the seasonal mean rainfall. The droughts were associated with considerable losses of life and property. Better distribution system and buffer food stock have gone a long way in reducing the adverse effects of drought.

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Most severe floods in recent years of Indian rivers [when floods are more than 10 m or more than their respective danger levels (DL)]

Sr.No.	River	Site	State from DL	Deviation	Date
1	Manas	NH crossing	Assam	11.03	13/7/84
2	Chambal	Dholpur	Rajasthan	14.21	25/8/82
3	Mahi	a) Dam Axis b) Vasaol	Gujarat	11.80 12.79	8/9/73 8/9/73
4	Teesta	a) Sanderson Bridge b) Coronation Bridge	West Bengal	18.10	4/10/68
5	Narmada	Garudeswar	Gujrat	17.87	6/9/70
6	Tapi	Burhanpur	M.P.	11.08	1968

Drought years in India

Year	Area affected ($X 10^6$ Sq. Km)	% of area of country affected	DI value	Category
1918	2.16	68.7	3.64	Calamitous
1877	2.03	64.7	3.38	Calamitous
1899	1.99	63.4	3.31	Calamitous
1987	1.55	49.2	2.37	Severe
1972	1.39	44.4	2.05	Severe
1965	1.35	42.9	1.95	Moderate
1979	1.24	39.4	1.72	Moderate
1920	1.22	38.8	1.69	Moderate
1891	1.15	36.7	1.54	Moderate

Stations in India which recorded 75 cms or more rainfall in one day (1875-1990)

Station	State	Rainfall (cms)	Date
Bano	Bihar	81	13/9/1959
Ragamandala	Karnataka	84	25/7/1924
Cherapunji	Meghalaya	104	14/6/1976
Dramapur	U.P.	77	18/9/1880
Dharampur	Gujarat	99	2/7/1941
Harnai	Maharashtra	80	5/8/1968
Jowai	Meghalaya	102	11/9/1877
Mawasynram	Meghalaya	99	10/7/1952
Quilandy	Kerala	91	28/5/1961

Positives and Negatives of Global Warming

Agriculture

Positive: Hiigher latitudes – Siberia, for example – may become productive due to global warming,

Negative: Disruption of steady water supplies, through floods and droughts.

Agriculture can also be disrupted by wildfires and changes in seasonal periodicity, which is already taking place, and changes to grasslands and water supplies could impact grazing and welfare of domestic livestock.

Increased warming may also have a greater effect on countries whose climate is already near or at a temperature limit over which yields reduce or crops fail – in the tropics or sub-Sahara, for example.

Too much water and too little water have always been the natural curse of *agriculture*

Positives and Negatives of Global Warming

Health

Positive: Warmer winters would mean fewer deaths, particularly among vulnerable groups like the aged.

Negative: However, the same groups are also vulnerable to additional heat, and deaths attributable to heat waves are expected to be approximately five times as great as winter deaths prevented. It is widely believed that warmer climes will encourage migration of disease-bearing insects like mosquitoes and malaria is already appearing in places it hasn't been seen before.

Positives and Negatives of Global Warming

Polar Melting

Positive: Opening of a year-round ice free Arctic passage between the Atlantic and Pacific oceans would confer some commercial benefits.

Negative: Loss of polar bear habitat and increased mobile ice hazards to shipping. Raising the temperature of Arctic tundra releases methane. Methane is also released from the sea-bed, where it is trapped in ice-crystals called clathrates.

Ocean Acidification

- Positive: Nil (no benefits to the change in pH of the oceans).
- Negative: This process is caused by additional CO_2 being absorbed in the water may have severe *destabilising effects on the entire oceanic food-chain*

Positives and Negatives of Global Warming

Melting Glaciers

Positive: Nil

Negative: many millions of people (one-sixth of the world's population) depend on fresh water supplied each year by natural spring melt and regrowth cycles and those water supplies – drinking water, agriculture – may fail.

The Rongbuk glacier on the northern slopes of Everest in 1968 (above) and in 2007 (below)

Positives and Negatives of Global Warming

Sea Level Rise

Positive: Nil

Negative: Many parts of the world are low-lying and will be severely affected by modest sea rises. Rice paddies are being inundated with salt water, which destroys the crops. Seawater is contaminating rivers as it mixes with fresh water further upstream, and aquifers are becoming polluted.

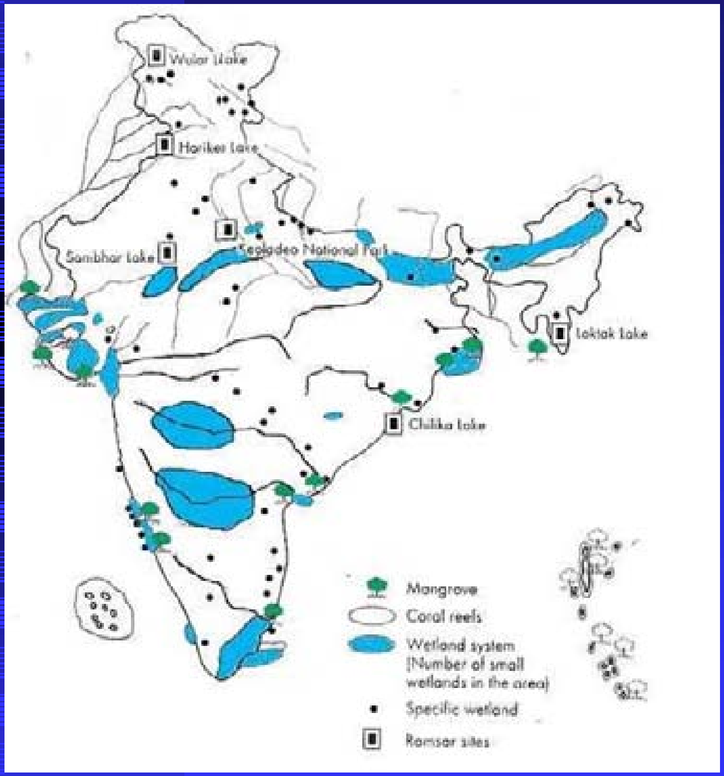
Positives and Negatives of Global Warming

Environmental

Positive: Greener rainforests and enhanced plant growth in the Amazon, increased vegetation in northern latitudes and possible increases in plankton biomass in some parts of the ocean.

Negative: Further growth of oxygen poor ocean zones, contamination or exhaustion of fresh water, increased incidence of natural fires, extensive vegetation die-off due to droughts, increased risk of coral extinction, decline in global photoplankton, changes in migration patterns of birds and animals, changes in seasonal periodicity, disruption to food chains and species loss.

Natural Ecosystems



Present distribution of natural ecosystems in India

Grasslands: Under enhanced CO_2 and increase in temperature, C4 species are likely to have a predominance over C3 plants.

Mangroves: Mangroves just next to the sea will be submerged due to SLR and plants with high salinity tolerance will survive

Increased glacier melt bringing larger quantities of fresh water will favor mangrove species with least tolerance to salinity Coral reefs: Increase in temperature would lead to bleaching of Corals and submergence due to SLR

Projections of Future Changes in Climate (IPCC, 2007)

- Anthropogenic warming and sea level rise would continue for centuries
- Snow cover to contract
- Sea ice to shrink in both the Arctic and Antarctic
- Arctic late-summer sea ice to disappear by end of the 21st century
- More frequent hot extremes, heat waves, and heavy precipitation events
- *Likely* that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation
- Extra-tropical storm tracks projected to move poleward with consequent changes in wind, precipitation, and temperature patterns

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India’s Risks from Climate Change are

Melting Glaciers: In the short term, this means increased risk of flooding, erosion, mudslides and during the wet season over north India

In the long term, serious impacts on populations relying rivers in Asia fed by melt water from the Himalayas.

Agriculture: Impact due to changing rainfall and temperature patterns

Health: Dengue, Malaria diarrhoea and malnutrition due to increased flooding, droughts and higher temperatures.

An increase in the frequency and duration of severe heat waves and humid conditions during the summer is likely to increase the risk of mortality and morbidity, principally in the old and urban poor populations

- Coast line: Increase in the sea levels can devastate our populous coastal cities

Stronger Cyclones due to increased Sea surface temperatures can also harm the coast.

- Politics: Refugee crisis if neighbouring countries submerge.

Ocean, Weather Information, data

National Institute of Oceanography:

www.nio.org

India Meteorological Department:
www.imd.gov.in

Indian Institute of Tropical Meteorology, Pune: www.tropmet.res.in

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