

**INTERANNUAL VARIATION OF FREQUENCY
OF CYCLONIC DISTURBANCES LANDFALLING
OVER INDIA**

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**HYDROLOGICAL ASPECTS OF CYCLONIC
DISTURBANCES INFLUENCING ORISSA**

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INTRODUCTION

- **INCREASE IN SOCIO-ECONOMIC IMPACT OF CYCLONIC DISTURBANCES (RAGHAVAN, 2002).**
- **COMMON PERCEPTION: INCREASE DUE TO INCREASE IN FREQUENCY AND INTENSITY OF CYCLONIC DISTURBANCES.**
- **SIGNIFICANT DECREASING TREND IN THE FREQUENCY OF CYCLONIC STORMS WITH MAXIMUM DECREASE IN LAST FOUR DECADES (SRIVASTAVA ET AL, 2000, RAJEEVAN ET AL 2000)**
- **SEVERE CYCLONIC STORM: MORE FREQUENT OVER BAY OF BENGAL DURING MAY AND NOVEMBER (SINGH ET AL, 2000)**
- **FREQUENCY OF CYCLONIC STORMS OVER NORTH INDIAN OCEAN HAS A 36 YEAR OSCILLATION SUPERPOSED ON A LONG TERM TREND (JOSEPH, 1999).**

OBJECTIVE

**INTERANNUAL VARIABILITY IN
FREQUENCY OF CYCLONIC
DISTURBANCES CROSSING MARITIME
STATES OF INDIA AND RELATION
WITH LARGE SCALE PARAMETERS.**

DATA

- ANNUAL FREQUENCY OF CYCLONIC DISTURBANCES WITH DIFFERENT INTENSITIES LANDFALLING OVER INDIA
- SOURCE : STORM ATLAS OF IMD
- PERIOD: 1891-2005 (15 YEARS)
- MARITIME STATES : WEST BENGAL, ORISSA, ANDHRA PRADESH, TAMILNADU, GUJARAT, MAHARASHTRA, GOA, KARNATAKA, KERALA
- DISTURBANCES WITH LIFE PERIOD OF < 12 HOURS NOT CONSIDERED

CLASSIFICATION OF CYCLONIC DISTURBANCES

<u>SYSTEM</u>	<u>SUSTAINED MAXIMUM WIND</u>
• DEPRESSION	• 17-27 KNOTS
• DEEP DEPRESSION	• 28-33 KNOTS
• CYCLONIC STORM (CS)	• 34-47 KNOTS
• SEVERE CS	• 48-63 KNOTS
• VERY SEVERE CS	• 64-119 KNOTS
• SUPER CS	• 120 KNOTS OR MORE

INTENSITY CLASSIFICATION IN STUDY

- 1. DEPRESSION/DEEP DEPRESSION (D)
- 2. CYCLONIC STORM (C)
- 3. SEVERE CYCLONIC STORM AND ABOVE (S)
- 4. TOTAL CYCLONIC STORM (C+S)
- 5. TOTAL CYCLONIC DISTURBANCES (D+C+S)

METHODOLOGY

- MEAN
- VARIATION WITH RESPECT TO MEAN
- LINEAR AND POLYNOMIAL TRENDS
- MOVING AVERAGES AND MOVING CV
- PERIODICITIES (AUTO-CORRELATION ANALYSIS, SPECTRUM ANALYSIS)
- MOVING CORRELATION
- EOF ANALYSIS
- RELATION WITH LARGE SCALE FIELD PARAMETERS OVER INDIAN REGION
- OUTLOOK

FREQUENCY OF CYCLONIC DISTURBANCES OVER BAY OF BENGAL AND ARABIAN SEA LANDFALLING OVER EAST AND WEST COASTS

Landfall region	D	C	S	CS	DCS
East coast	80%	58%	42%	51%	68%
West coast	36%	28%	22%	25%	30%
Total	74%	54%	38%	46%	62%

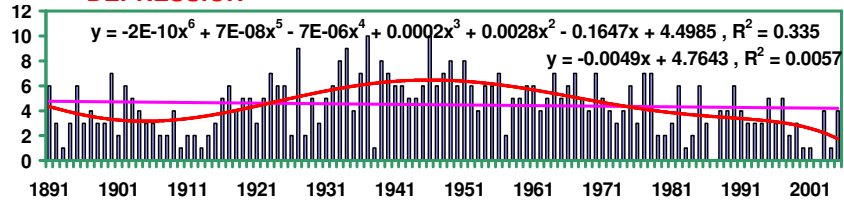
D: DEPRESSION, C: CYCLONIC STORM, S: SEVERE CYCLONIC STORM OR ABOVE, CS : C+S, DCS: D+CS

CYCLONIC DISTURBANCES CROSSING DIFFERENT STATES AS PERCENTAGE OF TOTAL LANDFALL ON EAST AND WEST COASTS

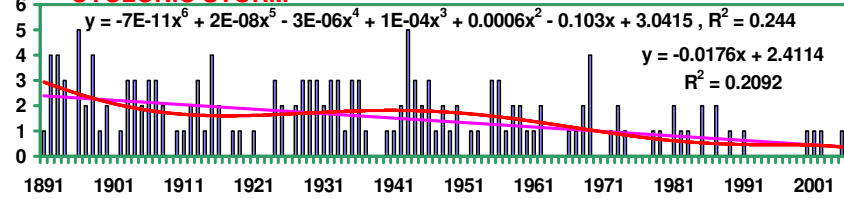
LANDFALL REGION	D	C	S	CS	DCS
EAST COAST					
WEST BENGAL	25.5%	21.4%	23.7%	22.2%	24.5%
ORISSA	48.2%	40.7%	23.7%	35.0%	44.0%
ANDHRA PRADESH	19.3%	27.9%	28.7%	28.6%	22.5%
TAMILNADU	6.7%	1.4%	26.3%	16.8%	9.9%
WEST COAST					
GUJARAT	93%	91%	69%	79%	85%

CYCLONIC DISTURBANCES CROSSING EAST COAST

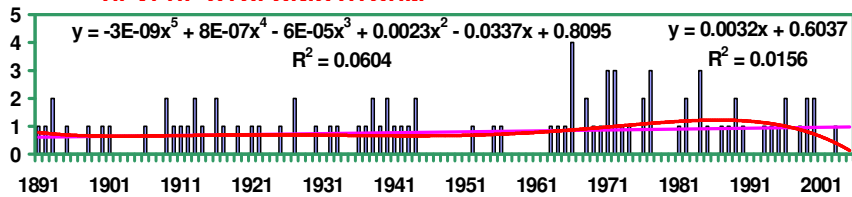
DEPRESSION



CYCLONIC STORM

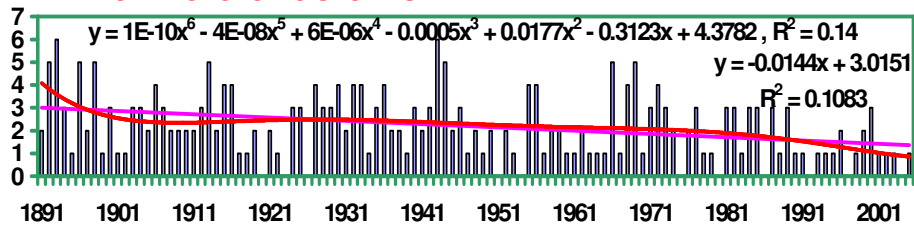


SEVERE CYCLONIC STORM

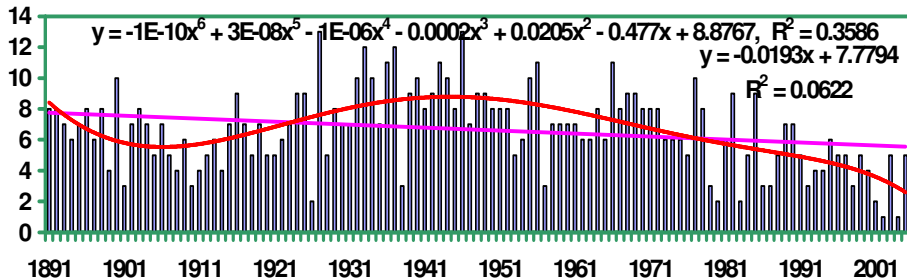


CYCLONIC DISTURBANCES CROSSING EAST COAST

TOTAL CYCLONIC STORMS

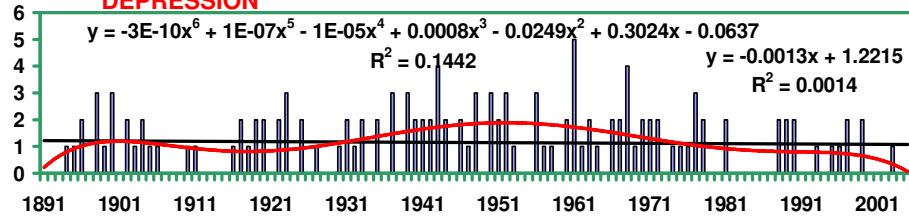


TOTAL CYCLONIC DISTURBANCES

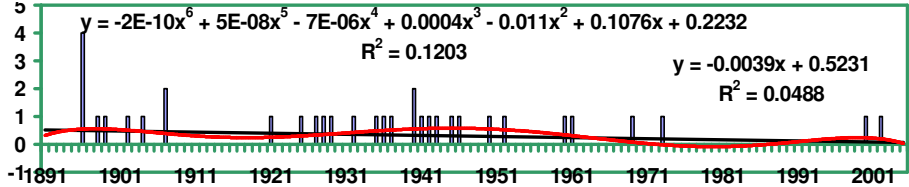


CYCLONIC DISTURBANCES CROSSING WEST BENGAL

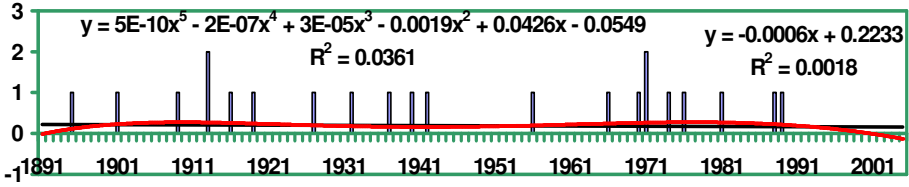
DEPRESSION



CYCLONIC STORM

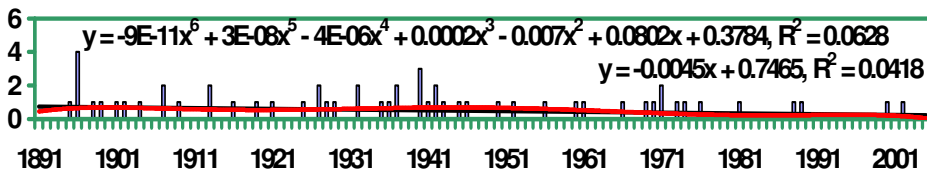


SEVERE CYCLONIC STORM

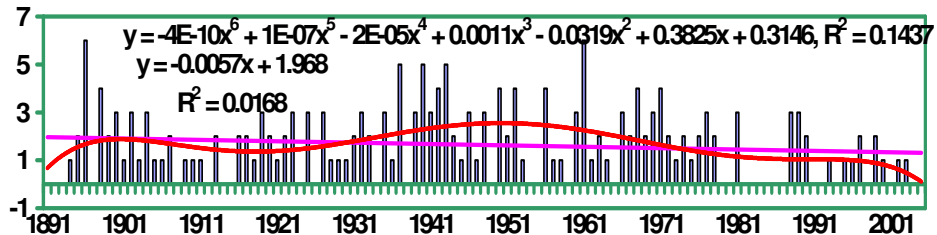


CYCLONIC DISTURBANCES CROSSING WEST BENGAL

TOTAL CYCLONIC STORMS

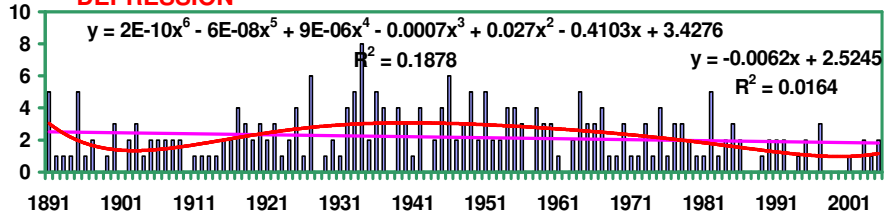


TOTAL CYCLONIC DISTURBANCES

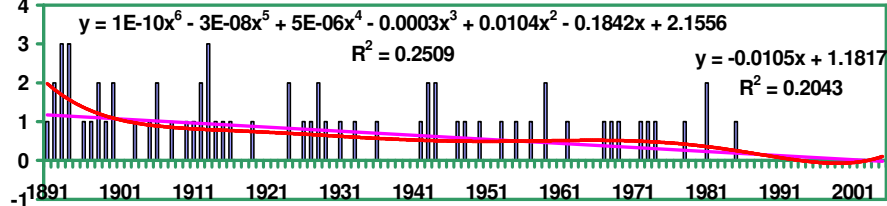


CYCLONIC DISTURBANCES CROSSING ORISSA

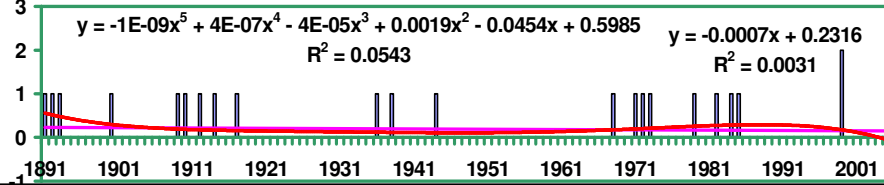
DEPRESSION



CYCLONIC STORM

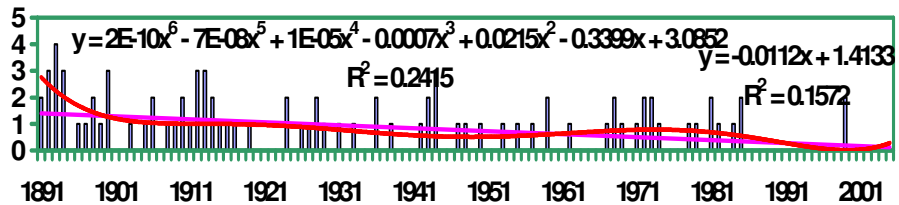


SEVERE CYCLONIC STORM

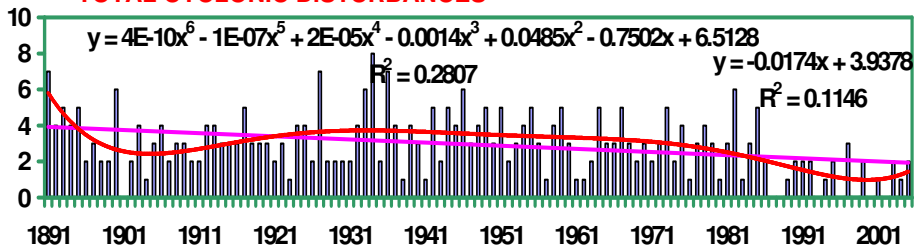


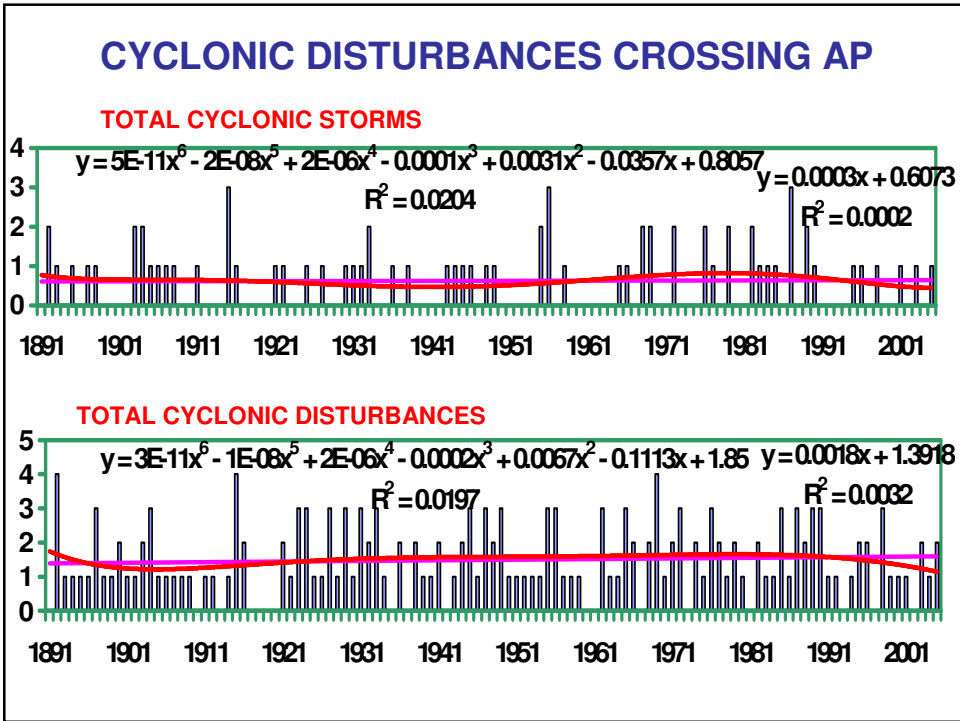
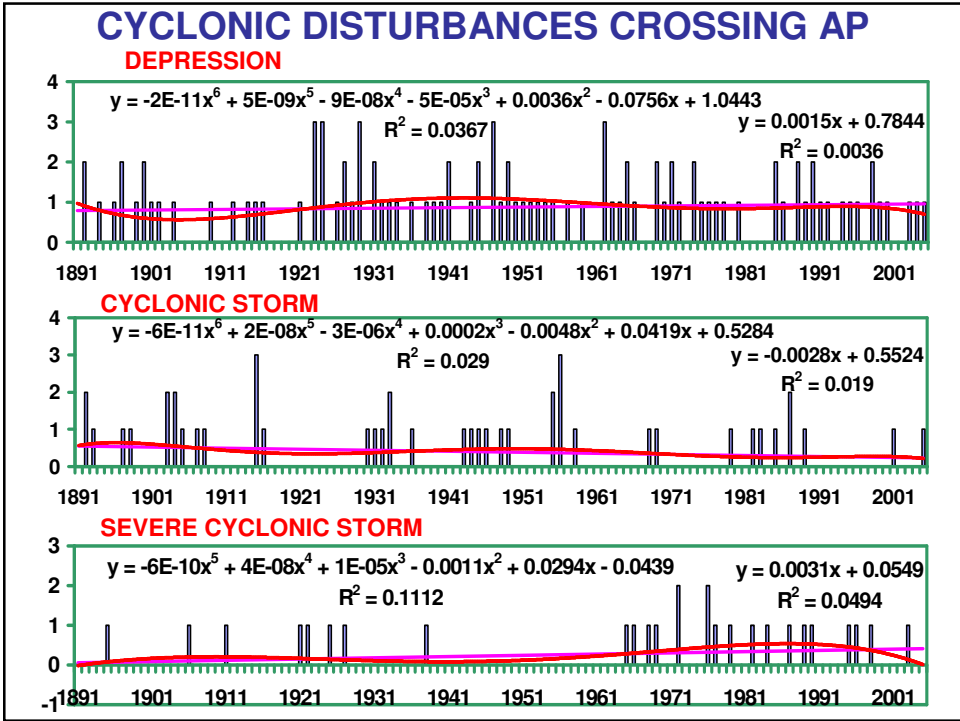
CYCLONIC DISTURBANCES CROSSING ORISSA

TOTAL CYCLONIC STORMS



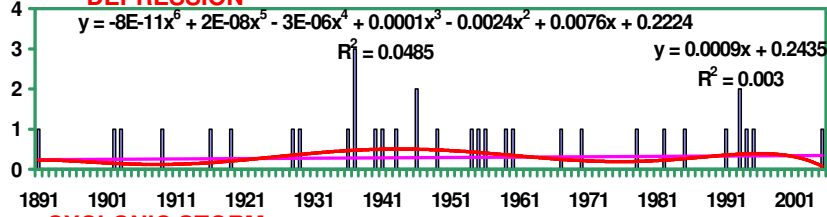
TOTAL CYCLONIC DISTURBANCES



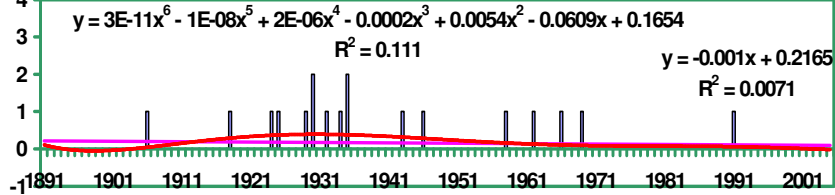


CYCLONIC DISTURBANCES CROSSING TAMILNADU

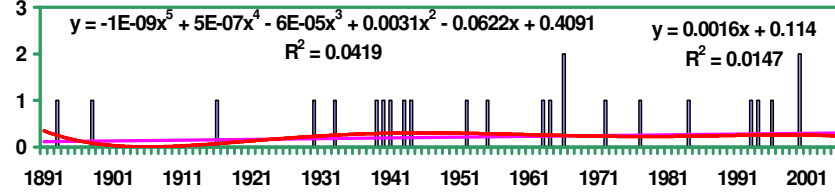
DEPRESSION



CYCLONIC STORM

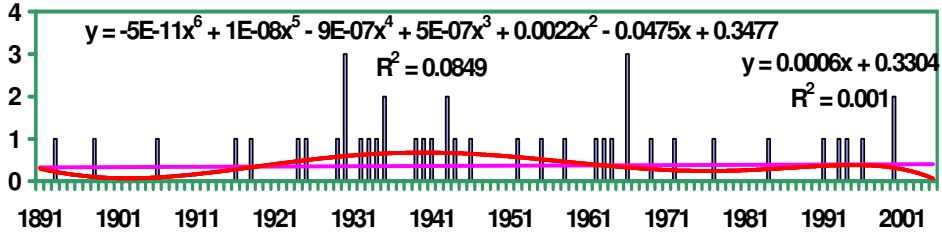


SEVERE CYCLONIC STORM

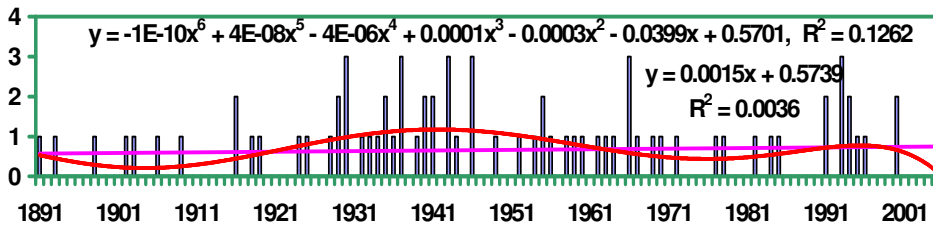


CYCLONIC DISTURBANCES CROSSING TAMILNADU

TOTAL CYCLONIC STORMS

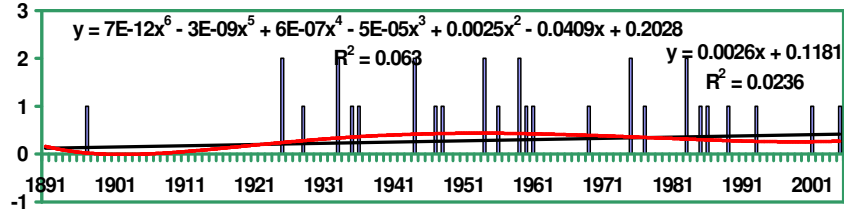


TOTAL CYCLONIC DISTURBANCES

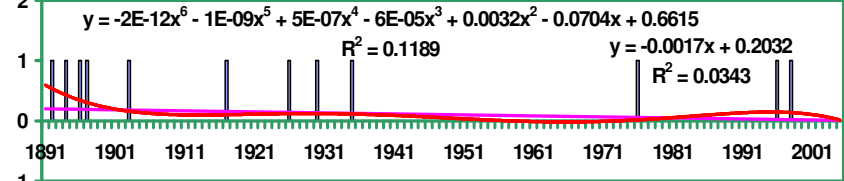


CYCLONIC DISTURBANCES CROSSING GUJARAT

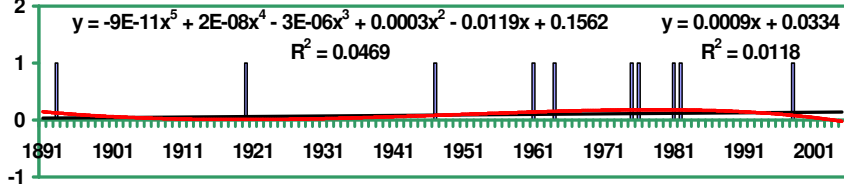
DEPRESSION



CYCLONIC STORM

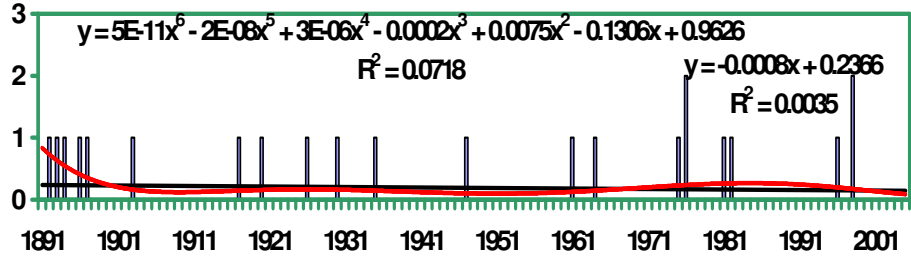


SEVERE CYCLONIC STORM

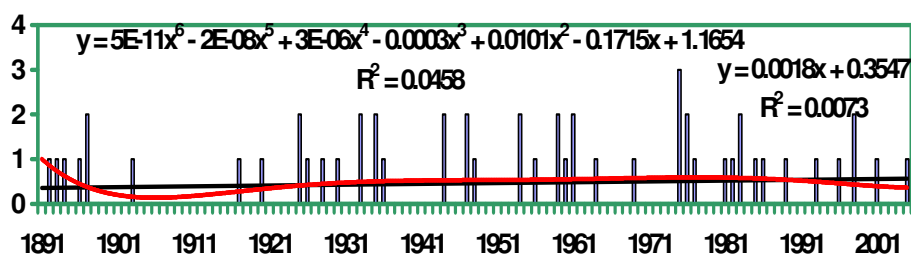


CYCLONIC DISTURBANCES CROSSING GUJARAT

TOTAL CYCLONIC STORMS



TOTAL CYCLONIC DISTURBANCES



PERIODICITIES OF OSCILLATION IN FREQUENCY

- **QBO CYCLE (2-2.8 YEARS):**

CYCLONIC STORMS CROSSING ORISSA

**SEVERE CYCLONIC STORM CROSSING ANDHRA PRADESH
AND WEST BENGAL**

- **ENSO CYCLE (4-6 YEARS):**

**CYCLONIC STORMS CROSSING ANDHRA PRADESH AND
TAMILNADU COAST**

SEVERE CYCLONIC STORM CROSSING WEST BENGAL

TRENDS

- **WEST COAST AND GUJARAT:** INCREASE IN DEPRESSION AND DECREASE IN CYCLONIC STORM
- **EAST COAST:** DECREASE IN CYCLONIC STORM AND INCREASE IN SEVERE CYCLONIC STORM LEADING TO NOCHANGE IN TOTAL CYCLONIC STORMS AND DECREASE IN TOTAL CYCLONIC DISTURBANCES
- **WEST BENGAL:** DECREASE IN CYCLONIC STORM LEADING TO DECREASE IN TOTAL CYCLONIC STORMS AND TOTAL CYCLONIC DISTURBANCES
- **ORISSA:** DECREASE IN DEPRESSION AND CYCLONIC STORM LEADING TO DECREASE IN TOTAL CYCLONIC STORMS AND TOTAL CYCLONIC DISTURBANCES
- **ANDHRA PRADESH:** INCREASE IN SEVERE CYCLONIC STORM
- **TAMILNADU:** NO CHANGE

IMPLICATIONS OF MAJOR RESULTS

TREND IN LANDFALLING DISTURBANCES OVER EAST COAST IS MAINLY DUE TO SIMILAR TREND FOR ORISSA COAST. TREND IN SEVERE CYCLONIC STORM DUE TO SIMILAR TREND FOR AP.

TREND IN LANDFALLING DISTURBANCES OVER WEST COAST IS MAINLY DUE TO SIMILAR TREND FOR GUJARAT COAST, HOWEVER THERE IS NO CHANGE IN TOTAL CYCLONIC DISTURBANCES, TOTAL CYCLONIC STORMS AND TOTAL SEVERE CYCLONIC STORMS CROSSING GUJARAT

HENCE, INTERANNUAL VARIATION INCLUDING TREND OF DISTURBANCES CROSSING ORISSA AND SEVERE CYCLONIC STORM CROSSING AP NEED SPECIAL INVESTIGATION

TRENDS IN LANDFALLING DISTURBANCES OVER ORISSA

- TREND IN ANNUAL FREQUENCY IS MAINLY DUE TO TREND IN FREQUENCY DUE TO MONSOON SEASON
- HENCE FREQUENCY DURING MONSOON SEASON ARE INVESTIGATED IN DETAIL

**AVERAGE FREQUENCIES (PER YEAR) OF DIFFERENT CATEGORIES OF
MONSOON DISTURBANCES OVER INDIAN REGION
DURING (A) 1901-2000 AND (B) 1980-1999.**

PERIOD	MEAN FREQUENCY OF MONSOON DISTURBANCES/ DISTURBANCES DAYS									
	CD-NIO		CD-BOB		CD-VK		LPS		LPS DAYS	
	A	B	A	B	A	B	A	B	A	B
JUNE	1.34	1.15	0.93	0.65	0.66	0.55	2.84	2.95	10.7	14.2
JULY	1.37	0.45	1.27	0.40	1.15	0.40	3.31	3.20	13.7	13.8
AUG	1.64	1.25	1.58	1.15	1.44	1.0	3.56	4.0	16.8	20.3
SEPT	1.46	0.60	1.37	0.55	1.0	0.30	3.23	3.05	16.1	17.8
SEASON	5.81	3.45	5.15	2.75	4.25	2.25	12.9	13.2	57.3	66.1

SIGNIFICANTLY DIFFERENT FREQUENCIES ARE HIGHLIGHTED

CD-NIO: CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN

CD-BOB: CYCLONIC DISTURBANCES OVER BAY OF BENGAL

CD-VK: CD CROSSING COAST BETWEEN VISAKHAPATNAM AND KOLKATA

LPS: LOW PRESSURE SYSTEMS

**CV OF FREQUENCIES (PER YEAR) OF DIFFERENT CATEGORIES OF
MONSOON DISTURBANCES OVER INDIAN REGION DURING
(A) 1901-2000 AND (B) 1980-1999**

PERIOD	MEAN FREQUENCY OF MONSOON DISTURBANCES/ DISTURBANCES DAYS									
	CD-NIO		CD-BOB		CD-VK		LPS		LPS DAYS	
	A	B	A	B	A	B	A	B	A	B
JUNE	82	76	92	90	104	110	42	36	54	41
JULY	86	134	87	126	94	126	40	36	42	34
AUG	69	103	68	99	75	112	33	30	40	36
SEPT	70	126	73	138	86	157	33	31	36	31
SEASON	40	44	42	55	49	70	17	16	21	16

THE CVS WITH A DIFFERENCE OF 20% OR MORE ARE HIGHLIGHTED

**MEAN FREQUENCY OF CD-VK WITH DIFFERENT
INTENSITIES DURING
(A) 1901-2000 AND (B) 1980-1999.**

PERIOD	DEPRESSION (D)		CYCLONIC STORM (C)		SEVERE CYCLONIC STORMS (S)		CS= C+S	
	A	B	A	B	A	B	A	B
JUNE	0.54	0.55	0.10	0	0.02	0	0.12	0
JULY	0.94	0.35	0.16	0.05	0.05	0	0.21	0.05
AUG	1.26	0.95	0.16	0.05	0.02	0	0.18	0.05
SEPT	0.83	0.2	0.08	0.1	0.09	0	0.17	0.1
SEASON	3.57	2.05	0.5	0.2	0.18	0	0.68	0.2

THE SIGNIFICANT DIFFERENT FREQUENCIES ARE HIGHLIGHTED.

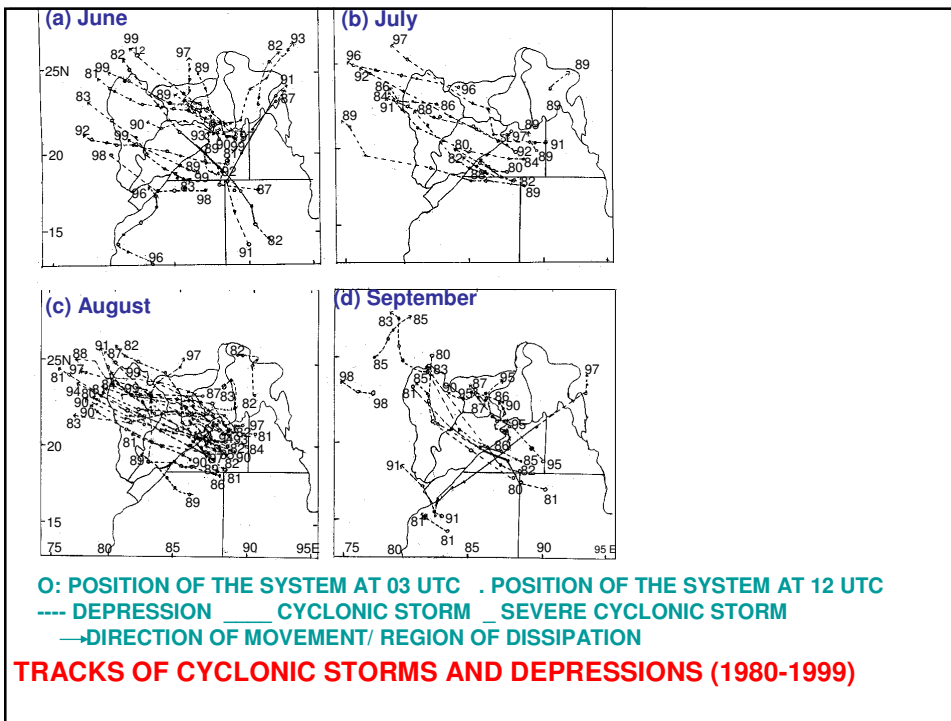
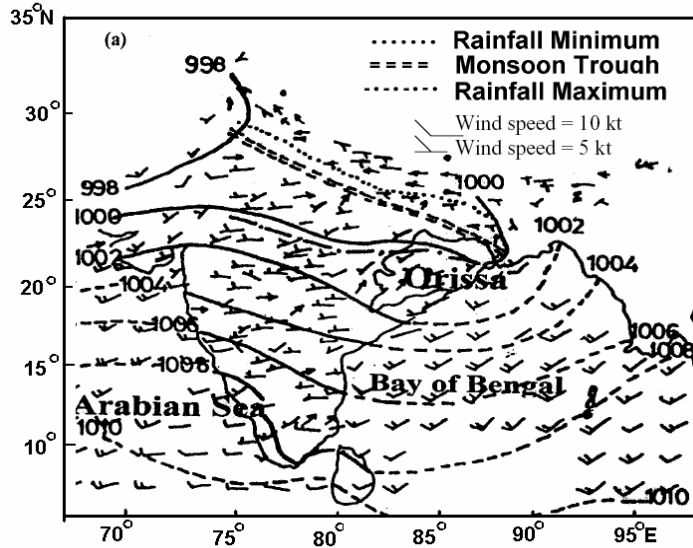
PARAMETER	LEVEL	MEAN	DIFFERENCE FROM LPA
MSLP	SURFACE	1007.0	0.78
GEOPOTENTIAL HEIGHT (METER)	1000	62.1	7.0
	850	1475.2	8.4
	700	3119.2	9.7
	500	5850.0	11.0
	400	7580.2	11.9
	300	9703.4	12.5
	200	12487.5	12.9
ZONAL WIND (METER/SECOND)	SURFACE	3.3	-0.12
	1000	3.4	-0.10
	850	5.5	-0.24
	700	3.3	-0.15
	500	1.3	-0.15
	400	0.2	-0.05
	300	-2.2	0.05
	200	-7.7	0.14
MERIDIONAL WIND (METER/SECOND)	SURFACE	2.1	-0.10
	1000	2.2	-0.10
	850	0.4	-0.09
	700	-0.6	0.03
	500	-0.3	0.01
	400	-0.2	-0.07
	300	-0.3	-0.07
	200	-0.9	0.09

PARAMETER	LEVEL	MEAN	DIFFERENCE FROM LPA
TEMPERATURE (°C)	SURFACE	23.8	0.22
	1000	29.5	0.18
	850	20.8	0.32
	700	11.1	0.12
	500	-3.9	0.16
	400	-14.2	0.10
	300	-28.3	0.08
	200	-49.1	0.07
RELATIVE HUMIDITY (%)	SURFACE	76.0	-0.1
	1000	75.9	-0.1
	850	65.3	-1.5
	700	61.8	-0.5
	500	51.1	-2.4
	400	47.5	-2.6
	300	52.3	-2.0

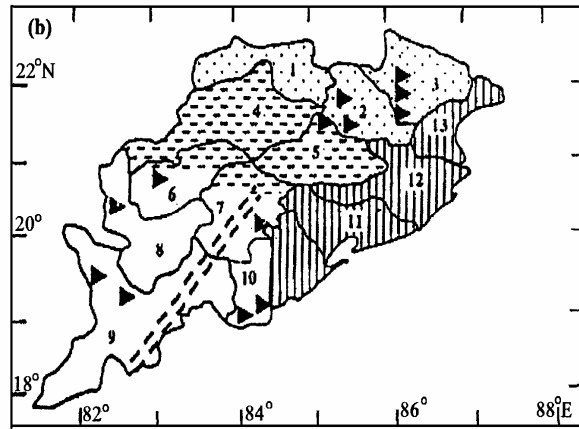
IMPACT OF TREND ON RAINFALL

DECREASING TREND IN FREQUENCY HAS RESULTED IN DECREASE IN RAINFALL IN JULY OVER CENTRAL INDIA INCLUDING ORISSA, CHHATTISGARH, MADHYA PRADESH AND INTERIOR MAHARASHTRA AS ADVERSE IMPACT OF DECREASE IN FREQUENCY OF CYCLONIC DISTURBANCES COULD NOT BE COMPENSATED BY THE INCREASE IN LOW

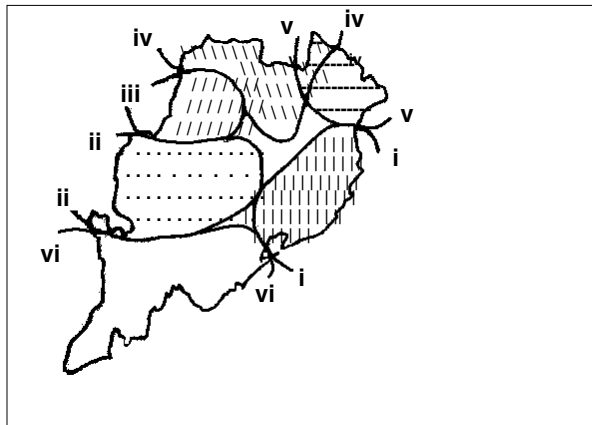
Mean sea level isobaric pattern (in hPa) and mean wind (in knots) in representative month of July, plotted according to WMO code over Indian region



PHYSIOGRAPHICAL MAP OF ORISSA.



HOMOGENEOUS REGIONS OF DAILY MONSOON RAINFALL OVER ORISSA BASED ON ROTATION OF SIGNIFICANT EOFs IN T-MODE



**PERCENTAGE CONTRIBUTION TO SEASONAL MONSOON RAINFALL
OVER ORISSA BY SYNOPTIC SYSTEMS**

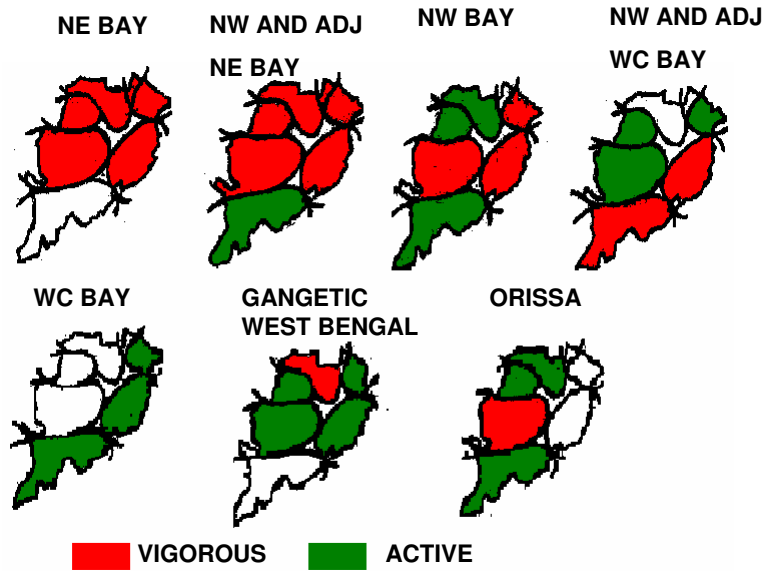
SYNOPTIC SYSTEMS	AVERAGE PERCENTAGE CONTRIBUTION DURING SEASON	AVERAGE PERCENTAGE CONTRIBUTION PER DAY
LOW PRESSURE AREA	41.5	1.2
DEPRESSION	11.8	1.8
CYCLONIC STORM	1.0	1.7
CYCIR	14.9	0.8
MONSOON TROUGH*	28.1	0.5
AIBM CONDITION	2.7	0.5
TOTAL	100	0.8
LOW PRESSURE SYSTEM (LPS)	54.3	1.3
LPS/CYCIR (LPSC)	69.2	1.1
LPSC OVER NW BAY	22	1.8

**AVERAGE RAINFALL PER DAY BY DIFFERENT SYNOPTIC SYSTEMS
EXPRESSED AS PERCENTAGE OF THE
SEASONAL MONSOON RAINFALL OVER ORISSA**

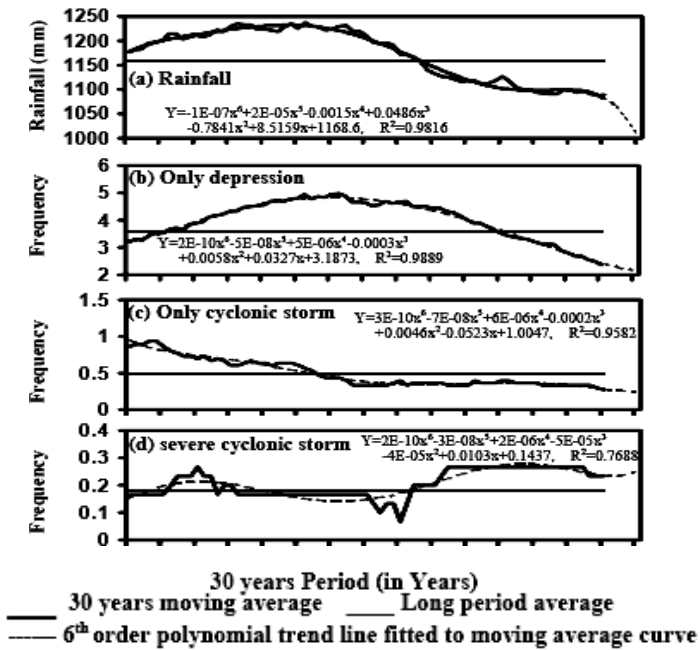
SYNOPTIC SYSTEM	REGION OF OCCURRENCE OF SYNOPTIC SYSTEMS											
	1	2	3	4	5	6	7	8	9	10	11	12
LOW	0.9	1.6	1.9	1.4	1.0	0.9	1.0	0.5	1.1	1.2	0.6	0.7
DEPRESSION	4.0	4.0	3.2	2.0	1.0	1.6	-	0.4	1.7	1.8	0.5	-
CYCLONIC STORMS	-	-	1.5	-	-	2.5	-	-	1.0	-	-	-
Cycir	0.7	0.7	1.1	0.8	0.5	0.5	0.3	0.5	0.7	0.9	0.7	0.7

1. NE NW BAY 2. NW AND ADJOINING NE BAY 3. NW BAY 4. NW AND ADJOINING WC BAY 5. WC AND ADJOINING NW BAY 6. WC BAY OFF NORTH COASTAL ANDHRA PRADESH (NCAP) 7. NCAP 8. EAST MADHYA PRADESH AND CHHATTISGARH 9. ORISSA 10. GANGETIC WEST BENGAL 11. JHARKHAND 12. BANGLADESH. ---: DATA INSUFFICIENT.

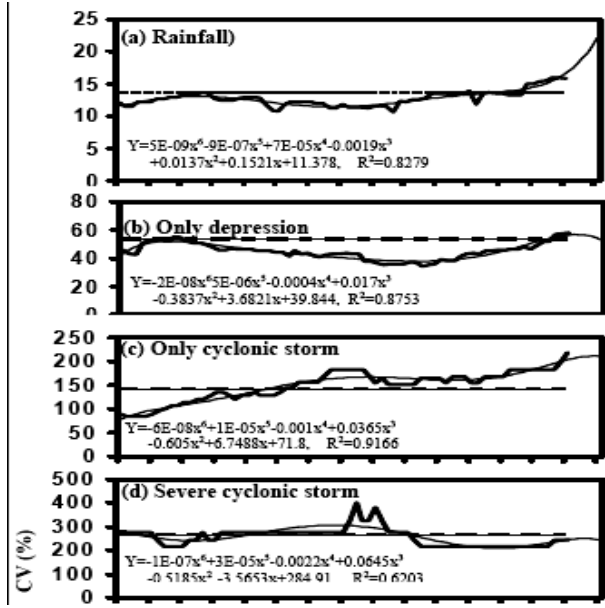
VIGOROUS/ACTIVE MONSOON CONDITION DUE TO MONSOON DEPRESSION



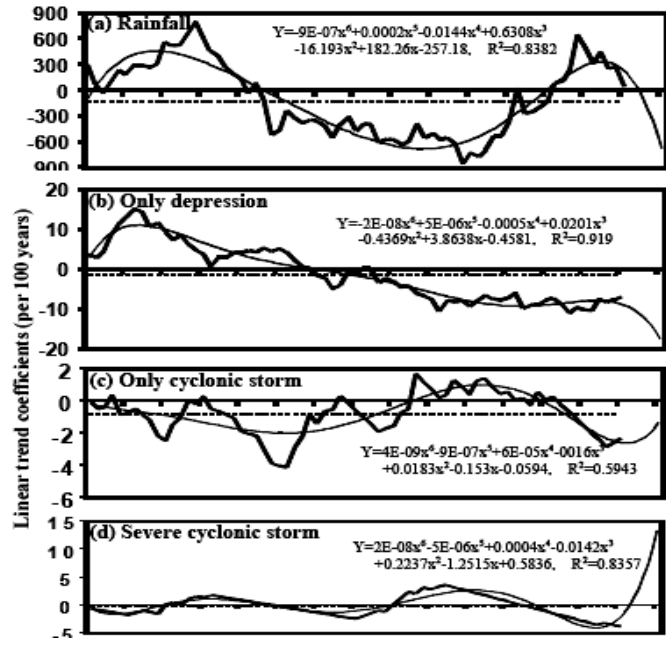
30 YEARS MOVING AVERAGE



30 YEARS MOVING CV



30 YEARS MOVING TREND



CONCLUSIONS

- 68% OF DISTURBANCES OVER BAY OF BENGAL LANDFALL OVER EAST COAST
- 30% OF DISTURBANCES OVER ARABIAN SEA LANDFALL OVER WEST COAST COAST
- OUT OF TOTAL LANDFALL OVER EAST COAST, 44% OCCUR OVER ORISSA
- OUT OF TOTAL LANDFALL OVER WEST COAST, 85% OCCUR OVER GUJARAT
- LANDFALLING DEPRESSIONS ARE MORE OVER ORISSA AND WEST BENGAL
- LANDFALLING CYCLONES ARE MORE OVER ORISSA AND ANDHRA PRADESH
- LANDFALLING SEVERE CYCLONIC STORMS ARE MORE OVER ANDHRA PRADESH AND TAMILNADU
- TREND IN LANDFALLING DISTURBANCES OVER EAST COAST IS MAINLY DUE TO SIMILAR TREND FOR ORISSA COAST

CONCLUSIONS (CONTD)

- OUT OF 6 DISTURBANCES OVER NORTH INDIAN OCEAN, 5 DEVELOP OVER BAY OF BENGAL AND 4 CROSS ORISSA COAST DURING MONSOON SEASON
- SIGNIFICANT DECREASING TREND (1 PER DECADE IN RECENT YEARS SINCE 1960) DURING MONSOON SEASON
- INCREASE IN INTERANNUAL VARIABILITY OF SEASONAL MONSOON RAINFALL DUE TO INCREASING VARIABILITY OF MONSOON DISTURBANCES CROSSING ORISSA
- QBO CYCLE IS SIGNIFICANT
- ENSO CYCLE IS NOT OBSERVED IN INTERANNUAL VARIATION OF MONSOON RAINFALL AND MONSOON DISTURBANCES CROSSING ORISSA
- WEAKER MONSOON CIRCULATION OVER THE REGION MIGHT HAVE RESULTED IN DECREASE IN FREQUENCY OF CYCLONIC DISTURBANCES

CONCLUSIONS (CONTD)

- FURTHER STUDY IS IN PROGRESS TO FIND OUT PRECURSORS FROM THE LARGE SCALE FIELDS FOR PREDICTION OF CYCLOGENESIS, ESPECIALLY THE LAND FALLING CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN

THANK YOU