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THE STUDY OF CYCLONIC DISTURBANCES OVER INDIAN SEAS DURING 1991 - 2004

1. Indian coasts around Bay of Bengal and Arabian Sea experience severe weather associated with cyclonic storms every year. Therefore the prediction of such storms with respect to their formation, movement and rainfall assumes great importance. Krishna Rao and Jagannathan (1953) studied the frequency of depressions and cyclonic storms which crossed the east coast of India, south of the latitude 16° N during October to December in the period 1906-1949 and their contributions to the northeast monsoon rainfall over Tamil Nadu. Rai Sarkar (1955) studied the frequency of cyclonic disturbances (depressions and cyclonic storms) crossing each one-degree latitude-longitude square in the Bay of Bengal for the period 1890-1950. Chellappa and Seshadri (1981) using the data for the period 1891 - 1970 enumerated the number of cyclonic storms that crossed four coastal segments on the eastern part of India. Month-wise distribution of storms and severe cyclonic storms crossing the coast of Andhra Pradesh was presented in the paper. Jenamani and Dash (2005) studied the characteristics of monsoon disturbances for different phases of El-Nino.

The present study is based on the data of last 14 years (1991 - 2004) and aims at calculating the number of cyclonic disturbances crossing each 3° latitudinal strip on the Indian coasts. In this study, the characteristics of cyclonic disturbances, namely their speeds, distance traveled before and after crossing the coast have been studied. The intensity of rainfall and wind speed in various sectors of the cyclonic disturbances have also been analyzed. The data of last 35 years (1970 - 2004)

TABLE 1

Total no. of cyclonic disturbances which crossed the east and west coasts of India in every 3° latitudinal strip during the period 1991 - 2004

Latitudinal strip	Number of cyclonic disturbances									
	Winter		Pre-monsoon		Monsoon		Post-monsoon		Total	
	East coast	West coast	East coast	West coast	East coast	West coast	East coast	West coast	East coast	West coast
5° – 8° N	-	-	-	-	-	-	-	-	-	-
8° – 11° N	-	-	1	-	-	-	5	1	6	1
11° – 14° N	-	-	1	-	-	-	9	-	10	-
14° – 17° N	-	-	-	-	2	-	6	-	8	-
17° – 20° N	-	-	2	-	6	-	5	1	13	1
20° – 23° N	-	-	6	2	15	2	11	2	32	6

TABLE 2

Type of cyclonic disturbances that crossed the east and west coasts of India during the period 1991 - 2004

Type of system	Season							
	Winter		Pre-monsoon		Monsoon		Post-monsoon	
	East coast	West coast	East coast	West coast	East coast	West coast	East coast	West coast
Depression	-	-	2	1	21	-	12	1
Cyclonic storm	-	-	-	-	3	-	7	1
Severe cyclonic storm	-	-	3	1	-	1	11	1

have been analyzed to study the relationship of cyclogenesis in Indian seas with Southern Oscillation Index (SOI).

2. The meteorological and cyclone data were collected from the India Meteorological Department, New Delhi. The total number of cyclonic disturbances, which crossed the Indian coast in each 3° latitude strip, during all four seasons, were calculated for the period 1991-2004. The term cyclonic disturbance is used in the text to refer the all stages of a cyclonic system from the depression stage *i.e*., depression, cyclonic storm and severe cyclonic storm.

The 0300 UTC positions of the cyclonic disturbances, as given in the tracks, are considered to compute the displacements and the speeds. As the time of crossing the coast need not necessarily coincide with 0300 UTC position of the system, the proportionate distance for the period between the time of crossing and the immediately preceding 0300 UTC position was calculated by assuming constancy of speed during the 24-hour period on the day of crossing. The total distance travelled, duration and average speed of a cyclonic disturbance before crossing the coast, termed as 'antecedent distance' and 'antecedent speed' respectively, were computed from the depression stage onwards. Likewise the parameters after crossing the coast, termed as 'subsequent distance', 'subsequent duration', 'subsequent speed', were computed.

For comparing the intensity of rainfall and surface wind speed around a cyclonic disturbance, a circle of radius 3° latitude is drawn keeping the cyclonic disturbance at the centre and the left, right and the front sectors are defined by dividing this circle in three sectors of 120° each around the centre. The rainfall and surface wind speed data of three stations (one in each sector) have been analyzed.

3. Table 1 gives the total no. of cyclonic disturbances that crossed the Indian coasts in each 3° latitudinal strip in all four season.

The maximum number of cyclonic disturbances crossed the east coast in 20° - 23° N latitudinal strip followed by 17° - 20° N and 11° - 14° N latitudinal strips during 1991-2004. The maximum number of cyclonic disturbances crossed the west coast in 20° - 23° N latitudinal strip followed by 17° - 20° N and 8° - 11° N latitudinal strips during the study period. Table 2 shows the no. of cyclonic disturbances in various stages at the

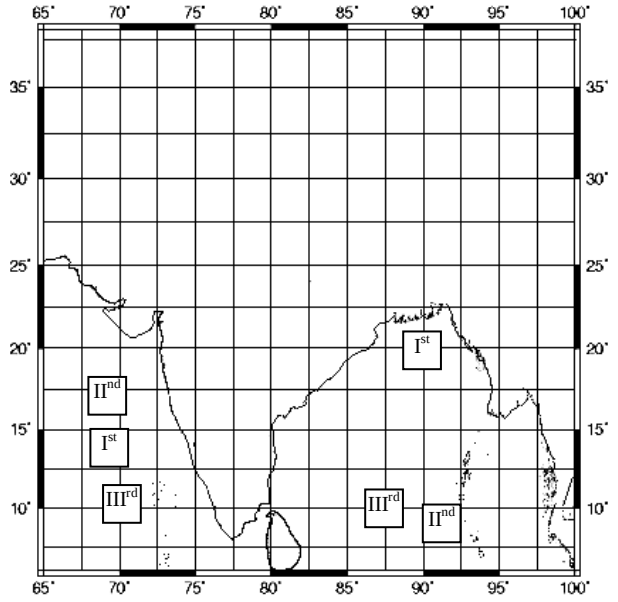
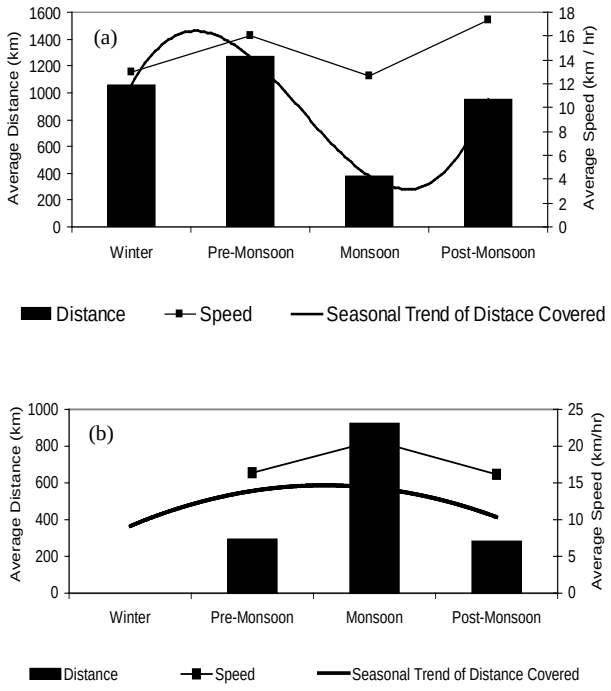


Fig. 1. Ranking of areas of generation of cyclonic disturbances over Indian seas



Figs. 2 (a&b). (a) Seasonal antecedent and (b) Seasonal subsequent parameters in Bay of Bengal during the period 1991-2004

time of crossing the east and west coasts respectively in each season. It has been observed that during the Monsoon season 87.5 % of the cyclonic disturbances crossed the east coast as depression, 12.5 % as cyclonic storm and none as severe cyclonic storm. During the Post-monsoon season 36.67 % of the cyclonic systems crossed the east coast as severe cyclonic storm, 40 % as depression and nearly 23.33 % as cyclonic storm. In the Pre-monsoon season 40 % of the cyclonic disturbances crossed the east coast as depression, 60 % as severe cyclonic storm and none as cyclonic storm.

During the period 1991-2004, 50 % of total number of cyclonic disturbances crossed the west cost of India as severe cyclonic storm, 16.67 % as cyclonic storm and 33.33 % as depression whereas 17 % and 63 % of total number of cyclonic disturbances, which have developed in Bay of Bengal and Arabian Sea respectively, disappeared over the sea or crossed the coasts of other neighbouring countries.

3.1. Although the total area over which the cyclonic disturbances have developed in Bay of Bengal during the study period, is found between 4° - 22° N and 78° - 99.5° E but the maximum number of cyclonic disturbances have developed in the area between 18.5° - 21.5° N and 88° - 91° E, followed by the areas between 7.5° - 10.5° N and 89.5° - 92.5° E and between 10.5° - 13.5° N and 86° - 89° E respectively.

While the total area over which the cyclonic disturbances have developed in the Arabian Sea during the study period, is found between 1° - 19° N and 65° - 73° E but the maximum number of cyclonic disturbances have developed in the area between 12° - 15° N and 67.5° - 70.5° E, followed by the areas between 16° - 19° N and 67.5° - 70.5° E and between 9° – 12° N and 69.5° - 72.5° E respectively as shown in Fig. 1.

3.2. The climatological value of antecedent and subsequent characteristics of a cyclonic disturbance like cyclonic storm in different months are useful to planners to estimate how far in advance they should take various steps to mitigate the disastrous consequences of a cyclonic storm that would cross the coast.

As shown in Table 3, the average antecedent distance travelled by cyclonic disturbances was maximum in April (1653.9 km) (during 1991 – 2004) at an average speed of 17.15 km / hour, followed by the distance travelled in November (1238.96 km) at a average speed of 20.68 km / hour.

The average subsequent distance travelled by the cyclonic systems was maximum in July (1409.55 km) at a average speed of 22.56 km / hour, followed by the

TABLE 3

Antecedent and subsequent parameters during the period 1991 - 2004

Month	Bay of Bengal			
	Antecedent parameters		Subsequent parameters	
	Average distance (km)	Average speed (km / hour)	Average distance (km)	Average speed (km / hour)
January	-	-	-	-
February	1060.05	13.095	-	-
April	1653.90	17.15	305.25	17.125
May	877.50	14.95	280.67	15.64
June	376.15	14.86	597.29	18.33
July	214.32	6.89	1409.55	22.56
August	132.07	15.59	1291.96	26.23
September	793.44	13.28	393.76	15.86
October	786.02	17.06	316.13	14.58
November	1238.96	20.68	309.49	16.44
December	813.55	14.17	219.20	17.45

TABLE 4

Average time and distance taken by a cyclonic disturbance to intensify into a cyclonic storm from depression stage during the period 1991 – 2004

Direction of movement of cyclonic disturbances	Bay of Bengal		Arabian Sea	
	Average time (hour)	Average distance (km)	Average time (hour)	Average distance (km)
W	22.29	289.27	24.01	387.31
NW	25.49	466.41	20.00	400.80
N	29.16	445.74	20.06	297.78

distance travelled in August (1291.96 km) at a average speed of 26.23 km/hour.

Figs. 2 (a&b) show that the seasonal average antecedent distance was maximum in Pre-monsoon season followed by Winter, Post-monsoon and Monsoon seasons in Bay of Bengal whereas the seasonal average subsequent distance was maximum in Monsoon season followed by Post-monsoon and Pre-monsoon.

3.3. The time taken by a cyclonic disturbance to intensify into a cyclonic storm from depression stage with distance traveled in different directions is shown in Table 4.

3.4. During the period 1991 - 2004, it has been found that in 68 % of total cyclonic disturbances (for which data is available), the amount of rainfall was highest in left sectors of cyclonic disturbances followed by front sectors (19.5 %) and right sectors (12.5 %).

The highest surface wind speed has been observed in left sectors (56.24 %) of cyclonic disturbances followed by front (25 %) and right sectors (18.74 %) respectively.

3.5. The analysis of Integrated Area Weighted South West Monsoon Rainfall (IAWSWMR) of 35 years (1970 - 2004) with the nature of the cyclonic storms during the month of October and November in Bay of Bengal and SOI from Table 5 has brought out the following :

(*i*) When IAWSWMR was less than 95 % then 18 cyclonic storms have developed over Bay of Bengal in the months of October and November, out of which 12 crossed the Indian coast and 8 either re-curved towards

TABLE 5

Number of tropical cyclones with area weighted rainfall and southern oscillation index (1970 – 2004)

Area weighted rainfall (%)	Year	SOI		No. of cyclones crossed (East coast)	No. of cyclones recurved
		Oct	Nov		
> 110	1970	0.8	1.8	2	2
	1975	1.7	1.3	-	-
	1983	0.3	-0.1	1	1
	1988	1.3	1.9	1	-
105 – 110	1973	0.6	2.9	1	-
	1978	-0.8	-0.1	1	1
	1990	0.1	-0.1	-	-
	1994	-1.6	-0.7	1	1
	2003	-0.3	-0.4	-	-
100 – 105	1971	1.8	0.5	1	2
	1976	0.2	0.7	3	1
	1977	-1.4	-1.6	2	1
	1980	-0.3	-0.5	1	1
	1996	0.4	-0.2	1	-
	1997	-1.9	-1.4	-	-
	1998	1.0	1.1	1	2
95 – 100	1981	-0.7	0.1	-	-
	1984	-0.6	0.3	3	1
	1989	0.5	0.6	1	-
	1993	0.3	0.3	-	-
	1995	-0.3	0.1	2	1
	1999	0.9	1.1	2	-
90 – 95	1985	-0.8	-0.4	2	1
	1991	-1.5	-0.8	1	-
	1992	-1.9	-0.9	2	-
	2000	1.0	2.0	1	1
	2001	-0.4	0.7	1	-
≤ 90	1972	-1.1	-0.4	-	1
	1974	0.8	-0.4	1	1
	1979	-0.4	-0.6	1	-
	1982	-2.2	-3.2	1	-
	1986	0.6	-1.6	1	1
	2002	-0.7	-0.6	1	1
	2004	-0.3	-0.9	-	-

other neighbouring countries or dissipated over sea. The integrated values of SOI during these October and November months were – 0.58 and – 0.59 respectively.

(*ii*) During the years in which IAWSWMR remained between 95 % to 105 %, 26 cyclonic storms developed over Bay of Bengal in the months of October and November, out of which 17 crossed the Indian coast and 9 either re-curved towards other neighbouring countries or dissipated over sea. The integrated values of SOI during these October and November months were – 0.0077 and 0.085 respectively.

(*iii*) Also, during the years, in which more than 105 % IAWSWMR occurred, 12 cyclonic storms developed over Bay of Bengal in the months of October and November, out of which 7 crossed the Indian coast and 5 either re-curved towards other neighbouring countries or dissipated over sea. The integrated values of SOI during these October and November months were 0.23 and 0.72 respectively.

4. The following conclusions have been drawn from this study :

(*i*) The total number of cyclonic disturbances, which crossed the east and west coasts of India in each 3° latitudinal strip during 1991 - 2004, were maximum in Post-monsoon season followed by Monsoon and Pre-Monsoon seasons.

(*ii*) In the Bay of Bengal, the maximum number of cyclonic disturbances have developed over the area between 18.5° - 21.5° N and 88° - 91° E in the Bay of Bengal during the period 1991 - 2004, followed by the areas between 7.5° - 10.5° N and 89.5° - 92.5° E and between 10.5° - 13.5° N and 86° - 89° E respectively.

(*iii*) In the Arabian Sea, the maximum number of cyclonic systems formed over the area between 12° - 15° N and 67.5° - 70.5° E, followed by the areas between 16° - 19° N and 67.5° - 70.5° E and between 9° - 12° N and 69.5° - 72.5° E respectively.

(*iv*) Seasonal average antecedent distance was maximum in Pre-monsoon season followed by Winter, Post-monsoon and Monsoon seasons in Bay of Bengal, while seasonal average subsequent distance was maximum in Monsoon season followed by Post-monsoon and Pre-monsoon.

(*v*) In 68 % cases of total cyclonic disturbances (for which data is available), the amount of rainfall was highest in left sector of cyclonic systems.

(*vi*) In 56.24 % cases of total cyclonic disturbances, the highest surface wind speed has been observed in left sectors.

(*vii*) The average value of SOI during the months of October and November was higher in the years of higher Integrated Area Weighted South West Monsoon Rainfall.

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SIDDHARTHA SINGH
R. K. GIRI
S. D. ATTRI

India Meteorological Department, New Delhi, India
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