

Recurving cyclonic storms during 1970-94

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सारा — 1970 से 1994 तक 25 वर्षों की अवधि के दौरान चक्रवातीय तूफानों के एक स्थान से दूसरे स्थान पर पहुँचने की गति और प्रतिवर्तन के स्थान का अध्ययन किया गया है। इससे मौसम की भविष्यवाणी करने वालों को चक्रवातीय तूफान से प्रभावित होने वाले क्षेत्रों की सही अवस्थिति के संबंध में पूर्वानुमान लगाने में सहायता मिलेगी।

ABSTRACT — Translation speed and place of recurvature of cyclonic storms during 25 years period 1970-94 are studied. This will help forecasters to predict exact landfall of cyclonic storm.

Key words — Recurvature, Landfall of cyclonic storm, Translation speed, Size of the cyclonic storm.

1. Introduction

The cyclonic storms which move towards north (south) and then northeast (southeast) in Northern (Southern) Hemisphere are called as recurving storms. During pre-monsoon (March, April and May) and post-monsoon (October, November and December) seasons over India, many cyclonic storms form over the Bay of Bengal and the Arabian Sea and some of them recurve to the north and to the northeast. Forecasting recurvature of such cyclonic storms is one of the difficult and vexed problems for forecasters. In fact, forecast of recurvature of cyclonic storms has two components. The first one is to forecast the time and place (in terms of latitude and longitude) of recurvature and the second is to forecast the speed of the cyclonic storm. Both of them are important in deciding the place and time of landfall for the effective storm warning work. Frequency of formation of cyclonic storms over the Bay of Bengal is more than over the Arabian Sea. So the number of storms recurving over the Bay of Bengal is more than the Arabian Sea.

When a cyclonic storm recurves over the Bay of Bengal it crosses the east coast of India anywhere between Andhra Pradesh coast and Myanmar coast depending upon the place (latitude and longitude) of recurvature. Recurving storms over the Arabian Sea cross west coast of India anywhere between Karnataka coast and north Gujarat coast.

For forecasting the exact place and time of landfall of recurving storms, we must develop suitable forecasting techniques.

2. Study of cyclonic storms during 1970-94

Tracks of cyclonic storms for 25 years from 1970 to 1994 were collected from the quarterly journal "Mausam". These tracks and storm accounts are published by the office of Deputy Director General of Meteorology (Weather Forecasting), Pune.

Table 1 gives number of cyclonic storms and recurved storms during 1970-94. Figs. 1-3 give the

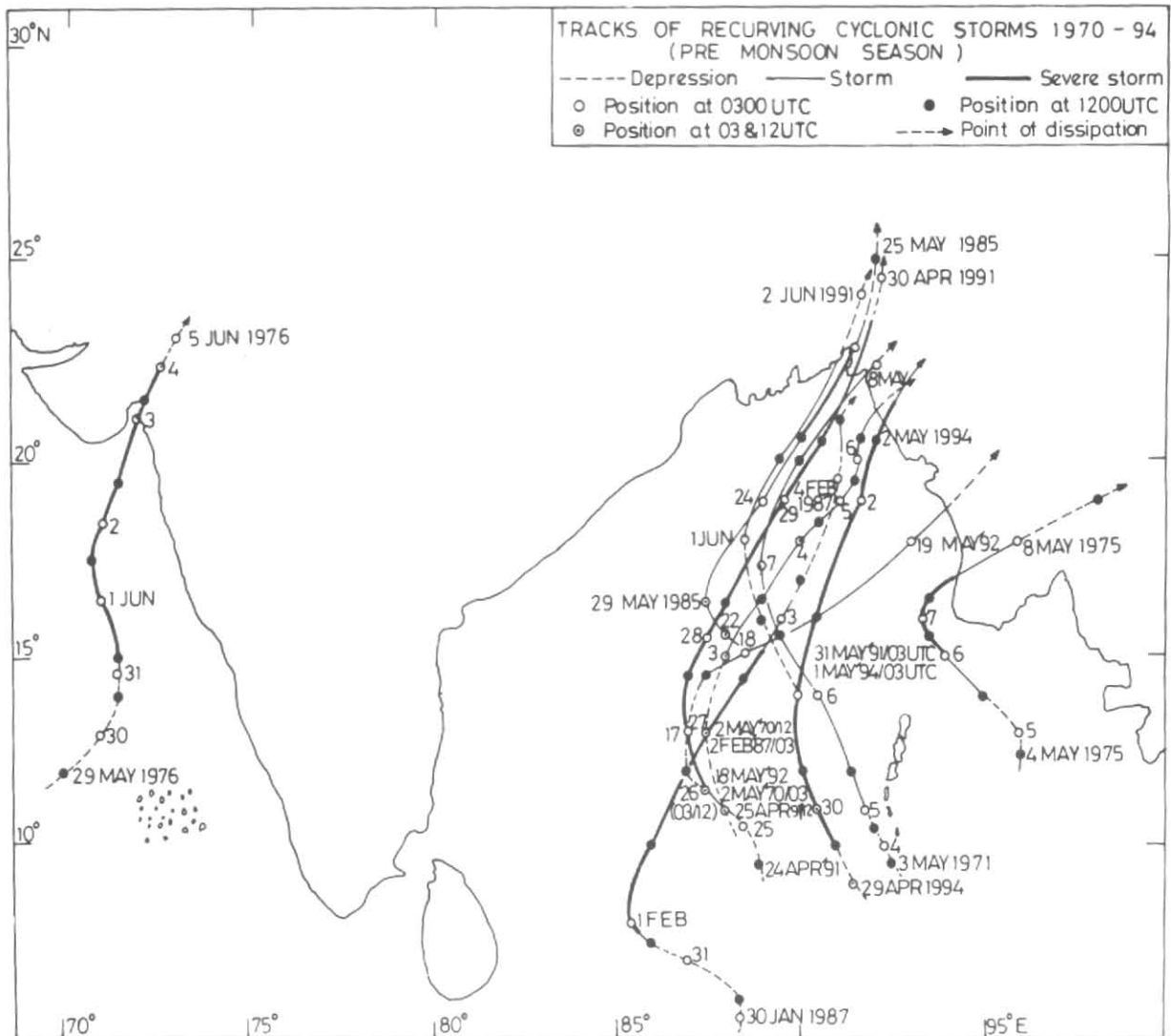


Fig. 1. Tracks of recurring cyclonic storms during 1970-94 (Pre-monsoon season)

tracks of cyclonic storms which recurved during 1970-94. There were in all 267 cyclonic storms during the twentyfive years period. In four years (1972, 1975, 1976 and 1977), 15 or more cyclonic storms formed in each year, the maximum being 19 in 1975. In 12 years (1970, 1971, 1973, 1974, 1978, 1979, 1980, 1981, 1982, 1985, 1989 and 1990) there were 10 to 14 cyclonic storms every year. In 1993 and 1994 there were three and four cyclonic storms respectively. In other seven years (1983, 1984, 1986, 1987, 1988, 1991 and 1992) there were 5 to 9 cyclonic storms.

Thirtyone cyclonic storms recurved out of 267 during the 25 years period, 1970-1994. No storm recurved in the seven years period, *i.e.*, in 1972 (out of 15), in 1977 (out of 18), in 1979 (out of 11), in 1980 (out of 11), in 1984 (out of 7), in 1986 (out of 6) and in 1989 (out of 10).

Twentyfive cyclonic storms recurved over the Bay of Bengal and six over the Arabian Sea.

Table 2 gives monthwise/seasonwise break up of the recurring cyclonic storms during 1970-94.

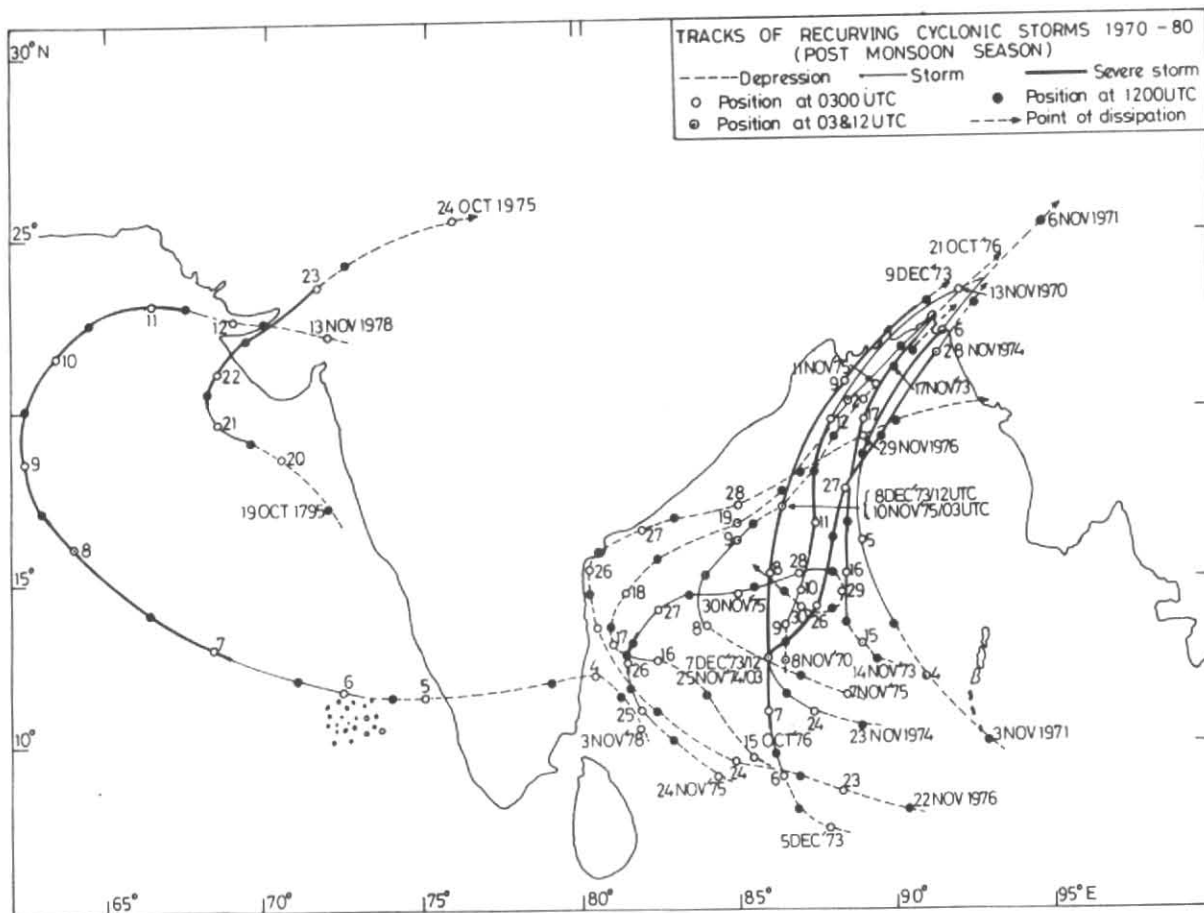


Fig. 2. Tracks of recurring cyclonic storms during 1970-80 (Post-monsoon season)

In the pre-monsoon season over the Bay of Bengal, 9 storms recurved out of which 6 were in May. One cyclonic storm recurved in the pre-monsoon season over the Arabian Sea.

In the post-monsoon season over the Bay of Bengal, 16 cyclonic storms recurved. Out of which 11 recurved in November, 3 in December and 2 in October. Five cyclonic storms recurved over the Arabian Sea out of which 3 in November, 2 in October and none in December.

Out of 9 cyclonic storms in the pre-monsoon season, 6 recurved over the Bay of Bengal in May.

Thus, frequency of recurvature of cyclonic storms is more in the month of May over the Bay of Bengal.

Out of 21 cyclonic storms in the post-monsoon season, 11 recurved over the Bay of Bengal, 3 over the Arabian Sea in the month of November. Thus frequency of recurvature of cyclonic storms is maximum in the month of November both in the Bay of Bengal and the Arabian Sea.

Table 3 gives the latitudes and longitudes of recurvature of the cyclonic storms. Table 4 gives the frequency of recurring cyclonic storm latitude-longitudewise over the Bay of Bengal.

In the pre-monsoon season over the Bay of Bengal, most of the storms recurved near Lat. 14°N and near Long. 87.5° E.

In the post-monsoon season over the Bay of Bengal, the most of the cyclonic storms recurved near Lat. 13° N and Long. 86.5° E.

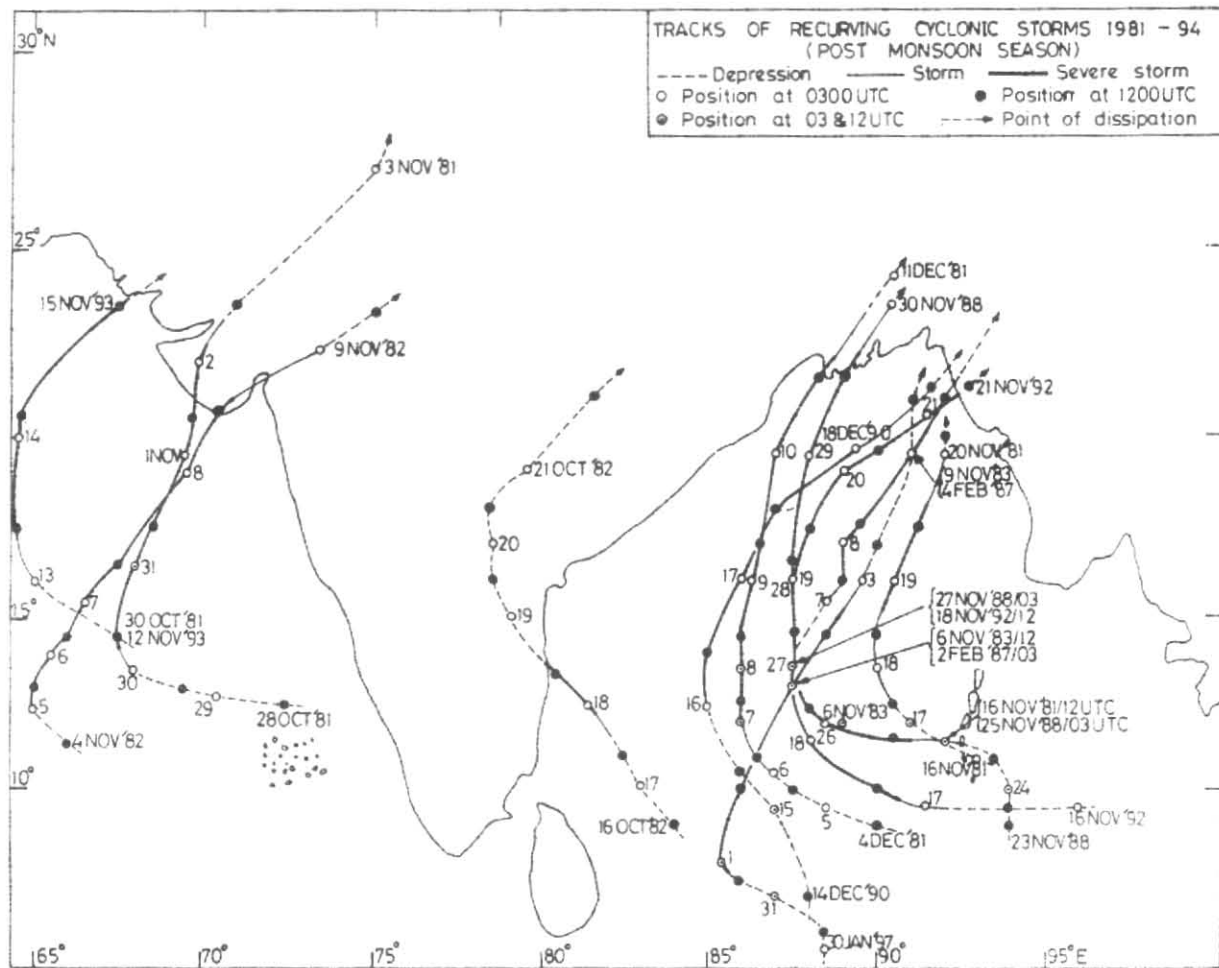


Fig. 3. Tracks of recurring cyclonic storms during 1981-94 (Post-monsoon season)

TABLE 1
Number of cyclonic storms and recurved storms
during the period 1970-94

S. No.	Year	Number of cyclonic storms over Bay of Bengal	Number of cyclonic storms over Arabian Sea	Total number of recurring cyclones	Total number of cyclones during the year
(1)	(2)	(3)	(4)	(5)	(6)
1.	1970	2	-	2	14
2.	1971	2	-	2	14
3.	1972	-	No recurvature	-	15
4.	1973	2	-	2	10
5.	1974	1	-	1	10
6.	1975	3	1	4	19
7.	1976	2	1	3	15
8.	1977	-	No recurvature	-	18
9.	1978	-	1	1	13

TABLE 1 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)
10.	1979	-	No recurvature	-	11
11.	1980	-	No recurvature	-	11
12.	1981	2	1	3	11
13.	1982	1	1	2	13
14.	1983	1	-	1	7
15.	1984	-	No recurvature	-	7
16.	1985	1	-	1	12
17.	1986	-	No recurvature	-	6
18.	1987	1	-	1	9
19.	1988	1	-	1	7
20.	1989	-	No recurvature	-	10
21.	1990	1	-	1	11
22.	1991	2	-	2	8
23.	1992	2	-	2	9
24.	1993	-	1	1	3
25.	1994	1	-	1	4
Total		25	6	31	267

TABLE 2

Monthwise/seasonwise break-up of recurving cyclonic storms during 1970-94

Season	Month	Bay of Bengal	Arabian Sea	Total
Pre-monsoon	January	1	Nil	1
	March	Nil	Nil	0
	April	2	Nil	2
	May	6	1	7
Total		9	1	10
Post-monsoon	October	2	2	4
	November	11	3	14
	December	3	-	3
Total		16	5	21
Total (Pre-monsoon + Post-monsoon)		25	6	31

3. Synoptic features causing recurvature of cyclonic storms

Generally, the cyclonic storms move along the steering current of upper tropospheric flow. But the difficulty is to identify the steering level. Even if you identify the steering level, there may not be wind observations in that level which adds to the problem of forecast movement of cyclonic storm. Generally cyclonic storms in the northern latitudes tend to move faster as they are under the influence of westerly winds aloft. The cyclonic storms in the lower latitudes move slower as they are in the easterly wind regime in lower levels.

The synoptic features causing the recurvature of the storms studied here can be in two categories :

- (i) Cyclonic storms recurve to the north and to the northeast when there is a passage of mid and upper tropospheric westerly trough aloft. More than 80% of the storms studied here fall under this category.

TABLE 3

Latitude and longitude of recurving of storms

S. No.	Date of cyclonic storm	Latitude of recurvature (N)	Longitude of recurvature (E)
Pre-monsoon season, Bay of Bengal			
1.	2 May 1970	13.0°	87.5°
2.	3 May 1971	17.5°	88.5°
3.	4 May 1975	16.0°	93.5°
4.	22 May 1985	16.5°	87.5°
5.	31 Jan 1987	8.0°	85.5°
6.	24 Apr 1991	14.5°	87.0°
7.	31 May 1991	18.0°	88.5°
8.	16 May 1992	13.0°	87.0°
9.	29 Apr 1994	14.0°	90.0°
Post-monsoon season, Bay of Bengal			
1.	8 Nov 1970	12.5°	86.5°
2.	3 Nov 1971	17.5°	88.0°
3.	14 Nov 1973	14.5°	88.5°
4.	5 Dec 1973	9.0°	86.0°
5.	23 Nov 1974	12.5°	76.0°
6.	7 Nov 1975	14.5°	83.5°
7.	24 Nov 1975	12.5°	81.5°
8.	15 Oct 1976	13.5°	80.5°
9.	22 Nov 1976	15.0°	80.0°
10.	16 Nov 1981	13.5°	90.0°
11.	4 Dec 1981	12.5°	86.0°
12.	16 Oct 1982	17.0°	80.0°
13.	6 Nov 1983	13.0°	87.5°
14.	23 Nov 1988	13.5°	87.5°
15.	14 Dec 1990	12.5°	85.0°
16.	16 Nov 1992	13.5°	87.5°
Pre-monsoon season, Arabian Sea			
1.	29 May 1976	12.0°	70.0°
Post-monsoon season, Arabian Sea			
1.	19 Oct 1975	20.5°	68.5°
2.	3 Nov 1978	18.5°	62.5°
3.	28 Oct 1981	14.5°	67.5°
4.	4 Nov 1982	13.0°	65.0°
5.	12 Nov 1993	19.0°	64.5°

TABLE 4

Frequency of recurving cyclonic storms (latitude and longitudewise) in Bay of Bengal

Latitude belts	Pre-monsoon	Post-monsoon
North		
≤ 12	0	1
≥ 12 < 13	1	5
≥ 13 < 14	2	5
≥ 14 < 15	2	2
≥ 15 < 16	0	1
≥ 16 < 17	2	0
≥ 17 < 18	1	2
≥ 18 < 19	1	0
East		
< 80	0	0
≥ 80 < 81	0	3
≥ 81 < 82	0	1
≥ 82 < 83	0	0
≥ 83 < 84	0	1
≥ 84 < 85	0	0
≥ 85 < 86	0	1
≥ 86 < 87	1	4
≥ 87 < 88	4	3
≥ 88 < 89	2	2
≥ 89 < 90	1	0
≥ 90 < 91	0	1
≥ 91 < 92	0	0
≥ 92 < 93	1	0

(ii) Cyclonic storms recurve around the periphery of the upper tropospheric anticyclone aloft. The remaining 20% of the cases are in this category.

TABLE 5

Speed of recurving storms before and after recurvature during day and night

S. No.	Storm date/year	Speed before recurvature (kmph)	Speed after recurvature (kmph)	Day speed 9 hr (kmph)	Night speed 15 hr (kmph)
1.	2 May 1970	-	14	26	6
2.	8 Nov 1970	-	19	14	12
3.	3 May 1971	4	30	23	18
4.	3 Nov 1971	16	44	30	18
5.	14 Nov 1973	5	16	18	12
6.	5 Dec 1973	7	33	16	7
7.	24 Nov 1974	10	27	18	8
8.	4 May 1975	6	26	16	13
9.	19 Oct 1975	8	24	10 (Day and Night)	
10.	7 Nov 1975	22	33	21	15
11.	24 Nov 1975	7	11	8	8
12.	29 May 1976	4	22	16	6
13.	15 Oct 1976	14	18	21	22
14.	22 Nov 1976	13	16	16	15
15.	3 Nov 1978	20	17	21	19
16.	16 Nov 1981	10	15	24	11
17.	28 Oct 1981	11	15	-	-
18.	4 Dec 1981	9	12	-	-
19.	16 Oct 1982	13	21	17	13
20.	4 Nov 1982	9	16	14	13
21.	6 Nov 1983	-	-	-	-
22.	22 May 1985	8	30	33	16
23.	31 Jan 1987	-	-	-	-
24.	25 Nov 1988	11	16	18	17
25.	14 Dec 1990	10	18	21	17
26.	24 Apr. 1991	-	-	-	-
27.	31 May 1991	-	-	-	-
28.	16 May 1992	7	10	16	15
29.	17 Nov 1992	19	17	-	-
30.	12 Nov 1993	19	21	-	-
31.	29 Apr 1994	20	40	22	16

4. Speed of recurving cyclonic storms

Translation speed of cyclonic storms depends upon many factors. One of the important factors is the size of the cyclonic storm. The cyclonic storms can be classified on the basis of their translation speed and also on the basis of their size as given below :

(i) Size of the cyclonic storm

- (a) Small size — Diameter upto 300 kms
- (b) Medium size — Diameter between 300 and 700 kms
- (c) Large size — Diameter 700 to 1000 kms

Small size cyclonic storms are fast moving while the large size cyclonic storms are slow moving.

(ii) Translation speed of cyclonic storm

- (a) Slow moving — 10-14 kmph.
- (b) Moving with a normal speed — 15-18 kmph
- (c) Fast moving — 19 kmph and more.

Small size cyclonic storms (diameter upto 300 km) move with the average speed of 19 kmph or more. Medium size cyclonic storms (diameter between 300 and 700 kms) move with the average speed of 15 to 18 kmph. Large size cyclonic storms (diameter between 700 and 1000 kms) move with the average speed of 10 to 14 kmph.

Hourly speeds of all the recurving cyclonic storms are calculated from the tracks. These are given in Table 5. Speed of the cyclonic storms before recurvature and speed of cyclonic storms after recurvature are also calculated. Speed of the cyclonic storm during the day (between 0300 and 1200 UTC) and during night (between 1200 and 0300 UTC) are also given in the Table 5.

During the day, speed of the cyclonic storms is more than that during the night. Day speeds are $1\frac{1}{2}$ times more than the night speeds of the storms in most of the cases.

The speed after the recurvature of the cyclonic

storms is between $1\frac{1}{2}$ and 2 times the speed before the recurvature of the cyclonic storm. Other interesting features are as follows :

- (a) When a cyclonic storm recurves in the lower latitudes (south of 14° N), its speed after recurvature is about $1\frac{1}{2}$ times of the speed before recurvature.
- (b) When a storm recurves in a northern latitudes (north of 14° N), its speed after recurvature is twice the speed before the recurvature.

5. Conclusions

- (i) In the pre-monsoon season, the preferred latitude and longitude of recurvature over the Bay of Bengal is 14° N and 87° E respectively.
- (ii) In the post-monsoon season, the preferred latitude and longitude of recurvature is 13° N and 86.5° E respectively.
- (iii) In the pre-monsoon season, most of the cyclonic storms recurve in the month of May over the Bay of Bengal. In the post-monsoon season, most of the storms over the Bay of Bengal recurve in the month of November.
- (iv) Cyclonic storms move faster during the day than during the night.
- (v) After recurvature, cyclonic storms move faster than before recurvature. When the cyclonic storms recurve in the lower latitudes (south of 14° N), their speed after recurvature is about $1\frac{1}{2}$ times more than before recurvature. When the cyclonic storms recurve in the northern latitudes (north of 14° N), their speed after recurvature is about 2 times the speed before recurvature.
- (vi) Small, medium and large size cyclonic storms move with an average speed of 19 kmph, 15 to 18 kmph and 10 to 14 kmph respectively.

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