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A statistical study of Bay of Bengal disturbances (1961-80) using satellite imagery

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सार — वर्ष के अनेक महीनों में बंगाल की खाड़ी में आने वाले विक्षोभों की संभावित तीव्रता को समझने के उद्देश्य से 1961 से 1980 तक की अवधि के अवदाबों और झंझाओं के सांख्यिकीय अध्ययन किया गया है । दवोरक के पैमाने पर आधारित टी नम्बर वर्गीकरण केवल 1974 से ही उपलब्ध है । इस अध्ययन के लिए 1961 से 1973 तक की अवधि की प्रणालियों को सम्बन्धित टी नम्बरों में परिवर्तित किया गया है ।

विक्षाभों की बारम्बारता वंटन से मई और अक्तूबर मास के दो अधिकतमों को उपस्थिति का पता चलता है । निदर्श वक्र से आभास मिलता है कि मई में भारी चक्रवाती तूफान आते हैं । लेकिन हरीकेन पवनों की कोर वाले तूफान सामान्यतया केवल नवम्बर और दिसम्बर में ही आते हैं ।

ABSTRACT. With a view to understand the probable intensity of disturbances in the Bay of Bengal that are likely to occur during the various months of the year, a statistical study has been undertaken of depressions and storms during the period 1961 to 1980. As T-number classification according to Dvorak's scale is available only from 1974, systems during the period 1961 to 1973 were converted to the corresponding T-numbers for the purpose of this study.

The frequency distribution of the disturbances reveals the presence of double maximum, one in May and the other in October. The modal curve suggests that while severe cyclonic storms occur in May, those with core of hurricance winds generally occur in November and December only.

1. Introduction

It is common knowledge that the Bay of Bengal disturbances, particularly in the months from October to December, intensify into cyclonic storms and on crossing the coast cause a lot of damage to life and property due to accompanying gales and tidal waves. With the advent of weather satellites the determination of intensity of systems has become much more accurate. To determine the intensity of tropical disturbances using satellite pictures, Dvorak's (1975) classification is presently used in India. The present study uses the satellite classification of tropical disturbances in the Bay of Bengal during the period 1961 to 1980 in terms of T-numbers according to Dvorak's technique. In this technique the intensity of a tropical cyclone is determined by assigning a T-number to the disturbance by using both the qualitative description of intensity based on commonly seen tropical cyclone patterns and the quantitative description based on the central features and the outer banding features of the disturbance.

2. Data

Data pertaining to all the disturbances in the Bay of Bengal for the period 1961-80 was collected. While the T-number classification readily available from the year 1974 has been used, for the systems prior to 1974, the maximum attained intensity of each disturbance as given in the cyclone reviews upto 1970 and the Annual Report on the depressions and cyclones published in *Indian Journal of Meteorology, Hydrology and Geophysics* (*Mausam* as now named) from 1971 was converted to the corresponding T-number using Dvorak's technique. In respect of each disturbance the maximum attained T-number in its life history has been taken.

3. Differences between conventional classification and T-number classification

In the India Meteorological Department (IMD) the wind speed alone is the main criterion for defining the intensity of the tropical disturbance. Dvorak (1975) uses an empirical relationship between the current intensity in terms of T-numbers and the maximum sustained wind speed in

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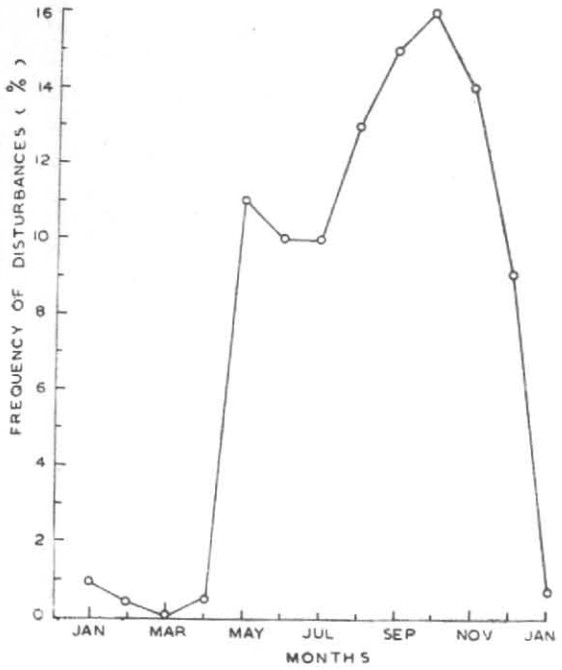

Fig. 1. Percentage frequency of disturbances

TABLE 1

Relationship between conventional classification (IMD) of tropical disturbances and T-number classification

Tropical disturbance	Wind speed observed or estimated (kt)	Associated T-number
Low pressure	≤17	—
Depression	18-27	1, 1.5
Deep depression	28-33	2
Cyclonic storm	34-47	2.5, 3
Severe cyclonic storm	48-63	3.5
Hurricane	64 & above	4.0 & above

the tropical disturbance. The relationship between the two classifications can be seen in Table 1.

4. Discussion of results

Table 2 gives the monthwise distribution of all disturbances from depression stage (equivalent to T-1) onward which occurred during this 20-year period, along with annual percentage. The frequency distribution of tropical disturbances according to their T-numbers for the months May to December is presented in Fig. 2. As severe cyclonic storms (T-3.5) and hurricanes (T-4 and above) are disaster producing, their frequencies with percentages are also given in Table 2. The statistical parameters like mean, median, mode and standard deviation are also presented.

Srinivasan and Ramamurty (1973) have given the monthly frequencies of depressions and cyclones for October, November and December for the period 1891-60. This table has been updated upto 1980 and presented in Table 3.

Table 2 clearly shows that intensification of tropical disturbances to severe cyclone stage (T. No. 3.5) occurs mostly in the months of May (61%), November (77%) and December (63%). There is a 38% chance of disturbances intensifying to severe cyclonic storm stage and above in October. Also 63% of the disturbances in November reach hurricane intensity while May and December have about 40%. There was only one occasion when a tropical storm reached the intensity of a 'super storm' (T-7.0) equivalent to a maximum sustained wind of about 140 kt (250 kmph). This occurred in November 1977, when the super storm crossed south Andhra coast near Chirala causing a storm surge of about 5.5 metres upto 11 km in the interior. The highest values of mean, median and mode also occur in May, November and December. Modal value of T-4 for the months of November and December compared to the mean values of 3.5 and 2.2 and median values of 3.7 and 3.3 respectively indicate that chances of very intense cyclones are more in these two months.

The modal curve of T-number is given in Fig. 3: the highest modal value occurs in October and November.

Fig. 2 shows the T-number frequency for various months. A general shift towards higher T-numbers can be noticed as we go from July to November. This is brought out clearly by the modal curve also.

The occurrence of depressions and cyclones is maximum in October as seen in Fig. 1, with a second maximum in May, agreeing with the conventional synoptic ideas. While the frequency of the disturbances is a maximum in October, the chances of their intensification is a maximum in November (Table 2 and Fig. 3). Though there is a fairly high frequency of disturbances in the monsoon months, the maximum intensity attained by them is about T-1.5 to 2.0. There is only one case of a disturbance reaching hurricane intensity in mid-monsoon, *viz.*, T-4 in August 1974. A hurricane of post-monsoon characteristics developed in the beginning of September 1972 and hit north Andhra coast (T-6.0).

The disturbances during the period 1961-80 are classified into depressions ($T \leqslant 2.0$), cyclonic storms (T-2.5 and 3.0), severe cyclonic storms (T-3.5) and severe cyclonic storms with core of hurricane winds ($T \geqslant 4.0$) and presented in Table 4. Table 5 gives the monthwise annual frequency of depressions, cyclones and severe cyclones and hurricanes for the period 1961-80 when T-number classification was available. The figures

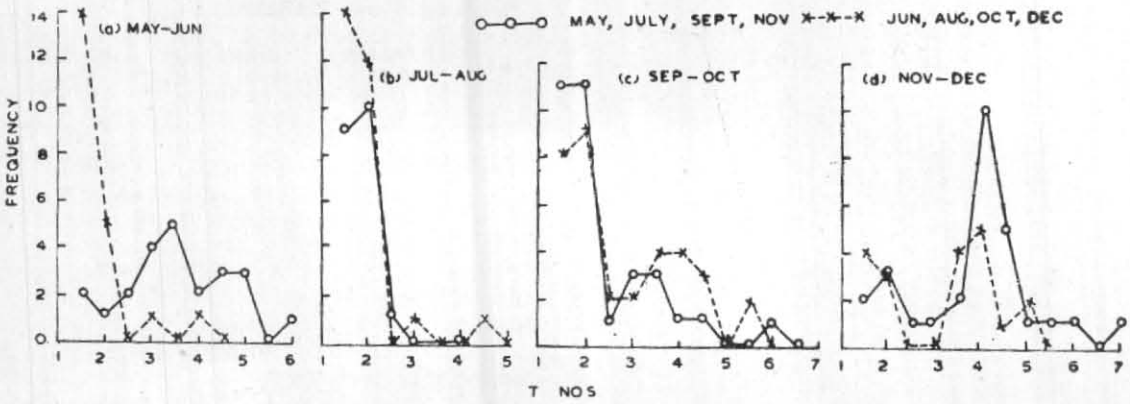

Fig. 2. Monthly frequency of T. Nos.

TABLE 2

Monthwise distribution of all disturbances (1961-80) according to T-numbers

S. No.		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Number of all disturbances (% to total annual)	2 (1)	1 (0.5)	—	1 (0.5)	23 (11)	21 (10)	20 (10)	28 (13)	32 (15)	34 (16)	30 (14)	19 (9)
2	Disturbances with T-No. 3.5 and above (severe cyclonic storms and above) (% to total in the month)	1	—	—	1	14 (61)	1 (5)	—	1 (4)	6 (19)	13 (38)	23 (77)	12 (63)
3	Disturbances with T-No. 4 and above (with hurricane core) (% to total in the month)	—	—	—	1	9 (39)	1 (5)	0	1 (4)	3 (9)	9 (26)	19 (63)	8 (42)
4	Maximum attained T-No.					6	4	2.5	4.5	6.0	5.5	7.0	5.0
5	Mean T-No.					3.3	1.3	1.4	1.7	2.1	2.8	3.5	2.2
6	Median T. No.					3.3	1.5	2.0	1.5	1.7	2.0	3.7	3.3
7	Mode T-No.					3.5	1.5	2.0	1.5	2.0	2.0	4.0	4.0
8	Standard deviation					1.5	1.0	0.8	0.8	1.2	1.2	1.6	1.8

within brackets indicate the corresponding frequencies for the rest period 1891-1960 when T-number classification was not possible due to absence of satellite pictures. The frequencies for the period 1891-1960 have been worked out with the help of the data given by Srinivasan and Ramamurty (1973).

This table shows that there is a marked increase in the annual frequency in the case of severe cyclones and hurricanes during 1961-80 compared to 1891-1960. There is also a considerable decrease in the frequency in respect of cyclones while the frequency of depressions is more or less the same. Also the total annual frequencies during the pre-satellite period and the post satellite period are more or less the same. Thus the differences in the intensity classification probably appear to be due to the better assessment of the intensities of the disturbances using satellite pictures. During the pre-satellite period, there could have been intense storms which escaped correct assessment due to absence of ships observations or other supporting evidence from the cyclone field about its intensity.

5. Conclusion

The present study reveals an increase in the average annual frequency of disturbances during the 20-year period 1961-80 compared to the 70-year period 1891-1960, which may be due to all systems having been detected with the help of satellite imagery and the maximum sustained winds of the disturbances being estimated to a high degree of accuracy.

It is also seen that the probability of a tropical disturbance developing into severe cyclone intensity is maximum in November (77%), followed by December (63%) and May (61%).

This study also shows that the probability of these storms developing further into hurricanes is very high in November (63%) followed by

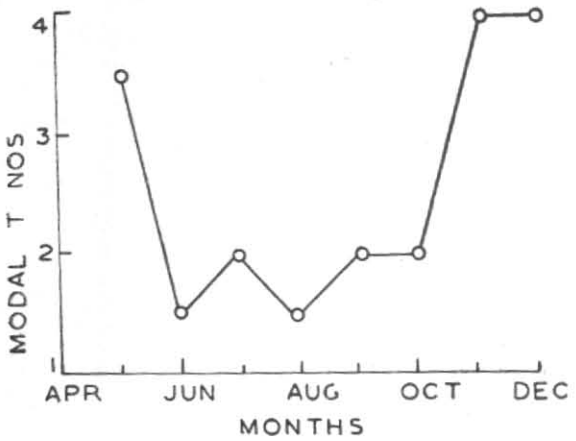

Fig. 3. Modal curve of T. Nos.

TABLE 3

Monthly frequency of cyclonic storms and depressions in the Bay of Bengal (for the 90-year period 1891-1980)

Disturbance	Frequency		
	Oct	Nov	Dec
Storms (cyclonic storms and above)	69	86	40
Depressions	71	32	23

TABLE 4

Statistics of cyclonic disturbances in the Bay of Bengal during the months of October to December for the period 1961-80

Cyclonic disturbance	Frequency		
	Oct	Nov	Dec
Depression ($T \leq 2.0$)	17	5	7
Cyclonic storm (T-2.5 & 3.0)	4	2	0
Severe cyclonic storm (T-3.5)	4	2	4
Hurricane ($T \geq 4.0$)	9	19	8

TABLE 5

Annual frequency of disturbances in the Bay of Bengal for October to December for the period 1961-1980

Disturbances	Frequency		
	Oct	Nov	Dec
Depression	0.85 (0.81)	0.25 (0.39)	0.35 (0.26)
Cyclonic storm	0.20 (0.46)	0.10 (0.47)	0.00 (0.23)
Severe cyclonic storms and hurricanes	0.65 (0.30)	1.05 (0.40)	0.60 (0.14)
Total	1.70 (1.57)	1.40 (1.26)	0.95 (0.63)

N.B. — Figures in brackets refer to the period 1891-1960

December and May with a probability of about 40%. This study will be useful to the forecaster in properly estimating the potentiality of the tropical disturbances in the various months.

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