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Intensification and landfall of tropical cyclone in Bay of Bengal, 22-25 May 1985

B. R. YADAV and G. R. GUPTA

Meteorological Office, New Delhi

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सार — इस शोधपत्र में 22–25 मई 1985 के बंगाल की खाड़ी में बने चक्रवात की प्रबलता का अनुमान लगाने के लिए, ड्वोरक द्वारा विकसित उष्णकटिबन्धीय चक्रवात विश्लेषण तकनीक का प्रयोग किया गया है, इस अध्ययन से इन्सेट-1बी उपग्रह द्वारा लिए गए वृद्धित अवरक्त (इन्हांस्ड इनफ्रारेड) चित्रों का पहली बार उपयोग किया गया। चक्रवात से प्रभावित होने वाले समुद्र तट के सम्भाव्य संकट योग्य क्षेत्र (थ्रेट जोन) का पूर्वानुमान देने वाली तकनीक भी विकसित की गई है।

ABSTRACT. The tropical cyclone analysis technique developed by Dvorak was used on an experimental basis for estimating the intensity of 22-25 May 1985 Bay of Bengal cyclone utilizing for the first time the Enhanced Infra-red (EIR) hourly pictures received from INSAT-1B. A technique to predict 'Threat Zone' for coastal areas affected by cyclones has also been developed.

1. Introduction

On 22 May in the morning, a depression formed in the east-central Bay of Bengal and adjoining Andaman Sea. It lay centred at 0830 IST about 700 km eastsoutheast of Visakhapatnam. It further intensified into a deep depression which was centred at 1430 IST about 600 km eastsoutheast of Visakhapatnam. This northwesterly movement of the system changed from NW'ly to northerly in the afternoon. The system moved in a northerly direction throughout the night of 22nd. In the morning of 23rd, it intensified into a cyclonic storm which was centred about 530 km east of Visakhapatnam or about 700 km south of Calcutta.

Fig. 1 shows the track of the storm with the details of the coastline of south Bangladesh in the inset. The locations of the centres of the cyclone were based on the estimates made out of the cloud features in the hourly satellite pictures of INSAT-1B.

The storm field was well supported by the cloudiness seen in the satellite pictures. The INSAT pictures were taken at hourly intervals for a close surveillance and watch from its deep depression stage. The system further intensified into a severe cyclonic storm on 24th morning when it was centred at 0830 IST about 350 km southsoutheast of Calcutta. During this period, the course of movement had changed from northwards to northnortheastwards. It crossed coast near Hatia Island in Bangladesh in the early morning of 25 May 1985. This change in the movement of storm and the type of cloud configuration associated with the system as seen in the enhanced IR cloud imagery of INSAT-1B pictures indicated its further march towards the coast of Bangladesh.

According to the press reports, the devastating cyclone and the high (4-5 metres) tidal waves lashed the coastal belt of Chittagong, Barisal and Noakhali and washed away several off-shore islands in the Bay of Bengal leaving a trail of death toll of 25,000 and over 40,000 people missing.

An attempt has been made in this paper to analyse and discuss the intensity T-number and the movement of this tropical cyclone.

2. Tracking and intensity analysis

For intensity analysis, full use was made of Dvorak (1975), Dvorak and Wright (1977) technique which is basically a set of rules which classifies tropical cyclones based on the degree to which certain measurable cloud features, collectively are realised. The capability of the geostationary satellite INSAT-1B to provide frequent images made cyclone classification feasible at an hourly interval. Since such shorter time periods were used for analysing enhanced IR pictures (Fig. 2) care was taken to be guided strongly by the 6, 12 or 24 hours earlier images. In case of this tropical cyclone the standard procedures of analysis given by Dvorak *et al.* were used to arrive at the estimates of T-numbers given in Table 1.

Similarly as per the laid down procedures of the technique, the pattern T-number and final T-number were estimated from the above data T-numbers.

The scientific methods for measuring the intensities from satellite pictures were used with enhanced IR imagery (Dvorak & Wright 1982). The EIR data lead to simple measurements instead of the more difficult unenhanced pictures. We first recognise the different

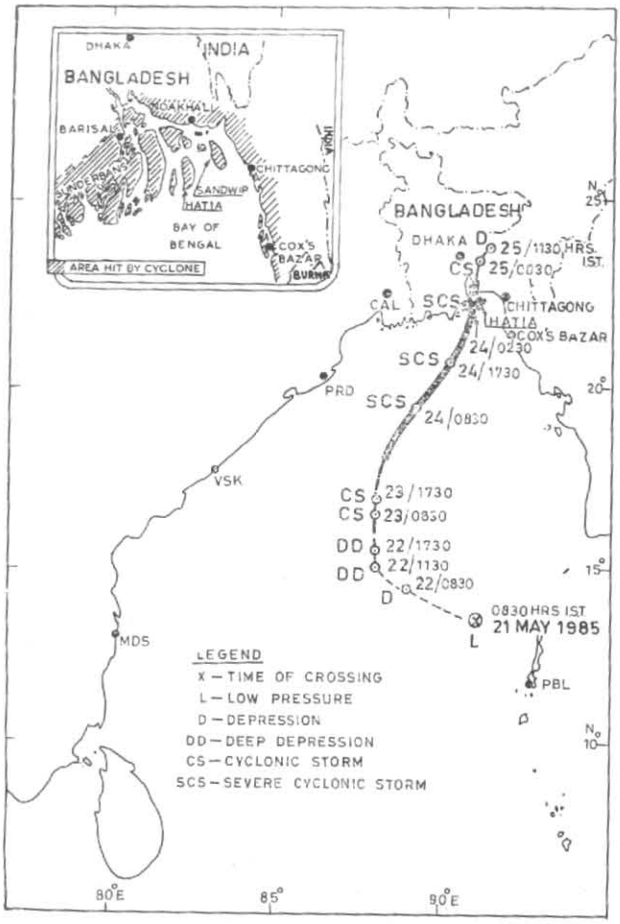


Fig. 1. Track of the cyclone, 22-25 May 1985

TABLE 1

Intensity and the movement of the cyclone

Date (May 1985)	Time (IST)	Intensity T-No.	Classification	Centre based on satellite picture	Dir. of movement	Av. speed (kmph)
22	0900	1.5	Dep.	14.8°N, 88.6°E (Approx.)	NW	22
22	1130	2.0	Deep Dep.	15.0°N, 88.0°E (Approx.)	N	17
23	0830	2.5	Cyclonic storm	16.5°N, 88.0°E	N	6
23	1730	3.0	Do.	16.7°N, 88.0°E	NNE	20
23	2330	3.0	Do.	17.0°N, 88.3°E	NE	18
24	0830	3.5	Severe cyclonic storm	19.5°N, 89.4°E	NE	22
24	1730	3.5	Do.	20.8°N, 90.2°E	NNE	24
25	0130	4.0	Do.	22.0°N, 90.7°E	N	40
25	0230	4.0	Do.	22.4°N, 90.8°E		

levels of enhancement corresponding to different temperature intervals. The black band around the centre represents the coldest range of the temperature. The warmest temperature is recorded in the gray shades. The temperature range of the band surrounding the centre can be used as the measurement of the intensity.

A 10° logarithm spiral overlay was fitted to the curvature of the cold band by first drawing a line along the "curved band axis" and then fitting the spiral curve to the line drawn. The comma axis is defined as the axis of the cloudest overcast gray shade (most dense clouds) within the cloud band. The intensity values that relate to the curved band length are the same as given in Dvorak's analysis diagram. By fitting the spiral and measuring the spiral arc length of dense (dark gray) band that followed the spiral curve, the estimates were made of T-numbers.

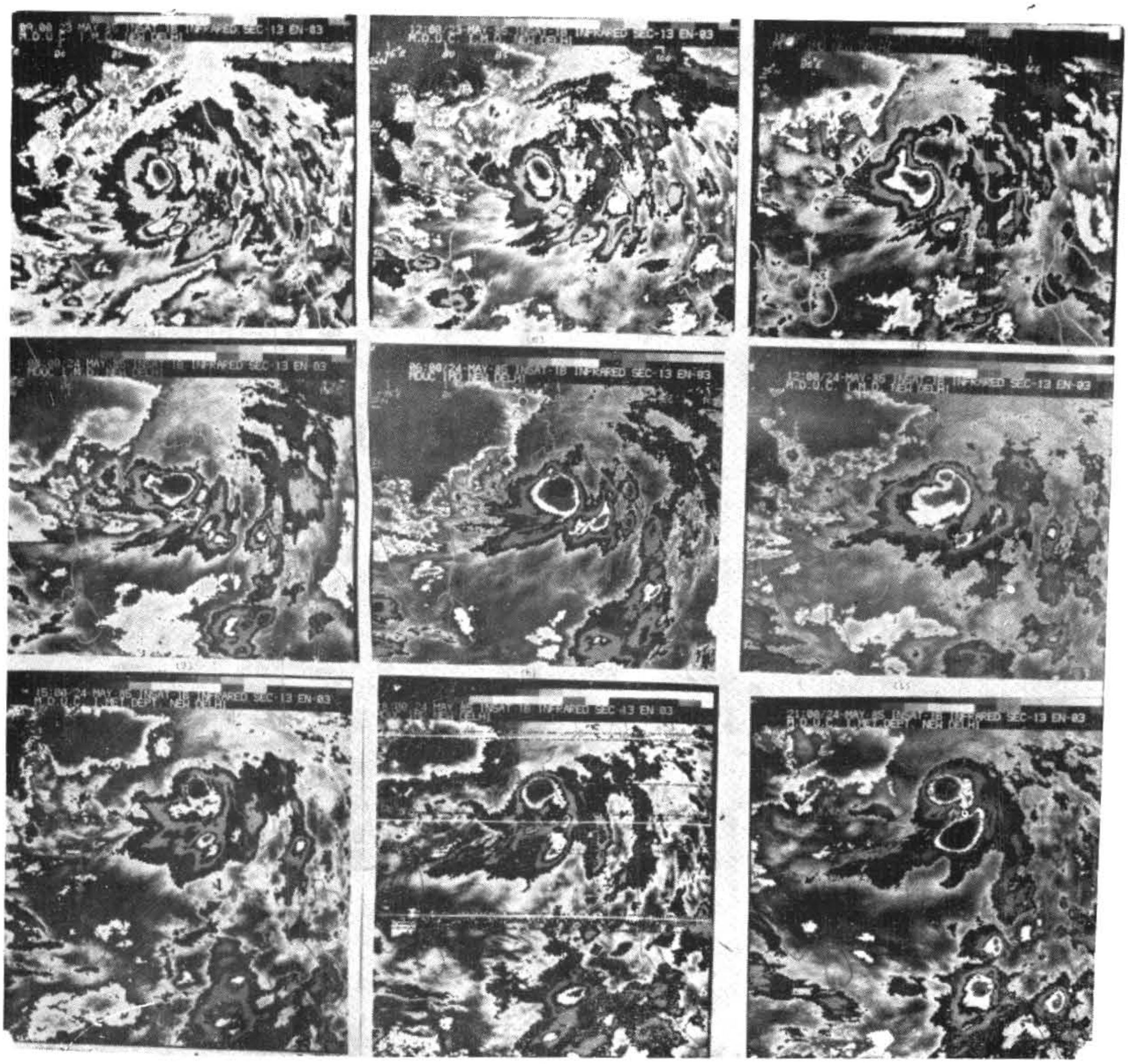
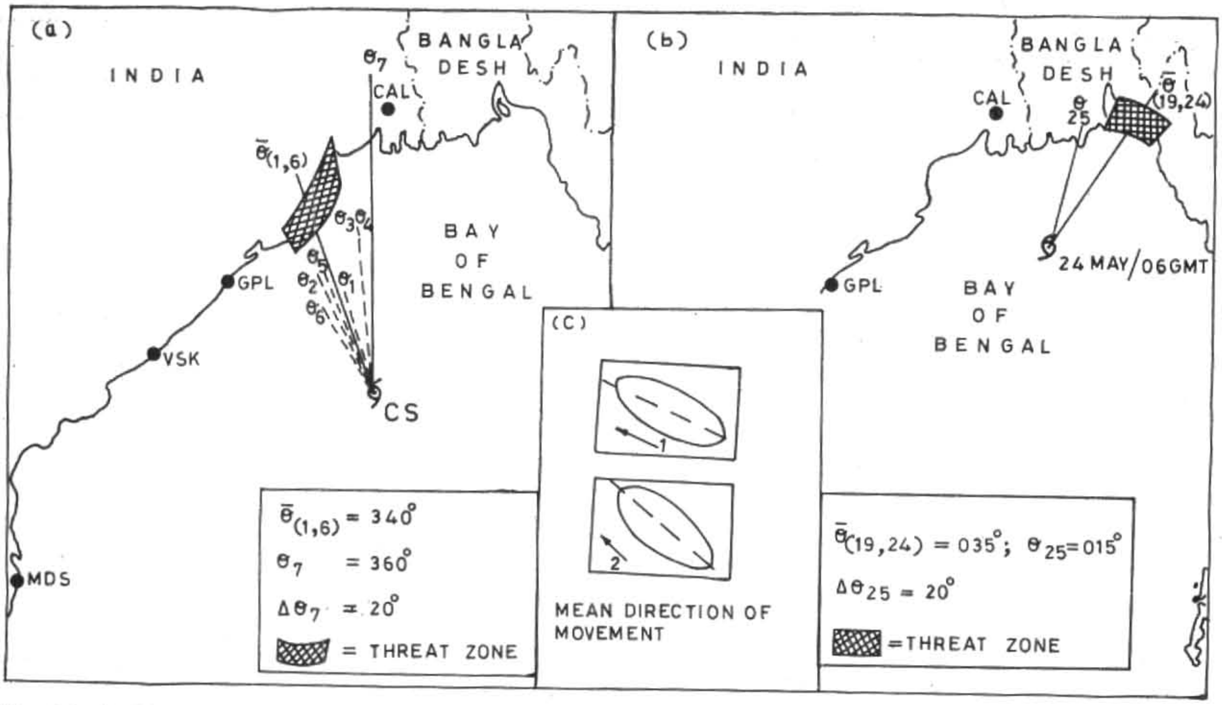


Fig. 2. A sequence of EIR pictures of 23 May (for 09, 12 and 18 GMT) and 24 May (for 00, 06, 12, 15, 18 and 21 GMT)



Figs. 3 (a-c). Threat zones (a) & (b) estimates, and (c) Mean direction of movement based on the rotation of elliptical shapes

The patterns of the shape and size were interesting features of bands in the EIR pictures near and around the centre of the cyclone. The changes in the direction of movement of the tropical cyclone during the subsequent intervals of time were highly correlated with rotational changes in their gross cloud features in the previous intervals of time. A schematic example can be illustrated in Fig. 3(c) of the rotation of elliptical shape.

Here the arrow labelled 1 gives the mean direction in 6-hour between two pictures while the arrow labelled 2 gives the mean direction over the next 6 hours. The time interval could be changed, as required, to 3 hours, 12 hours and 24 hours. However, every hour the characteristic changes in the rotation of elliptic shapes associated with track changes of this cyclone were examined.

3. Threat zone

In day to day cyclone warning work, the forecaster needs to know precisely the area of the coastline to be likely under the cyclone threat at least 48 hours before the strike. In other words, it is important to determine where and when a cyclone will make landfall and which region will have the disastrous weather under its threat. A hypothesis may be constructed as given below based on the EIR satellite data :

Let θ be defined as the approach direction in degrees (clockwise from north) from which the cyclone is moving towards the impact point. This direction is inferred every hour from the hourly EIR pictures as revealed by the rotational axis of the elliptic shapes as discussed earlier. If θ_1, θ_2, θ_3, θ_4, θ_5 and θ_6 are the values for the first, 2nd, 3rd, 4th, 5th and 6th hour pictures respectively, let $\bar{\theta}_{1,6}$ be the mean direction for this set of six values,

$$\bar{\theta}_{1,6} = (\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6)/6$$

Next, when we get the 7th hour picture, we make a set of six values by omitting the 1st and including the 7th value, *i.e.*,

$$\bar{\theta}_{2,7} = (\theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7)/6$$

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and so on.

Let $\triangle\theta_7 = \bar{\theta}_{1,6} \sim \theta_7$

and $\triangle\theta_8 = \bar{\theta}_{2,7} \sim \theta_8$ and so on.

Here we call $\triangle\theta_7$ as the change in direction of approach of the storm towards the coast at the 7th hour from the average of previous 6 values upto θ_6. This would make a change in the coastal area falling within the directions $\triangle\bar{\theta}_7/2$ on either side of $\bar{\theta}_{(1,6)}$. This has been illustrated in Fig. 3(a) as an hypothetical case to calculate threat zone. The process of calculation of such values continues with the addition of a new value of every hour and the threat zone of the coast could be chalked out accordingly.

Let us generalize these values of θ

$$\bar{\theta}_{i,\,(i+n-1)} = \frac{1}{n} \sum_{i}^{i+n-1} \theta_i$$

$$\triangle\theta_{i+n} = \bar{\theta}_{i,\,(i+n-1)} \sim \theta_{i+n}$$

where, $i = 1, 2, 3, 4, 5, \ldots\ldots\ldots$

n = the total values in a set (for example, here the set value was 6).

TABLE 2

Comparative statistics of the cyclone movement by the conventional and threat zone techniques

Date (May 1985)	Time (IST)	Storm T-No.	Direction of movement technique	
			Present	Conventional
23	1730	3.0	355°	N
23	2030	3.0	345°	N
23	2330	3.0	350°	N
24	0230	3.0	355°	N
24	0530	3.0	030°	NE
24	0830	3.5	050°	NE
24	1130	3.5	035°	NE
24	1430	3.5	020°	NE
24	1730	3.5	010°	NNE
24	2030	3.5	015°	NNE

In order to make it realistic from the operational forecasting point of view, the following conditions may be imposed on the use of this technique :

(1) The value of $\frac{1}{2}\triangle\theta_{i+n}$ should not be taken more than 20 degrees.

(2) The storm centre should not be more than 500 km away and not less than 100 km from the coastline likely to be under its impact.

(3) The limits of $\frac{1}{2}\triangle\theta_{i+n}$ are : $5 \geqslant \frac{1}{2}\triangle\theta_{i+n} \leqslant 20$

The above hypothesis for estimating the "Threat zone" of coastline was studied in the present storm and was found to be useful for operational forecasting.

It may be seen that the threat zone as shown in Fig. 3(b) based on the values of $\triangle\theta_{i+n}$ covered very well the actual landfall point located at Hatia, an island of Bangladesh on 24 May 1985.

4. Comparison of forecast movement

A comparison was also made of the forecast movements of the cyclone based on the present technique with the conventional techniques used by the various forecasting offices in India. The new technique gives both the direction of movement and the threat-zone for the likely landfall on the coast line when the storm is 500 km to 100 km away from the coast. The Table 2 shows the comparative statement of such track locations for every three hourly estimates by the conventional and the present techniques. These values of the forecast movements although specific to scan out the coast-line for the probable area of the landfall but agree well with the conventional ones derived at the forecasting offices.

5. Upper level steeering

When a well defined cyclonic circulation exists upto 400 mb/300 mb, the steering flow winds are considered at 300 mb/ 250 mb level. This is particularly so when a greater meridional (northerly) component in movement (or even recurvature) is being considered, and usually when a trough exists on the poleward side of the cyclone. The cyclone centre was on the western side of the upper anticyclone, with southwestern stream a few degrees to the poleward side of the cyclone as shown in Fig. 4. But forecast of a change in movement using this "upper level steering" flow is good on a time scale of 24 hours.

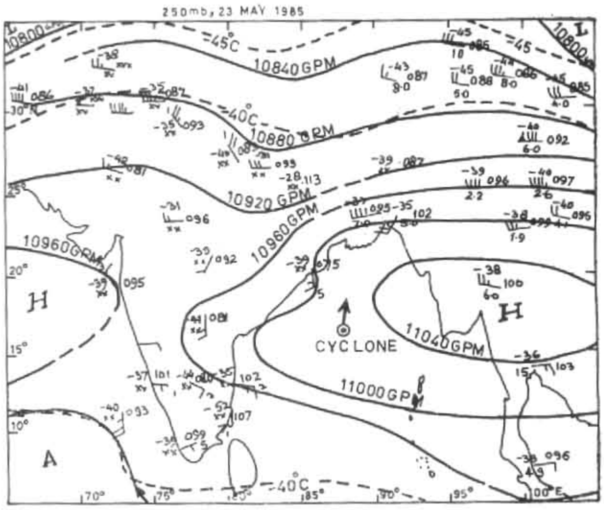

Fig. 4. Upper level steering flow at 250 mb on 23 May 1985

The open cellular cloud field associated with the trough in westerlies was within 20° latitude of the southerly to westsouthwesterly wind field. The interaction between these was, perhaps, responsible for accelerating the poleward movement. Such cases lead to minimal warning time.

Acknowledgements

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