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A study of the Bangladesh cyclone of May 1985 as seen from INSAT satellite imagery

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सार — 25 मई 1985 की सुबह को प्रभंजनन तीव्रता के साथ एक प्रचंड चक्रवाती तूफान ने बंगलादेश के तट को पार किया। प्रेस विज्ञप्तियों के अनुसार इसके कारण दक्षिण बंगलादेश तट के निकट स्थित द्वीपों पर बहुत अधिक विनाश हुआ। इस अध्ययन में, इस तूफान के विकास की विभिन्न अवस्थाओं के दौरान 25 मई 1985 के बंगलादेश चक्रवात की सघनता का विवेचानत्मक परीक्षण करने का प्रयास किया गया है। बृहद अवरक्त चित्रों और मेघ-शीर्ष तापमान रूपरेखाओं की सहायता से डर्वोक के मान में टी 4.5 पर चरम तीव्रता को बैठाना संभव हो सका। उपग्रह चित्रों की सहायता से व्युत्पन्न तीव्रता चक्रवात के दौरान प्राप्त हुए चरम पवन वेग और ज्वारीय तरंग के साथ यथोचित रूप से मेल खाती है।

ABSTRACT. In this study an attempt has been made to critically examine the intensity of the 25 May 1985 Bangladesh cyclone during the various stages of its development and relate it to the damages caused by it. With the help of enhanced infrared pictures and cloud top temperature contours, it was possible to fix the peak intensity at T 4.5 in Dvorak's scale. The peak wind velocity and the tidal wave reported to have been reached during the cyclone agree reasonably well with the intensity derived with the help of satellite pictures.

1. Introduction

During pre-monsoon months, March to May, especially in the later half, cyclones develop in the Bay of Bengal region. Some of them intensify into severe cyclones and cross Bangladesh and Arakan coasts causing extensive damage to life and property. These cyclonic disturbances develop in the central Bay of Bengal and travel northwest initially and then recurve northeastwards affecting either the east coast of India or Bangladesh. One such cyclone formed over the Bay of Bengal near 15.0° N, 88.0° E on 22 May 1985. The track of the cyclone is given in Fig. 1. According to reports, this cyclone caused severe damage to the offshore islands near Bangladesh coast.

Details of destruction caused by the cyclone are given in Sec. 2. In this paper, a detailed study of this cyclone has been made from the satellite data. Attempt has also been made to study the intensity of the cyclone as revealed by the satellite picture *vis-a-vis* the damage reported in the press.

2. Destruction during Bangladesh cyclone

As reported in the *Indian Express* of 27 May 1985 the cyclone hit Bangladesh coast on the night of 24-25 May at about 0330 IST and caused great destruction on the off-shore islands, especially Sandwip and Sonadia and coastal areas of Noakhali, Cox's Bazar, Chittagong, Patuakhali and Bhola. The wind velocity, as reported, reached 150 km per hour and tidal waves reached four to five metres high.

About 75 per cent of homes were destroyed in the districts of Noakhali, Chittagong, Cox's Bazar and Bhola, and damage to crops was extensive. At least 400 fishermen were drowned or missing near island Kutubalra and 25 fishing boats capsized. About three ocean going vessels including the Singapore flag carrier MV *Reunion* broke their anchors and went around near the southeastern port city of Chittagong.

The entire population of Sandwip island, estimated to be 10,000, was swept away. Nearly 11,000 people were injured. A Bangladesh daily '*Ittefaq*' reported about 4000 people were missing from the fishing island of Sonadia which was submerged by the surging waters of sea waves.

3. Data

This cyclone could not be seen by the cyclone detection radars located at Paradip and Calcutta. Radiosonde data of Indian stations located near the storm track did not show, any marked change in wind velocity. Thus, the study is mainly based on INSAT-1B cloud imagery.

In this study the intensity of the tropical storm is estimated with the help of INSAT-1B visible and infrared pictures using Dvorak's technique (1975). INSAT-1B (geostationary satellite) normally provides three hourly cloud pictures but in severe weather situations hourly data of cloud cover of Arabian Sea, Bay of Bengal and Indian Ocean are taken. Visible and infrared imagery are available during day time and

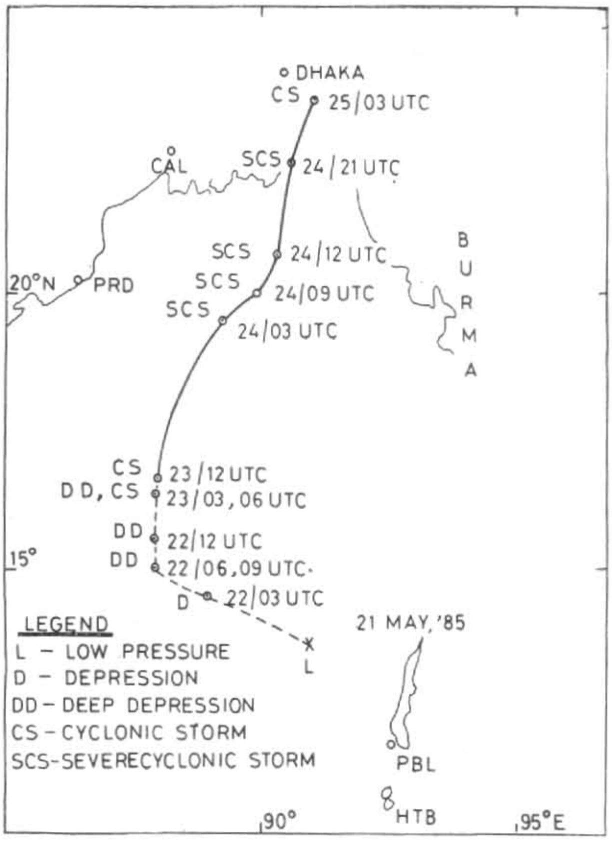


Fig. 1. Storm track of 22-25 May 1985 Bangla cyclone

during night infrared imagery is available. The Cloud Top Temperature (CTT) contours of the cyclonic storm were specially taken for the hours 06, 18, 19, 21 and 23 GMT of 24 May and used in the study. In the absence of ships' observations in the storm field, satellite imagery provided sufficient characteristics to enable us to estimate the intensity of the storm with reasonable accuracy.

4. Intensity estimates of the tropical storm as seen from satellite imagery

This disturbance was first seen as a vortex of intensity T1.5 on Dvorak's scale in the 2100 GMT infrared imagery of 21 May 1985. By 0330 GMT of 22 May, it intensified to T2.0 and by 0600 GMT, it became a marginal cyclone (Fig. 2a) of intensity T2.5 with centre near 15.5°N, 88.0°E. On 23 May a banding feature had become prominent as revealed by a thick convective band (Fig. 2b).

The intensity of the system remained at T3.0 till 1700 GMT of 24 May when the centre of the storm was located at 21.0° N, 90.5° E. At 2100 GMT, the cyclone further intensified to T4.0, corresponding to minimal hurricane intensity. The IR picture taken at the time corroborates to this intensification (Fig. 2c). The cloud organisation has taken a typical 'comma' shape, characteristic of minimal hurricane intensity. In order to understand this intensification which has taken place during the night of 24-25 May, enhanced IR pictures, using the cyclone enhancement curve (Fig. 3d), have been prepared. The enhanced IR pictures (EIR) corresponding to 0600, 2100 and 2300 GMT of 24 May can be seen at Figs. 3 (a-c). The intensification of the system from 0600 GMT to 2300 GMT is clearly brought out in the EIR pictures.

5. Cloud top temperature (CTT) contours of the cyclone field

Veeraraghavan (1986) demonstrated the use of Cloud Top Temperature (CTT) fields of the the tops of cumulonimbus cloud clusters to have a knowledge of their severe weather potential. In the same paper, he has also used the CTT contours to study the wall cloud region of two cyclones of 1984, one of which reached an intensity of T6.0. He has brought out the importance of the steep increase in the temperature gradient by the packing of isotherms in understanding the increase in intensity of the cyclone.

Veeraraghavan and Kalsi (1986) have also used cloud top temperature field in respect of monsoon clouds to understand their rainfall potential.

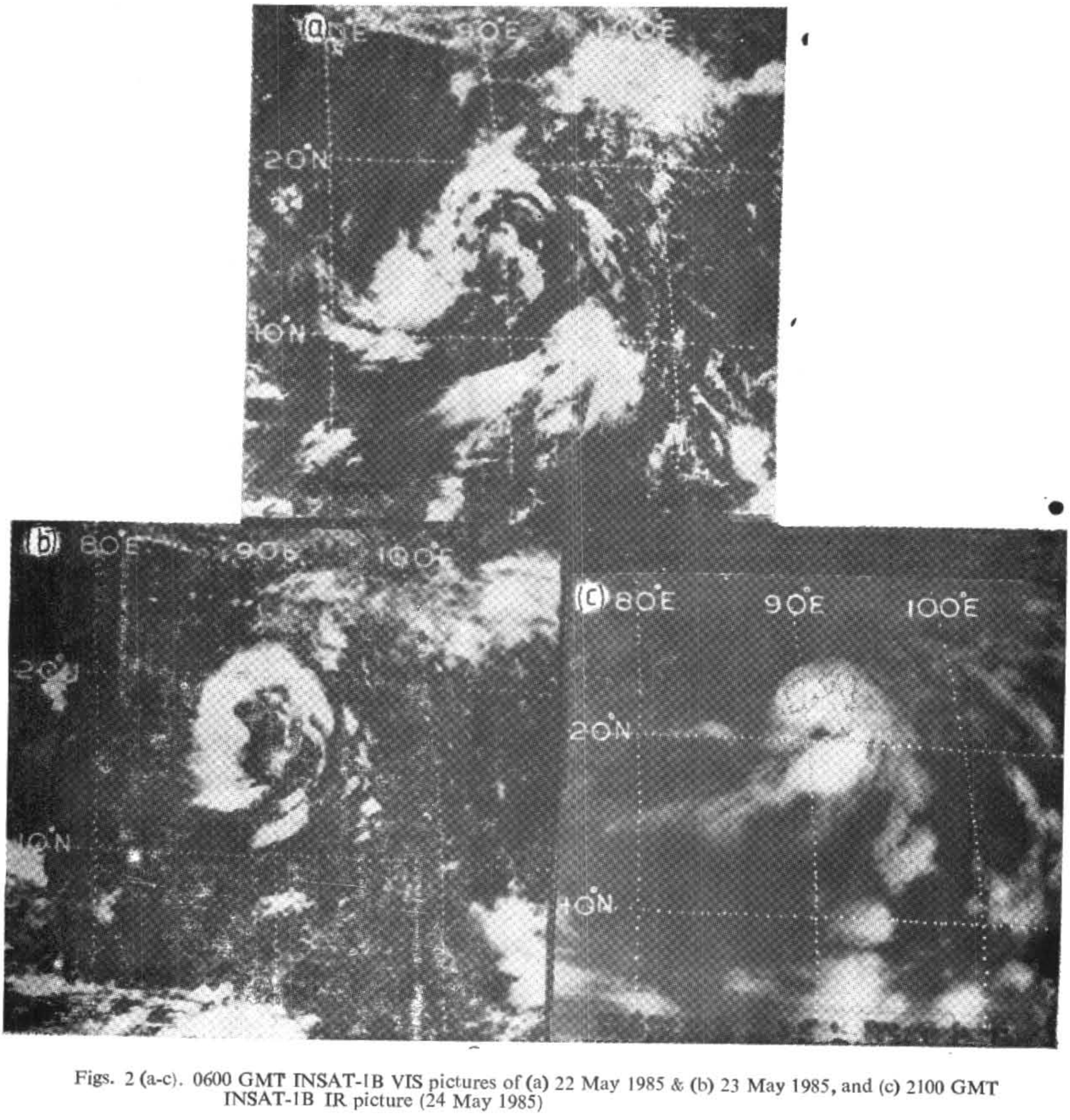
Thus, in addition to the enhanced infrared picture taken of this cyclone using cyclone enhancement curve depicted in Fig. 3 (d), we have also taken CTT contours corresponding to 273, 243, 233, 223, 213, 203, 193 and 188°K using the DAID (Data Analysis and Interactive Display) facility of INSAT computer at Meteorological Data Utilisation Centre (MDUC), New Delhi. While taking the output temperature field of the top of the cyclone, it is possible to note the coldest temperature to which the tops have reached in the storm fields.

The EIR pictures gave the grey shade representation in certain temperature intervals. But the cloud top temperature contour maps have the advantage of giving us the areas where the temperature gradient is strong and where it is weak. In addition, the warm temperature contours, especially in the 'eye' region of a hurricane, are brought out more strikingly in this representation than in the EIR pictures.

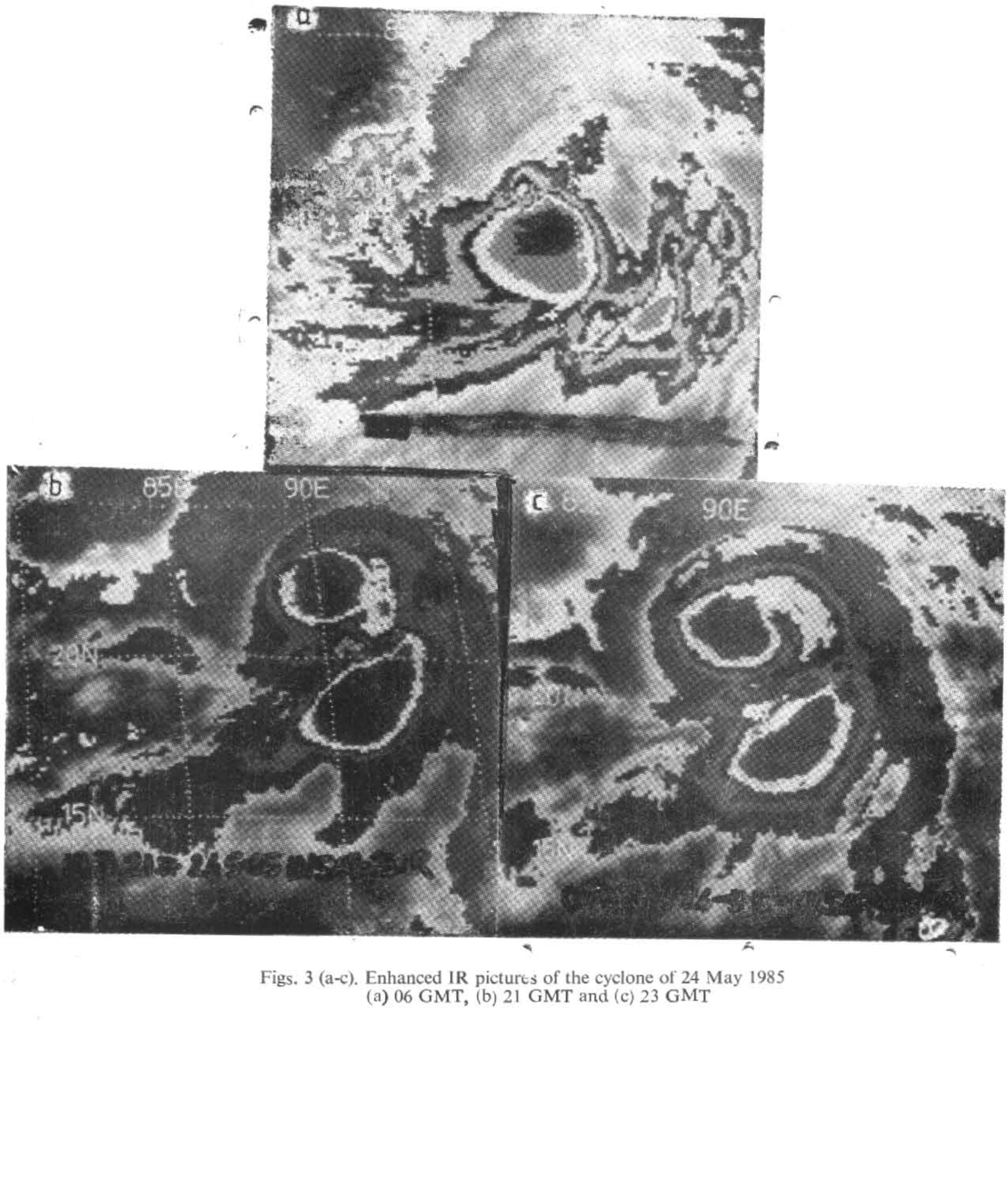
The CTT contours of the tops of the cyclone corresponding to 06, 18, 19, 21 and 23 GMT of 24 May 1985 taken with the help of the DAID facility mentioned earlier are given in Figs. 4 (a-e) .While the CTT contour analysis was done in respect of every IR picture of this cyclone from the intensity of T2.5 corresponding to minimal cyclone, we have taken the output and shown the CTT contours of 24 May 1985 to bring out the growth in intensity of the cyclone. The combined study of EIR pictures and CTT contours taken at these hours makes us assign an intensity of T4.5 to the cyclone at 2200 GMT, the time landfall of the system.

6. Observed destruction *vis-a-vis* intensity

The satellite analysis of this cyclone as seen from VIS, IR and enhanced IR pictures and CTT contour patterns has enabled us to fix the intensity of this cyclone at T4.5 on the Dvorak's scale. From the empirical relationship between the T numbers and maximum mean wind speed (MWS) given by Dvorak, we can take 84 kt (148 kmph) as corresponding to T4.5, the intensity at the time of landfall. This wind speed agrees well with the estimate of 150 kmph reported in the press. The centre of the cyclone was located in north Bay of Bengal very near to the Ganga-Meghna



Figs. 2 (a-c). 0600 GMT INSAT-1B VIS pictures of (a) 22 May 1985 & (b) 23 May 1985, and (c) 2100 GMT INSAT-1B IR picture (24 May 1985)



Figs. 3 (a-c). Enhanced IR pictures of the cyclone of 24 May 1985
(a) 06 GMT, (b) 21 GMT and (c) 23 GMT

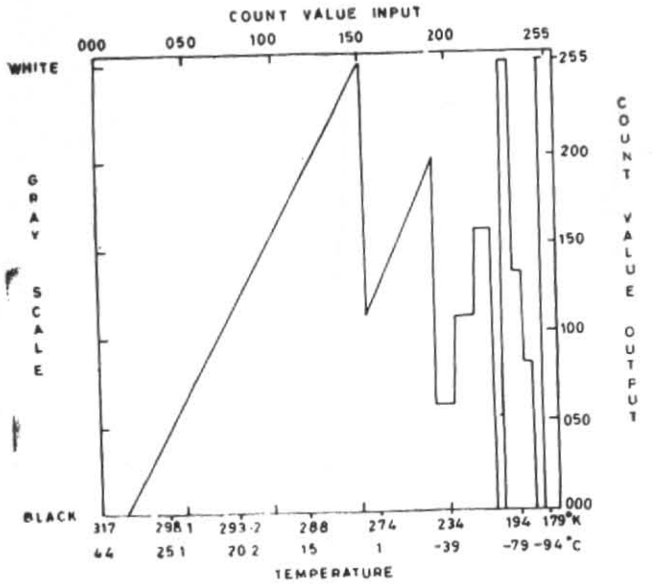


Fig. 3 (d). Cyclone enhancement curve

Fig. 4(a). CTT contours of the cyclone of 24 May 1985

estuary where the sea is very shallow. This gives rise to a higher storm surge. Further this part of the coast has a high range of astronomical tide (*Tide Table* 1985). Though the tide figures were not available for Bangladesh ports in the tide table available with India Met. Dept. for the year 1985, a fairly good approximation could be had from the figures for Sagar Island (West Bengal) which is the nearest Indian port for which tide information was available. The storm crossed the coast near about 2200 GMT on 24 May (Nootan Das *et al.* 1987), near Hatia. The tide figures for Sagar Island near to the crossing time were as follows :

25 May	*Time (IST)*	*Tide (m)*
High water	0022	4.31
Low water	0640	1.55

This will mean that the time of crossing was almost midway between the high and the low tide times and the sea level rise due to the astronomical tide will be about 2.9 m above datum point. This datum point is 3.0 m below mean sea level as seen from the *Tide Tables*, 1985.

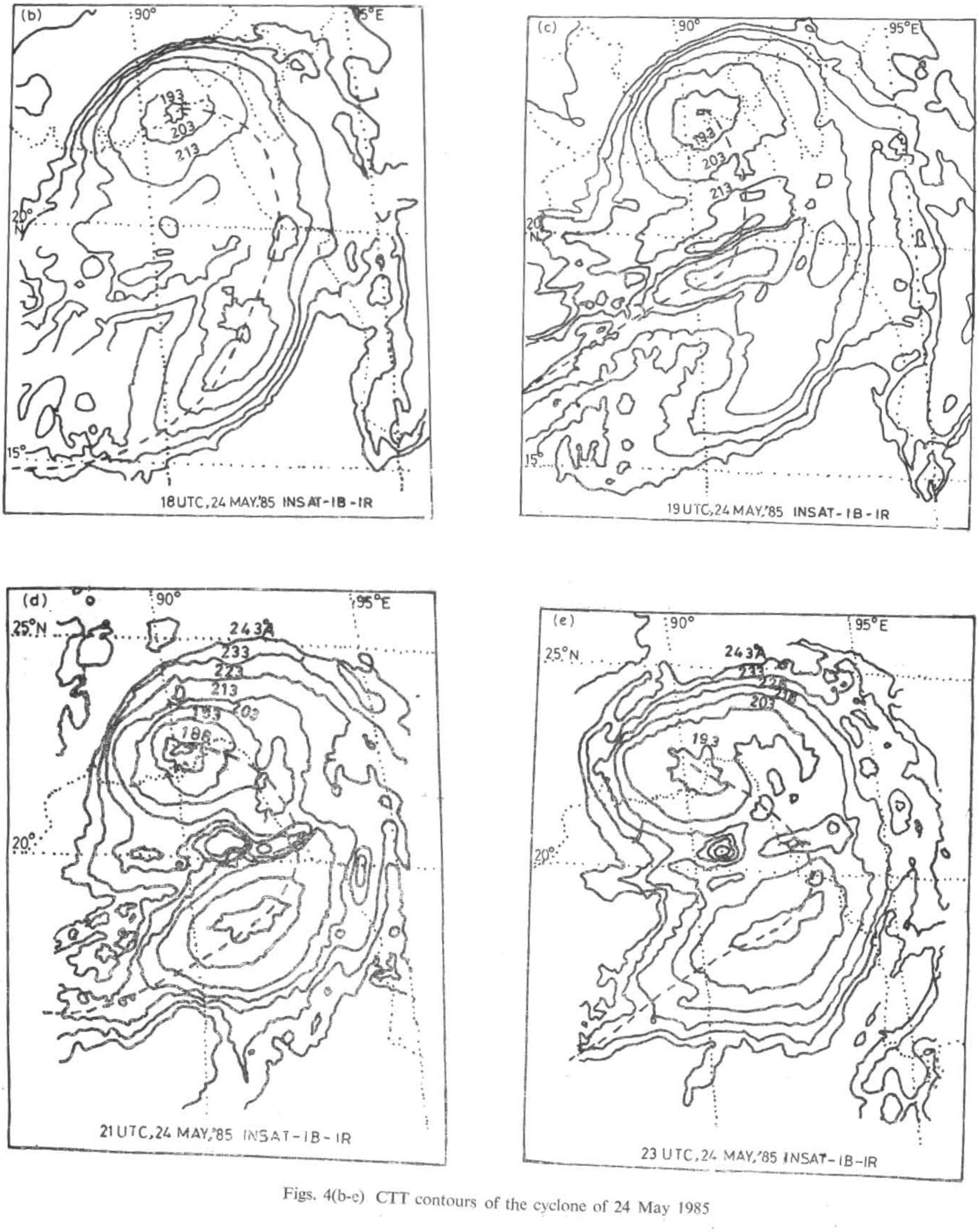
The estimated intensity of T4.5 corresponding to a maximum mean wind speed of 84 kt is equivalent to a pressure drop of nearly 35 mb as obtained from the relationship :

$$V_{max} = 14.2 \sqrt{\triangle p} \quad (1)$$

proposed by Mishra and Gupta (1976) where V_{max} stands for maximum mean wind speed in kt and $\triangle p$, the pressure drop at the centre of the cyclone. It is important to state that while several formulae are available relating V_{max} with the pressure drop from different studies, we have chosen to use the one proposed by Mishra and Gupta as it is based on the analysis of the wind data available from several cyclones in the the Indian seas.

Ghosh (1983) has developed a system of objective prediction of storm surges on the coasts of India and Bangladesh. This is based on the meteorological parameters of the cyclone, namely, the pressure drop of the cyclone, $\triangle p$, the radius of maximum winds, the speed of the cyclone and the direction of motion of the cyclone relative to the coast just before landfall.

In this case $\triangle p$=35 mb and the radius of maximum winds is estimated to be 50 km. This assumption is valid as most of the past studies have come to the conclusion that the radius of maximum winds is of the order of 40-50 km. The speed of propagation of the cyclone just before landfall was about 25 kmph and the direction of motion of the cyclone relative to the Bangladesh coast was nearly 100°. By using the nomograms given by Ghosh (1983), we get a peak surge of 4.2 m. The astronomical tide at the time of landfall was 2.9 m above datum point or 2.9—3.0 m =—0.1 m below mean sea level. Thus, the total elevation due to storm surge and astronomical tide is of the order of 4.2 m—0.1 m = 4.1 m above mean sea level. The correction to be applied due to tide-surge interaction being negligible, the total sea level elevation works out to be about 4.1 m. This agrees well with the press reports. A 4-5 m surge above the mean sea level in this part of the subcontinent is bound to cause the magnitude of destruction which occurred during this cyclone.



Figs. 4(b-e). CTT contours of the cyclone of 24 May 1985

7. Radius of maximum wind

In the above storm surge calculation we have taken the radius of maximum wind as 50 km. We have examined whether it is possible to find a relationship between the radius of maximum wind and CTT contours of the cloud fields of the cyclones. For this purpose CTT contours were taken at 06, 18, 19, 21 and 23 GMT.

The broken curved lines drawn on the CTT contours represent the axis of the tallest clouds of the cyclone at different synoptic hours. It is reasonable to expect that this line is related to the axis of maximum convergence in the very low levels as defined by the eyewall. As the near circular zone of maximum winds at the surface coincides with the eyewall, we feel that the axis of the tallest cloudiness as revealed by the CTT contours should be related with this circular zone of maximum winds at the surface. From a knowledge of the centre of the cyclone as determined hourly by satellite analysis, we calculated the radius at five different times by taking four points on each of the axis. The mean radius, thus obtained, was nearly 2.3° at the top of the cyclone which, more or less, represented the tropopause level. Analysis of multiple aircraft data obtained from radial penetrations of the eyewall at multiple levels in the region of hurricane *Allen* showed that the radius of maximum wind at about 5.5 km is nearly 1.5 times larger than that at 1 km. This finding of Jorgenson (1984) makes us believe that the radius of 2.3° obtained at the top of the Bangladesh cyclone of 1985 appears to be logical.

Measurements of the diameter of the wall-cloud of Andhra cyclone of November 1977 taken with the help of cyclone detection radar located at Madras is in several directions have enabled Ghosh (1983) to conclude that the radius of maximum of winds of the cyclone was of the order of 45 km. Gupta *et al.* (1977) have made measurements of the diameter of the wall-cloud of Porbandar cyclone of November 1975 from the satellite cloud pictures and found that the mean radius of maximum winds works out to be 40 km.

These two measurements of the radius of the maximum wind taken for two cyclonic storms which reached hurricane intensity in the Indian seas agree very well with observations of Gray (1981) and Jorgenson (1984) who have found on the basis of research aircraft flights through the eye of the hurricane that the radius of maximum wind at the lowest level is of the order of 15 to 50 km. While this works out to be about half a degree at the maximum, we were consistently getting a radius of 2.3 degrees at the top of cloud level where the temperature is of the order of 190° K (—83° C). This suggests that a relationship may exist between the RRMW and the radius at the tropopause level as observed from the satellite data analysis.

It is important to understand that while it is possible to calculate the radius of maximum wind from satellite imageries of cyclonic storms showing an eye and the wall-clouds, in weak storms like the present one, where eye was not seen, it is difficult to measure the radius of maximum wind as the wall-clouds are not well formed or clearly discernible. The only measurement that is possible with the help of satellite pictures is to get the radius of the tallest clouds around the centre at about tropopause level from the CTT field.

A detailed study of the CTT contour pattern and the RMW has to be done for a number of cyclones before we could understand the relationship between the two. This itself will be an independent investigation problem.

8. Conclusions

This study brings out the great utility of enhanced infrared imageries taken with the cyclone enhancement curve and the cloud top temperature contour patterns taken with the help of DAID facility of INSAT in estimating intensity of the tropical cyclone in a fairly accurate manner.

The intensity, thus derived, agrees fairly well with the wind velocity and tidal wave height reported in the newspaper. The tidal wave calculation was done using Ghosh's nomograms for prediction of storm surges on the coasts of India and Bangladesh.

Even though we have assumed 50 km as the radius of max. wind in storm surge calculations based on the data available for two cyclones in the Indian seas, we have explored the possibility of obtaining the same through the CTT pattern of the top of the cyclone. The idea for such an approach is derived from Jorgenson's classical study of the inner core structure of hurricane *Allen* where it was observed that RMW about 5.5 km a.m.s.l. is nearly 1.5 times larger than that near to the sea level. However, this aspect of estimating RMW satellite picture needs further study of a large number of tropical cyclones. The present one is only a beginning giving an insight into the problem.

The destruction in the cyclone was more extensive in off-shore islands of Bangladesh as they are formed of sand and silt brought by *Ganga* and *Meghna* rivers and deposited in the head Bay of Bengal. Thus, the destruction is not truly representative of the cyclone intensity. This has been demostrated by Veeraraghavan & Manikiam (1983) by applying Saffir-Simpson scale to Indian cyclones.

References

Dvorak, V.F., 1975, 'Tropical cyclone intensity analysis and forecasting from satellite imagery', *Mon. Weath. Rev.*, **103**, 5, 420-430.

Ghosh, S.K. 1983, 'Objective prediction of storm surges on the coast of India and Bangladesh', Ph. D. Thesis, Jadavpur Univ., Calcutta.

Gray, W.M., 1981, 'Recent Advances in Trop. Cyclone Research from Rawinsonde Composite Analysis', WMO Publ.

Gupta, G.R., Yadav, B.R. and Mishra, D.K., 1977, 'Porbandar cyclone of October 1975', *Indian J. Met. Hydrol. Geophys.*, **28**, 2, pp. 177-188.

Jorgenson, D.O., 1984, 'Mesoscale, and convectional scale characteristics of mature hurricane, Part II : Inner core structure of Hurricane Allen (1970)', *J. atmos. Sci.*, **41**, 8, pp. 1287-1311.

Mishra, D.K. and Gupta, G.R., 1976, 'Estimation of max. wind speeds in tropical cyclones occurring in Indian seas', *Indian J. Met. Hydrol. Geophys.*, **27**, 3, pp. 285-290.

Nootan Das, Rao, M.R.M. and Biswas, N.C., 1987, 'Cyclones and depressions over the Indian seas and the Indian sub-continent in 1985', *Mausam*, **38**, 1, pp. 1-14.

Veeraraghavan, K., 1986, 'Temperature distribution of the top of *cb* clouds associated with tropical cyclone', Proc. of the Seminar on local severe storms Bangladesh Met. Report, pp. 84-94.

Veeraraghavan, K. and Kalsi, S.R., 1986, 'Use of satellite data in real time hydrological forecasting', *Vayu Mandal,* **16,** 1 & 2, pp. 31-35.

Veeraraghavan, K. and Manikiam, B., 1983, "Applicability of Saffir-Simpson scale to Indian cyclones', *Vayu Mandal,* **13**, 3 & 4, pp. 55-58.