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Satellite study of a Bay Cyclone

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(*Received 3 August 1966*)

ABSTRACT. A severe tropical storm hit the East Pakistan-West Bengal coast near Long. 90°E on the night of 11-12 May 1965. Sun-synchronous weather satellite TIROS-9 used to photograph the Bay of Bengal area every day at about 0600 GMT. The first indication of formation of tropical depression was obtained on 7 May and on 12 May it was seen breaking up. TIROS photographs for these days along with the synoptic situation have been examined in the present paper in order to have a clear idea about the development, intensity, extension and movement of the storm. The storm could be followed fairly systematically during the course of its life cycle. The results of this study is presented in the paper.

1. Introduction

Satellite cloud photography has proved to be a very important tool in the detection, tracking and study of tropical cyclones specially over the oceans where data are sparse. From a few ships' observations, it is very difficult to make a composite picture of the extension and patterns of cloud and of weather distribution. The satellite cloud pictures show the extension and distribution of cloud pattern as well as reveal the intensity of the disturbance (Sadler 1964).

A severe tropical storm hit the East Pakistan-West Bengal coast near Long. 90°E on the night of 11-12 May 1965. The storm accompanied by tidal wave had caused extensive damage affecting nearly 20 million people. According to press reports 5492 people died and there was hardly any sign of human habitation in the large areas close to the Bay of Bengal coastline.

Sun-synchronous TIROS-9 photographed the storm once every day near about 0600 GMT, that is the local noon. The first indication of formation of a tropical depression was obtained on 7 May and on 12 May it was seen to be breaking up against the Himalayas and the mountains of Yunan. The object of this paper is to study some of the characteristics of the storm in the formative and decay stages. Attempt has been made to estimate the intensity of the disturbance from the cloud photographs on consecutive days.

2. Method of analysis

In order to study the synoptic features associated with the formation, intensification and decay of the tropical storm, the surface and 300 mb (streamline) charts at 1200 GMT have been presented on some days between 7 and 11 May. On 12 May when the storm had already crossed coast and considerably weakened over land, only the surface chart is presented. In the surface stream line charts the winds plotted over land are for 3000-ft level pertaining to the hour of chart. To avoid congestion on charts, isotach patterns are not shown. In view of the usefulness of nephanalysis in understanding TIROS photographs, the nephanalyses of 10-12 May are also presented. On these diagrams are also superimposed the 0600 GMT synoptic cloud observations.

3. Chronology

The tropical storm had its origin in an easterly wave. The time cross-section chart for Port Blair during 4 to 8 May is shown in Fig. 1. The 24-hour height changes in this diagram have been plotted in the centre of the 24-hour interval. The chart shows the passage of an easterly wave at about 12 GMT of 6 May. It was probably more pronounced to the south of Port Blair. The passage of an upper trough between 400 and 200-mb level was also seen to have taken place at about 12 GMT of 7 May. The superposition of low level convergence associated with the passage of the easterly wave and the divergence due to upper trough seems to have caused intensification of the system and ultimate development of the storm.

3.1. *7 May 1965* — TIROS photograph for 7 May at 0627 GMT indicates the existence of disturbed areas in the Bay of Bengal. Fig. 2 shows an irregular unorganised cloud mass of considerable extent. The surface isobaric analysis at 0600 GMT (not reproduced) shows at least one closed isobar with its centre near Lat. 8·5°N and Long. 84·8°E. Wind speed in the immediate vicinity of the centre of circulation could not be ascertained due to lack of ships' observations. However, at 1200 GMT a ship at a distance of about 225 km towards northwest reported a wind of 15 knots from ENE direction (Fig. 3). The cyclonic circulation extended beyond 700-mb level. The disturbance *most probably* had reached the tropical depression stage at the time the TIROS photograph was taken.

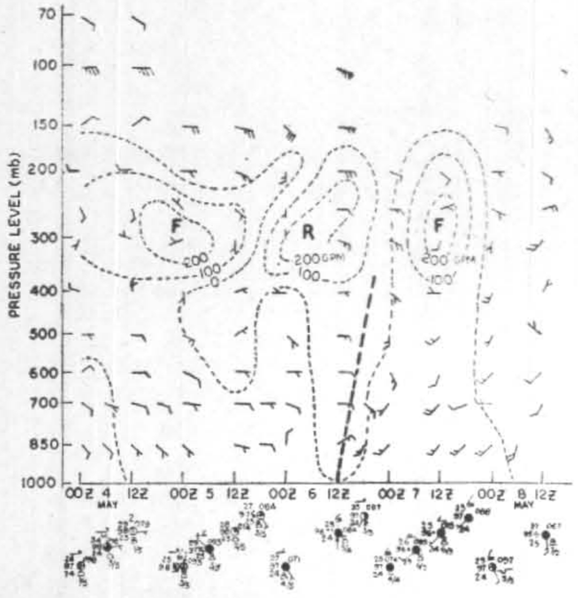

Fig. 1. Vertical time cross-section of Port Blair for 4-8 May 1965

Height change in gpm

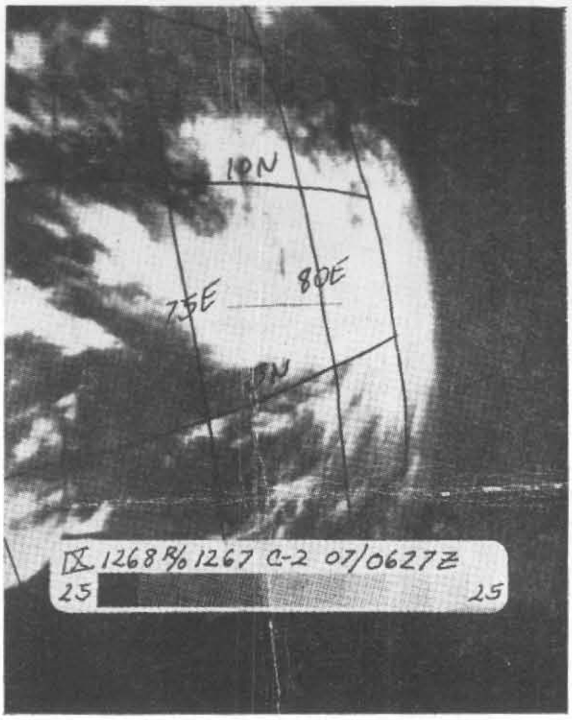

Fig. 2. TIROS photograph of Bay of Bengal at 0627 GMT of 7 May 1965 (Orbit 1268, Frame 25)

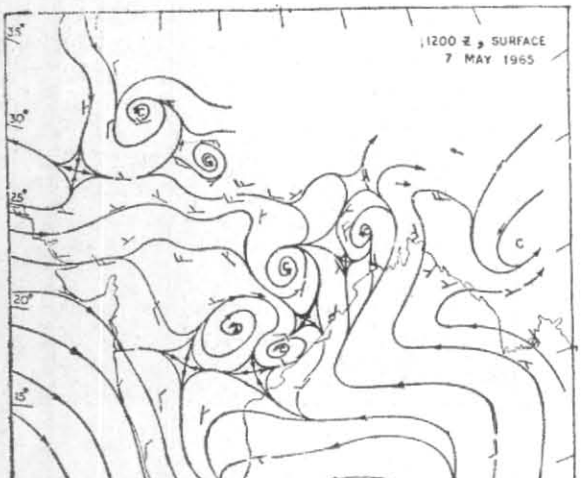

Fig. 3. 1200 GMT surface chart of 7 May 1965

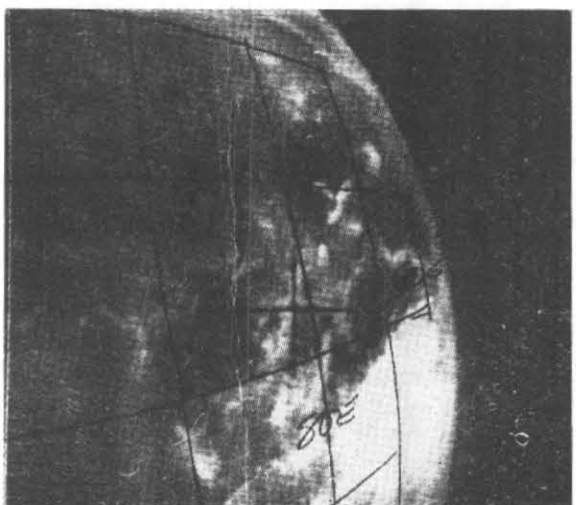

Fig. 4. TIROS photograph of Bay of Bengal at 0616 GMT of 8 May 1965 (Orbit 1280, Frame 23)

3.2. *8 May*—The TIROS photograph at 0616 GMT of 8 May is shown in Fig. 4. Unfortunately the photograph of this day contain picture of clouds much towards the horizon. The conclusions drawn will therefore have some limitations. It shows that the cloud pattern has become very much symmetrical round the centre of circulation as inferred from surface analysis. The cloud coverage seems to have become less extensive. The centre of circulation has become obscured by heavier cloudmass. The TIROS photograph of this day is brighter than the photograph of the previous day. This is due to marked increase in cumuliform development and dense altostratus formations. The TIROS photograph also shows that the boundary between the central cloudmass and the clear area roughly towards the direction of motion of the system has become marked by a smooth cloud edge. According to Merritt (1964) this suggests further intensification.

Though the TIROS photograph indicates intensification of the system, the surface pressure field at 1200 GMT of 8 May (Fig. 5) does not show any clear evidence of intensification of the depression. However the cyclonic circulation had extended upto 300 mb at 1200 GMT.

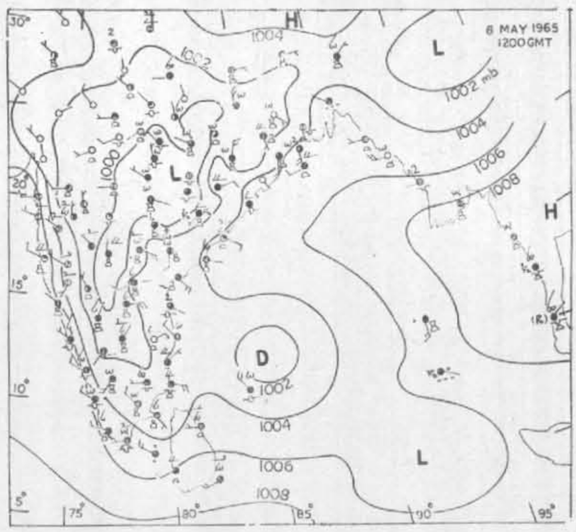

Fig. 5. 1200 GMT surface isobaric chart of 8 May 1965

3.3. *9 May* — TIROS photograph at 0610 GMT of 9 May (Fig. 6) reveals considerable intensification of the disturbance.

The main features of intensification are—

(*a*) significant increase in the circulatory organisation of the cloudmass ;

(*b*) marked areal extension of the cloud mass;

(*c*) increase in amount and organisation of cirrus cloudiness; and

(*d*) formation of the rift between the cirrus mass of the core cloud and the surrounding cloud.

Fig. 6

The increase in the amount and organisation of the cirrus cloudiness is a measure of intensification of the storm (Widger *et al.* 1965). The TIROS photograph (Fig. 6) shows the rift on the southwest edge of the core cloud separating it from the convergence zone cloudmass to the southeast, south and southwest.

Timchalk *et al.* (1965) suggested an empirical technique of deriving maximum wind speed from TIROS pictures of storms in the tropics. This technique is somewhat subjective and estimated wind speed may be accurate to about 20 kt. The photograph of 9 May is ranked in category 1 having an overcast circle of diameter 4 degrees latitude. The maximum derived wind speed seems to be 40 kt. However, there was no ships' observations in the vicinity of the centre of circulation where the maximum wind speed is expected. A ship reported a wind of 25 kt at a distance of about 120 km from the centre at 1200 GMT (Fig. 7). It can be expected that the maximum wind speed near the core of the storm might have reached the derived value. The above mentioned argument suggests that the deep depression might have reached the tropical storm stage of moderate intensity.

Another feature of the cloud photograph is the equatorward trailing convective cloudiness generating cirrus. This feature appears in many storms progressing towards higher latitudes. This feature generally appears directed towards the equator

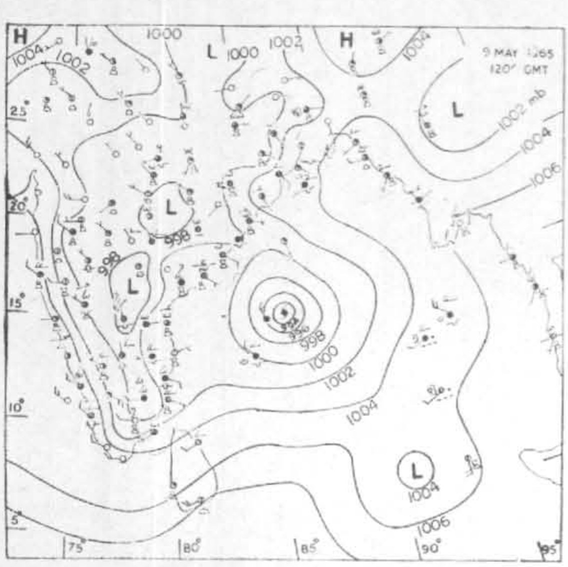

Fig. 7. 1200 GMT surface isobaric chart of 9 May 1965

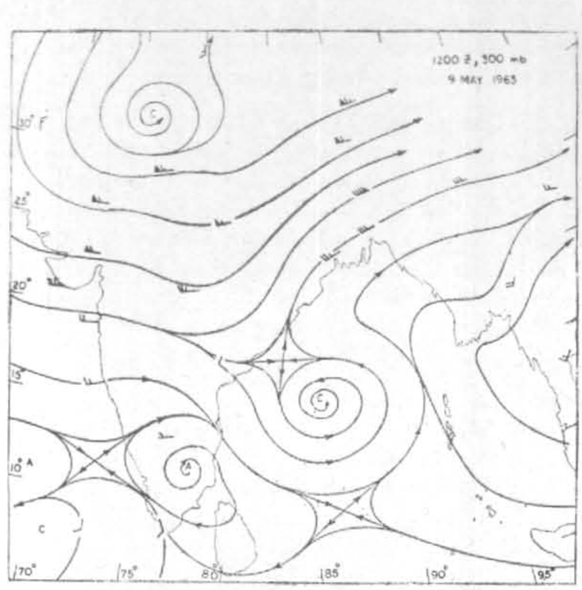

Fig. 8

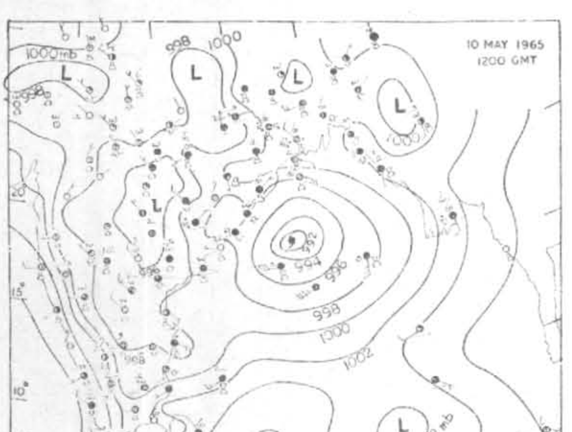

Fig. 9. 1200 GMT surface isobaric chart of 10 May 1965

Fig. 10

in both hemispheres (Fett 1963).

The TIROS photograph further reveals that the tropical cyclone has undergone rapid intensification during the last twentyfour hours. This rapid intensification was caused by the favourable flow pattern at higher levels.

According to Miller (1958) circulation at 200 mb, most favourable for intensification of tropical cyclones, has the following characteristics —

(*a*) A large high lies to the east of the centre of cyclonic circulation;

(*b*) A secondary and somewhat smaller high lies to the southwest of the storm;

(*c*) A trough of low pressure in the westerlies lies to the northwest; and

(*d*) The cyclonic circulation extends to the 200-mb level.

An identical circulation pattern (Fig. 8) exists at the 300-mb level at 1200 GMT of 9 May.

In the 200-mb level the cyclonic circulation if at all present is confined to a very small area. Because of lack of upper air data in the vicinity of the storm centre it is not possible to determine whether the cyclonic circulation extended upto 200-mb level or not. However, other features of circulation at 200-mb level are also to some extent similar to those suggested by Miller.

3.4. *10 May* — There were many evidences of intensification of the storm in the sea level chart (Fig. 9). A ship at 1800 GMT reported a wind of 40 kt at a distance of about 300 km from the centre. A few more ships' observations were available on this day reporting surface winds between 25 to 35 kt. The main identifying features of intensification of the storm as revealed in the TIROS photograph at 0610 GMT of 10 May (Fig. 10) are the following —

(*a*) A significant increase in organisation of the cloudmass;

(*b*) Development and circulatory organisation of the peripheral cumuliform and cirriform bands in the northwestern sector; and

(*c*) The rift between the core cloud and the surrounding cloud. The rift has surrounded the storm from northeast through east to southwest.

The cloud photograph of this day is ranked in the category 2 having an overcast circle of diameter 4 degree latitude. Maximum derived wind is of the order of 60 kt. However, there were no ships' observations to verify this wind speed. The storm perhaps had reached the most intense formative stage for the development of hurricane. The cloud photograph did not show any 'eye' of the storm (Fig. 11).

According to Malkus (1958), formation of the eye is a necessary condition before hurricane speeds can be attained. The eye had perhaps formed shortly after this photograph was taken. The ship's report of 40 kt at 1800 GMT at a distance of about 300 km is quite indicative that by this time the storm might have reached the hurricane stage with winds of hurricane force near the centre.

The cloud canopy surrounding the storm in the TIROS photograph shows considerable asymmetry. The cirriform canopy to the right of the direction of motion was much bigger than that to the left. The weather which had occurred in the last 24 hours ending at 0300 GMT of 11 May (Fig. 12) shows that the extent of weather to the right

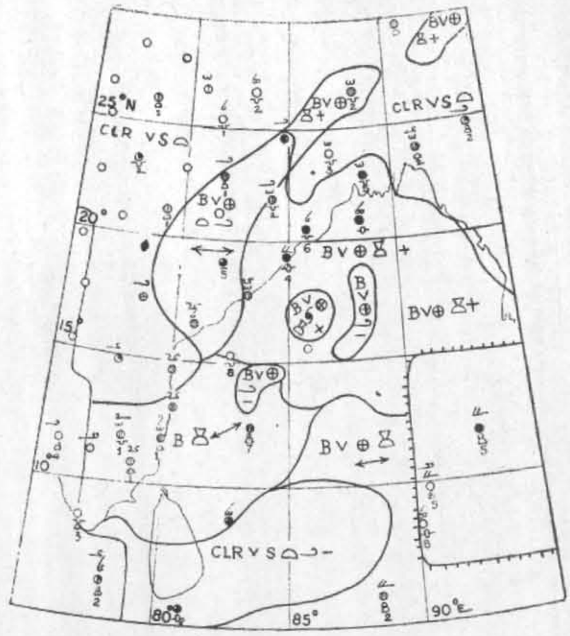

Fig. 11. Nephanalysis at 0557 GMT of 10 May 1965

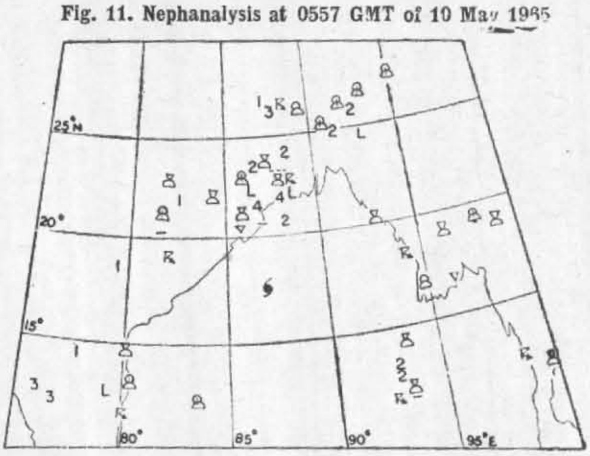

Fig. 12. Weather during 24-hr period ending 03 GMT of 11 May 1965

Position of storm at 12 GMT of 10 May shown

of the direction of motion of the storm was more than that to the left. The coast of Burma which was far away from the centre of the storm compared to Orissa and Andhra coasts had experienced weather. Considering the distance of weather belts on east and west this asymmetry is apparent. This asymmetry in weather distribution was perhaps caused by the unequal moisture incursion over the two coasts. There had been continuous moisture feed by the moist southerly flow over Burma coast whereas the extent of cloud on the east coast of Orissa and Andhra Pradesh was restricted by the mixing of the dry continental current with the circulation.

A portion of the cloudmass in the north in this TIROS photograph had entered land. The land area appears to have made indentations along the northnortheast edge of the storm. Fett (1963)

Fig. 13

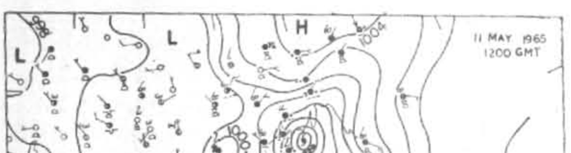

Fig. 14. 1200 GMT surface isobaric chart of 11 May 1965

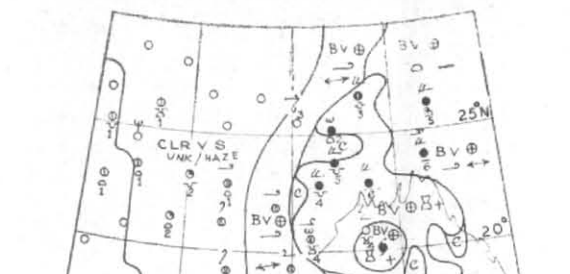

Fig. 15. Nephanalysis at 0547 GMT of 11 May 1965
Tropical vortex near 20°N,89°E

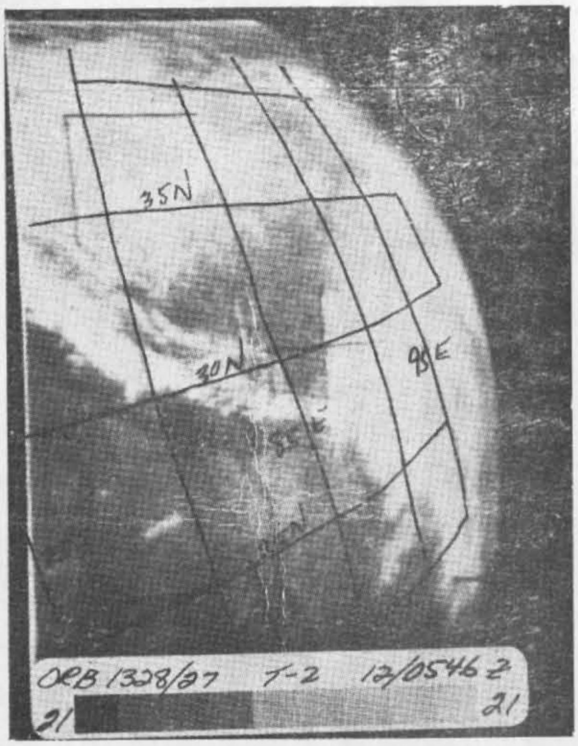

Fig. 16

had put forward an explanation for the occurrence of these indentations.

3.5. *11 May* — The TIROS photograph of 11 May at 0530 GMT (Fig. 13) shows further intensification of the tropical cyclone. The features of intensification are —

(*a*) Further increase in organisation of cirriform canopy;

(*b*) Formation of the eye of the storm at 20°N and 89°E; and

(*c*) Increase in the extent and degree of the clear to minimum cloud area surrounding the storm.

One of the better subjective clues for estimating intensity may be the appearance, size and sharpness of the organised clear to minimum cloud area on the periphery of the storm (Sadler 1964). The sharpness of the clear to minimum cloud area on the western periphery of the central cloud shield indicates pronounced subsidence in that region.

The TIROS photograph of this day is ranked in category 4 having an overcast circle of diameter 5-degree latitude. Maximum derived winds are of the order of 100 kt. There were no ships' observations in the neighbourhood of the storm centre to confirm this wind speed (Fig. 14). However, Agartala reported winds of 50 to 60 kt at times reaching 70 kt in gusts when the centre of the storm was passing nearest to the station. By this time the storm had weakened to some extent due to its passage over land. From the reports of the widespread damage, maximum wind speed appears to have exceeded 100 kt.

An important modification of the cloud shield compared to previous day was that the extension of cloud cover on all sides had decreased considerably except for an extension of the cloud mass towards its direction of motion (Fig. 15). The orography of Assam and sub-Himalayan West Bengal could have some role in this northward extension of the cloud mass.

Another important feature of the TIROS photograph is that the extent and the opacity of the cloud mass in the southern section had decreased considerably compared to previous two days. As the storm was moving northwards, there was more and more prevalence of comparatively drier air in the southern sector resulting in gradual fall in low level cloud developments.

3.6. *12 May* — The storm had moved very much inland at the time of TIROS photograph (Fig. 16). At 1200 GMT the centre of circulation was estimated to be near 27·5°N and 92·5°E (Fig. 17).

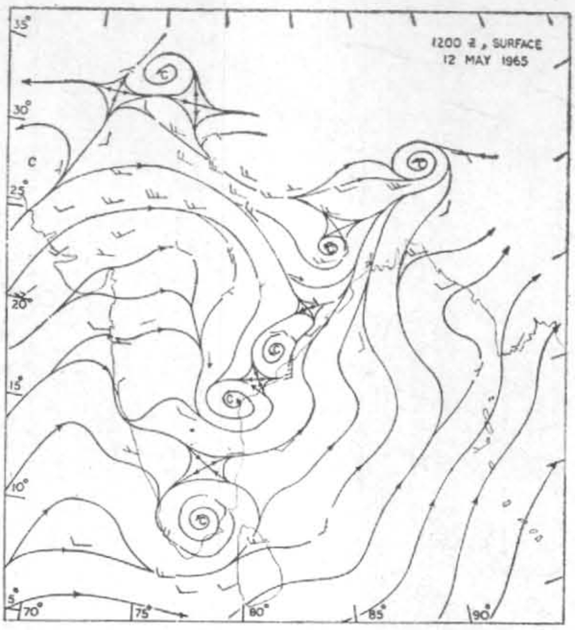

Fig. 17. 1200 GMT surface chart of 12 May 1965

Fig. 18. Nephanalysis at 0538 GMT of 12 May 1965

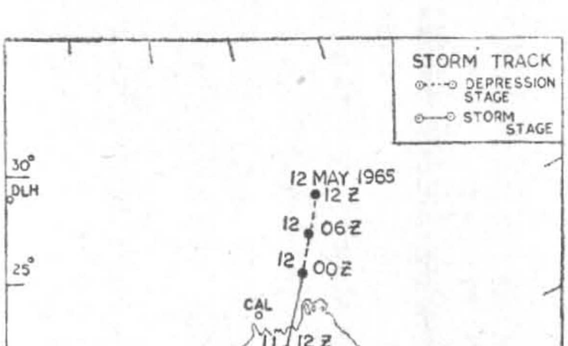

Fig. 19. Storm track during 6–12 May 1965

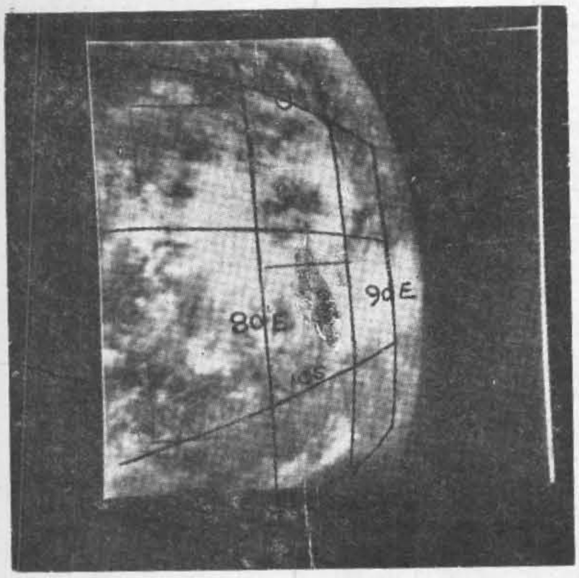

Fig. 20. TIROS photograph of Indian Ocean south of Bay of Bengal at 0610 GMT of 8 May 1965 (Orbit 1280, Frame 29)

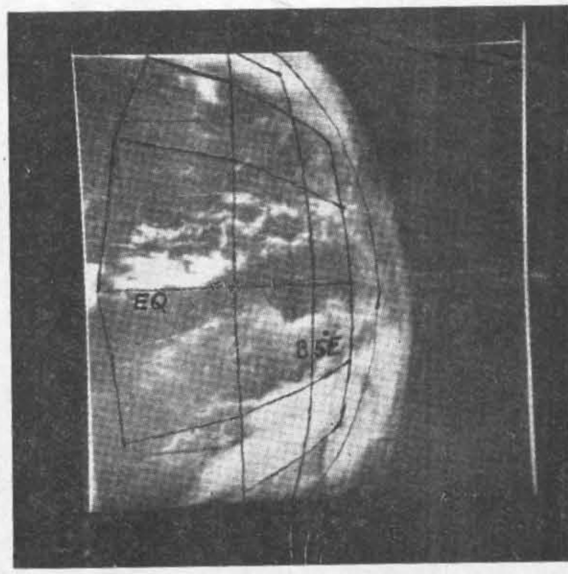

Fig. 21. TIROS photograph of Indian Ocean and Bay of Bengal at 0606 GMT of 9 May 1965 (Orbit 1292, Frame 27)

By this time the storm had weakened into a depression. The TIROS photograph of this day lies very much towards the horizon and as such the conclusions drawn will have some limitations. The photograph reveals the weakening of the storm in the following characteristics —

(*a*) The eye of the storm had filled up;

(*b*) The banding organisation inside the cloud mass is hardly distinguishable; and

(*c*) The brightness of the photograph had decreased considerably.

The fall in the brightness of the photograph suggests considerable fall in the convective activity and consequent thinning of the cirriform canopy. The uniform less white cloud mass is indicative of mainly overcast altostratus with active precipitation and of clouds below and far above (Fig. 18).

4. Track of the storm

The track of the storm is shown in Fig. 19. The track of a tropical storm to a large extent depends upon the direction and speed of the basic current in which it is embedded. A favourable steering level is taken to be the level at which the cyclonic circulation has virtually disappeared. The storm under consideration appears to have followed the steering current at 200-mb level. Though the 200-mb level analysis is to some extent subjective due to lack of data, the steering effect of the level is more or less satisfactory.

5. System in the Southern Hemisphere

TIROS 9 photograph of 7 May (not shown) also shows the presence of a developing disturbance in the southern hemisphere approximately near 7°S and 81°E. The cloudmass was without any distinct recognizable pattern. There were scanty ships' observations in the disturbed area and the location of the central region of the disturbance was only approximate. This cloudmass had developed in the trough formed in the southern hemisphere, south of the equator, as the south-easterly trade winds turn cyclonically from south-east through south to southwest. Mention of this trough has been made by Koteswaram (1958), Raman (1965) and others. The TIROS photographs of 8 May at 0610 GMT and on 9 May at 0606 GMT are given in Figs. 20 and 21. These photographs as well as the sea level charts indicate that the disturbance did not intensify into the depression stage. TIROS photographs of 10 May and of later days show that the system had weakened afterwards.

6. Conclusion

From this study it is found that we can follow a tropical storm systematically during the course of its life cycle with the help of satellite pictures of the storm taken at least once every 24 hours. The satellite pictures give us clear insight of the distribution of clouds and of circulations. It may also be used to infer surface winds from empirical techniques. However, this technique of deriving surface winds from satellite photographs is very much subjective. Nevertheless this may be utilised as an additional help in ranking a disturbance specially in absence of adequate ships' observations.

In the present case from the study of the synoptic charts and also the time cross-section chart of Port Blair, a synoptician could have anticipated the development of a cyclonic storm. But that the system developed into a depression on 7 May and intensified into a tropical storm on 9 May could not be inferred from the synoptic observations whereas it can be seen from the discussions in the previous pages that these conclusions could be drawn with reasonable confidence if he was provided with the photographs. The TIROS photograph at 0530 GMT on 11 May shows a clear eye and indicates the existence of a severe cyclonic storm. Due to lack of sufficient synoptic observations this could not be inferred until the storm was very close to the coast.

7. Acknowledgement

The authors' thanks are due to the National Weather Satellite Centre, U.S. Weather Bureau, Suitland, Maryland, U.S.A. for supplying the TIROS photographs, some of which are reproduced in this paper.

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