

## A note on the Vertical Structure of a few disturbances of the Bay of Bengal

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### 1. Introduction

Some aspects of the vertical structure of three disturbances of different intensities in the Bay of Bengal has been studied with a view to getting some useful insight into the mechanism leading to the genesis and intensification of such disturbances. A critical and detailed study of a problem of this nature is very difficult, for want of adequate upper air data over the sea areas where disturbances develop. As the radiosonde stations are very sparsely distributed over the country and ascents are made only once a day, sufficient data are rarely available from the vicinity of the centre of such disturbances even when they move inland. For the storms discussed in this paper upper air data were available upto sufficient heights for 5 or 6 consecutive days in each case. The changes that occurred in the vertical structure of the atmosphere over the head of the Bay of Bengal, as represented by the radiosonde data of Calcutta, during the formation and subsequent movement of the above disturbances have, therefore, been studied in some detail and the results discussed.

### 2. Case 1—Cyclonic storm of August 1953

On the morning of 1 August, a shallow depression developed at the head of the Bay of Bengal, with its centre about 60 miles southeast of Calcutta. During the next 24 hours the depression rapidly intensified into a cyclonic storm (Fig. 1) and it was centred about 75 miles southsouthwest of Calcutta at 0300 GMT of the 2nd. Later, the storm gradually weakened and followed a track as shown in Fig. 1.

The heights of the different standard pressure surfaces over Calcutta for the

period, 28 July to 4 August, are shown in Fig. 2. It will be seen that there was a sharp fall of pressure in the levels above 20,000 ft between the 28th and the 30th, while the pressures at the lower levels commenced falling only from the 31st and reached the minimum on the 2nd. It is also noticed that there was a rapid rise of pressure in the higher levels on the same day. A comparative study of radiosonde data of Calcutta, Allahabad, Nagpur, Visakhapatnam and Shillong indicates that there was a well-marked contour low in the higher levels over the head of the Bay of Bengal on the 30th and a contour high over the same area on the 2nd. The upper winds at these levels were easterly. It is thus seen that when the conditions were becoming unsettled at the head of the Bay of Bengal, a well marked low was moving westwards in the higher levels across the same area. Further, when the unsettled conditions were concentrating into a severe cyclone, a well marked high appeared over the same region in the higher levels. In the storm stage, while the pressure gradient force was directed towards the centre in the lower layers, it decreased gradually upwards and eventually was reversed. In such a situation, air converging into the storm field in the lower levels would be depleted by divergence at the higher levels where there is a 'high' and such a mechanism would help maintain the pressure fall inside the storm.

In order to have an idea about the vertical circulation associated with this storm, isentropic and isothermal surfaces have been drawn in the storm field and are shown in Fig. 3. This diagram represents the cross-section on an eastwest vertical plane passing through Calcutta at a distance of about

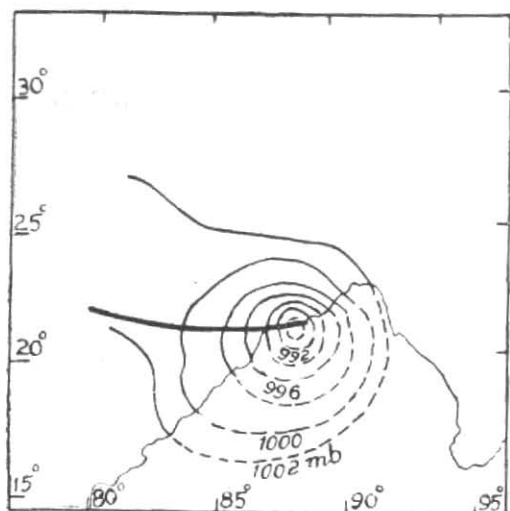


Fig. 1. Cyclonic storm of 2 August 1953 and its track

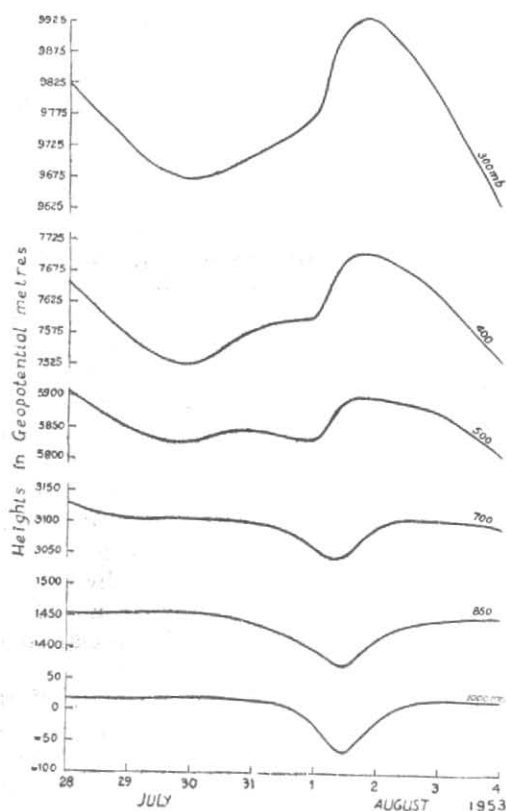


Fig. 2. Heights of various standard pressure surfaces

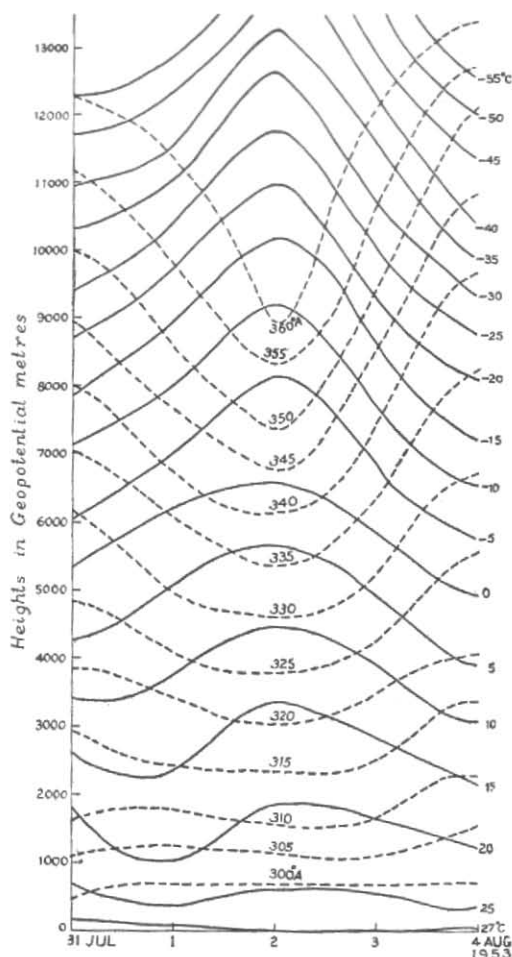


Fig. 3.  $T-\phi$  Solenoidal field in the storm of August 1953  
(— isotherms, ..... isentropes)

50 miles to the north from the storm centre, and is roughly representative of the vertical cross-section through the centre particularly in the higher levels. The right hand and the left hand sides of this diagram represent the conditions in the eastern and the western regions of the storm respectively. The diagram shows that while the temperature near the surface had undergone little variations, there was a rise at the upper levels as the storm centre approached, the gradient being quite high in the layers above 20,000 feet. The isentropic surfaces sloped upwards from the centre to the periphery of the storm. The pattern of the  $T-\phi$  Solenoidal field as shown in Fig. 3, is more or less

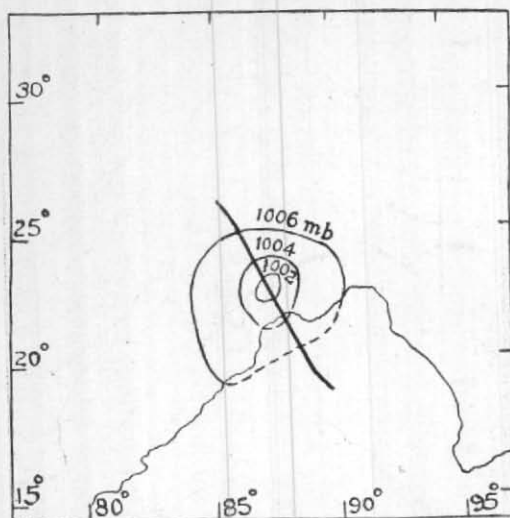


Fig. 4. Depression of 3 October 1948 and its track

similar to that drawn by Bergeron (1954) in the case of the famous Miami-New Orleans hurricane and would suggest that there was strong vertical circulation in the region outside the central core.

### 3. Case 2—Depression of October 1948

A depression formed at the head of the Bay of Bengal on the 2nd morning with its centre at 0830 IST near lat.  $20.5^{\circ}$  N, Long.  $90^{\circ}$  E. The depression rapidly moved northwestwards and crossing the Sunderbans coast between Saugor Island and Barisal in the early hours of the 3rd, lay at 0830 IST of the same day with the central region near Krishnanagar (Fig. 4). Thereafter, it continued to move northwestwards and gradually became unimportant. The track of the depression lay within about 25 miles from Calcutta and is shown in Fig. 4.

The heights of the different standard pressure surfaces over Calcutta during the period 1 to 5 October are shown in Fig. 5. It will be seen that during the period 2nd to 4th there was a 'low' in the lower levels and a 'high' aloft, the transition layer being near the 700-mb surface. In this case also, the divergence associated with the pressure 'high' in the higher levels helped

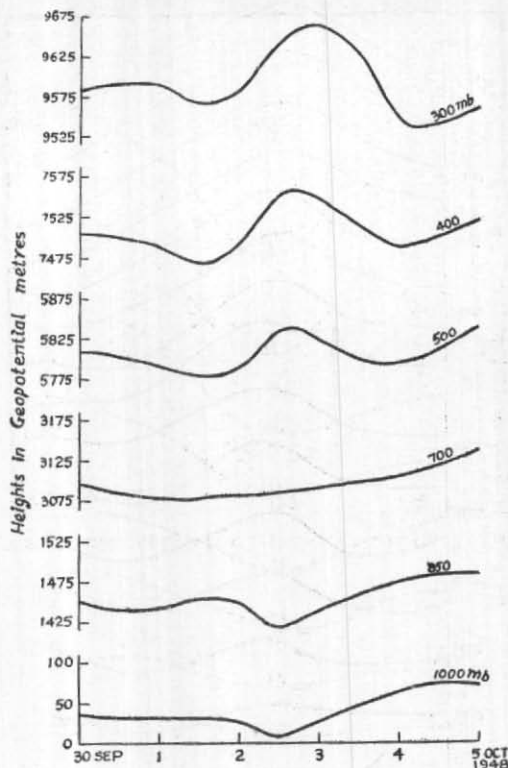


Fig. 5. Heights of the various standard pressure surfaces

to remove the air which accumulated in the lower layers below 700-mb level due to convergence. It is noticed that 'high' aloft facilitating the depletion of air was not so well marked in this instance as in the first case and this is perhaps one of the reasons why the depression did not intensify further. There was also a pressure fall in the higher levels prior to the formation of this depression but the fall was not so large as in the case of the storm studied earlier.

The  $T-\phi$  Solenoidal field in respect of this depression is shown in Fig. 6, the right and the left hand sides of this diagram representing the conditions in the southern and the northern regions of the depression respectively. It will be seen that there was lesser concentration of solenoids in this case, suggesting that the circulation associated with this depression was much weaker.

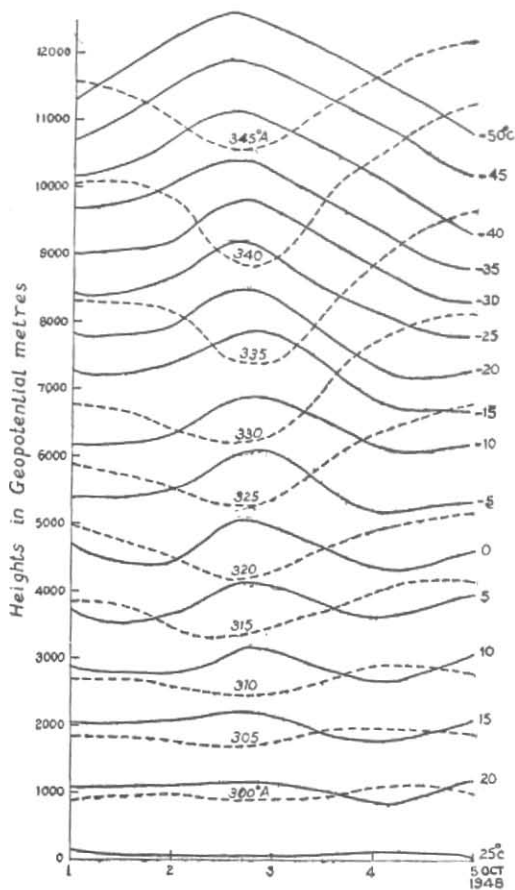


Fig. 6.  $T-\phi$  Solenoidal field in the depression of October 1948

(— isotherms, - - - isentropes)

#### 4. Case 3—Shallow depression of June 1948

On the morning of 24 June 1948, a shallow depression formed over the northwest Bay of Bengal and was centred at 0830 IST near lat.  $21^{\circ}\text{N}$ , Long.  $89^{\circ}\text{E}$ . The depression moved northwestwards and was centred on the 25th morning close to the coast about 50 miles south of Calcutta (Fig. 7). It passed inland during the course of the afternoon, and was centred slightly to the west of Calcutta in the evening. It then continued to move northwestwards and lay on the 26th morning over Chota Nagpur with its centre about 30 miles to the east of Hazaribagh, and on the 27th morning about 20 miles to the northwest of Hazaribagh. Later, the depression gradually became unimportant. Its track is shown in Fig. 7.

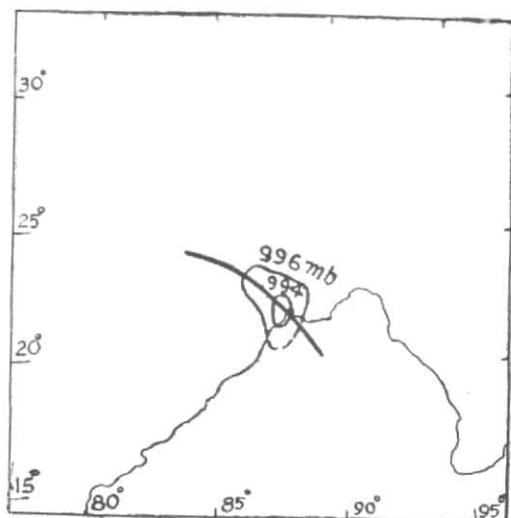


Fig. 7. Shallow depression of 25 June 1948 and its track

It will be seen from Fig. 8 that in this case also, there was convergence in the lower layers and divergence in the higher layers, the transition level, being between 700 and 500-mb levels. The divergence field in this case was very weak, compared to those in the previous two cases.

The  $T-\phi$  Solenoid pattern in respect of this depression is shown in Fig. 9. As in case 2, the left hand side of this diagram represents the northern half of the depression and the right hand side represents the southern half. It is observed that unlike the other two cases, the isotherms in this instance generally ran more or less parallel to the isentropes in the layers above 400-mb level, suggesting that the circulation almost ceased in those layers over this shallow depression. The solenoidal field in the lower layers also indicates that the circulations were generally weak over this depression, as compared with those of the other two disturbances.

A study of these three cases seems to confirm that a divergence field in the upper troposphere is a necessary condition for the maintenance of a disturbance and that its intensification apparently depends largely on the strength of this divergence field above,

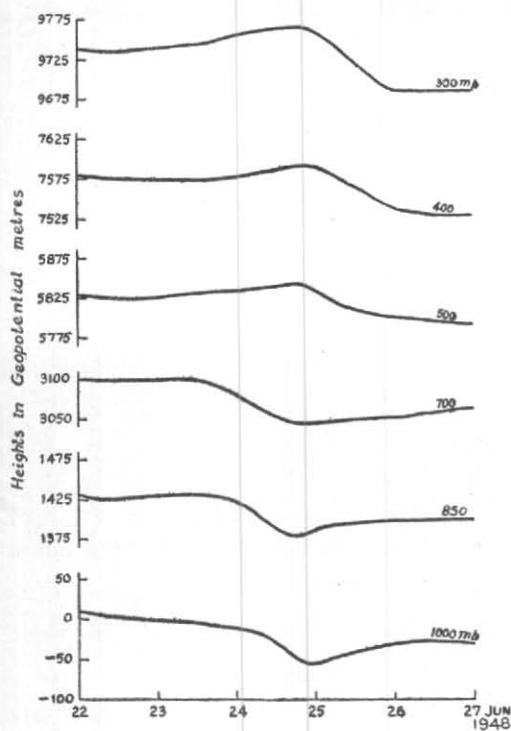


Fig. 8. Heights of the various standard pressure surfaces

#### 5. The 'eye' of the storm of August 1953

Most meteorologists agree that all tropical cyclones are fairly symmetrical and have at their centres a funnel shaped core of warm descending air known as the 'eye' of the storm where the winds are calm or light. In Fig. 3, it is seen that there is a core of well-marked warm air in the central region of the storm under study. A correct determination of the extent of this core at the different levels is not possible, unless there is a good network of radiosonde stations located in and around the storm field making ascents at short intervals. An attempt has, however, been made to make a rough estimate of the structure of the eye with the help of the available upper air data of Calcutta.

The characteristic curve on a thermodynamical diagram representing the vertical structure of air inside the rain area outside the 'eye' of a storm, is what would be obtained by raising an air parcel dry adiabati-

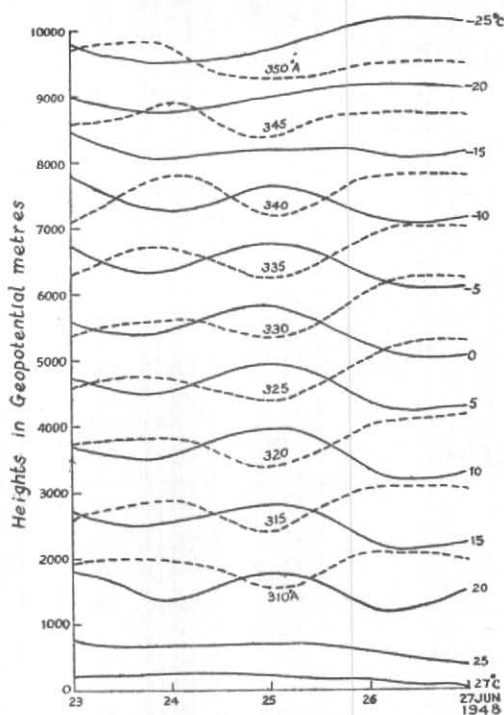


Fig. 9.  $T-\phi$  Solenoidal field in the shallow depression of June 1948

(— isotherms, - - - - isentropes)

cally from the surface to the condensation level, and thereafter moist-adiabatically. On the first evening, the storm was about 50 miles away from Calcutta and the radiosonde ascent (Fig. 10) showed that below 760-mb level (about 2.5 km) the lapse rate was either moist-adiabatic or higher than moist-adiabatic while the lapse rate above was distinctly less than the moist adiabatic value. It would thus appear that the height of the funnel surface of the storm over Calcutta was about 2.5 km on that evening. The heights of the funnel surface over Calcutta on the 2nd and the 3rd evenings were determined on the same basis. On the 4th evening, the radiosonde ascent reached 150-mb level and the air was found to be sufficiently cold right upto that height. This suggested that the funnel surface over Calcutta, if any, was above that height on the evening of that day. The heights of the funnel surface over Calcutta as obtained by the method

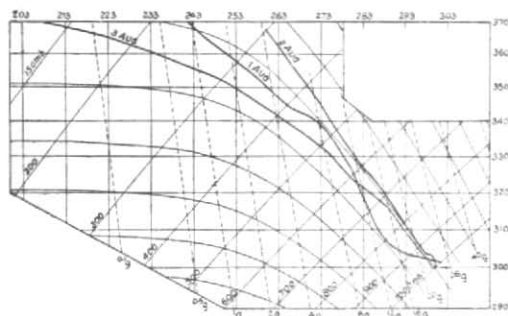


Fig. 10. Dry bulb temperature curves of Calcutta during 1-3 August 1953

discussed above have been plotted against the corresponding distances of the storm centre from Calcutta and a smooth line drawn. A study of surface temperatures of Sandheads, Saugor Island, Balasore etc where the storm centre lay on the 2nd appears to indicate that the radius of the 'eye' on the surface was not more than 20 miles. Another symmetrical line has been drawn on the left hand side of the smooth line referred to above at a distance of about 40 miles on the surface. Thus a vertical section of the 'eye' of the storm under study has been roughly estimated and is shown in Fig. 11.

#### 6. Temperature distribution in the storm field outside the 'eye'

The mean temperatures at different levels over Calcutta during the period 1st to 4th were worked out and these roughly represented the average temperatures at the same levels in the storm field. The deviations of the day-to-day temperatures from the mean values were then plotted at the corresponding observation points. The isopleths of these deviations are shown in Fig. 11 by dotted lines. It will be seen that there are two cold regions (C1 and C2) and two warm regions (W1 and W2) inside the storm field, C1 and W1 being more marked than C2 and W2 respectively. The warm region W1 can be interpreted as due to the latent heat released by the rising moist air. The warming in the

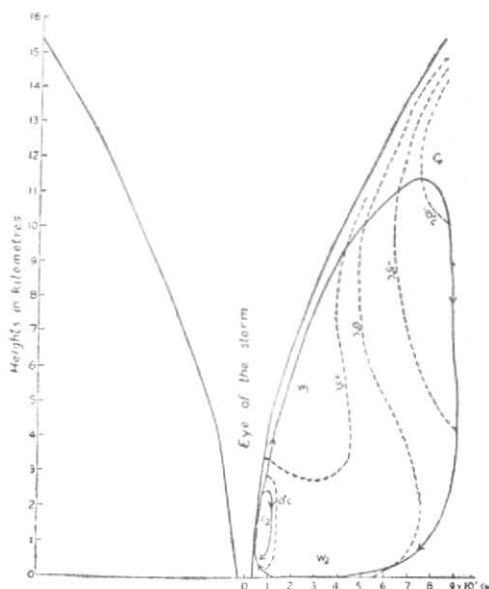


Fig. 11. Vertical structure of the 'eye' of the storm of August 1953 and the vertical circulation outside the 'eye'

region W2 might be due to the heat transmitted from the sea surface by turbulence. In the region C1, the air has perhaps been cooled by radiation and also by the evaporation of the upper cloud and its precipitation. It is seen that the negative deviation in the column through this region decreased steadily towards the lower levels presumably due to the sinking of air through that column. Within the region C2 the cooling was caused by heavy precipitation. The distribution of temperature as indicated above would suggest that the circulation outside the eye of the storm was as shown by arrows in the diagram.

#### 7. Acknowledgement

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