Mausam, (1987), 38, 3, 345-352

551.515.1(267)

Cyclonic storm of October 1983 in the Bay of Bengal — A diagnostic study

RANJIT SINGH and C. P. THORAT

Meteorological Office, Pune

(*Received 13 January 1984*)

सार — अक्तूबर 1983 के प्रथम सप्ताह में बंगाल की खाड़ी में एक चक्रवाती तूफान निर्मित हुआ जिसने विशाखापट्टणम के बहुत समीप समुद्र तट पार किया। भूउपग्रह प्रतिमावली, समदाब चार्टों, विशाखापट्टणम तथा इस केन्द्र से होकर गुजरने वाले अनुप्रस्थ-काटों के समय-काटों के उपयोग द्वारा मानसूनोत्तर एक चक्रवाती तूफान के विभिन्न विकास पक्षों के अध्ययन का एक सुअवसर प्रदान हुआ। यह ज्ञात हुआ है कि (1) मध्य-क्षोभमण्डलीय परिसंचरण का और समुद्र सतह के ऊपर निम्न दाब क्षेत्र का प्रारम्भिक विकास उसी क्षेत्र के ऊपर हुआ जहाँ उससे पहले दिन मेघ समूह बना था, (2) विकास प्रक्रिया के दौरान तापन उत्पन्न हुआ था। सर्वप्रथम अधिकत्तम तापन 300 और 250 मिलीबार के उच्च क्षोभमण्डलीय स्तरों पर प्रकट हुआ। यह प्रावस्था बाद में निम्न क्षोभमण्डलीय स्तरों पर नीचे उतरी। यह तापन विशाखापट्टणम और उसके अति निकटवर्ती क्षेत्रों में उत्तर-दक्षिण अनुप्रस्थ काट तक सीमित था, (3) समय और अनुप्रस्थ-काट पर निर्मित ताप असंगताओं में उच्चिष्ट, द्रवस्थैतिक घटनाओं की भांति उच्च क्षोभमण्डलीय स्तरों में भूस्थितिज तुंगता असंगताओं में उच्चिष्ट द्वारा आच्छादित रहे, (4) 3 अक्तूबर के 00 ग्री० मा० स० के अनुप्रस्थ-काट पर भूस्थितिज तुंगता असंगताओं में उच्चिष्ट उसी स्तर में उसके दक्षिण-उत्तर भाग में पूर्वी पवनों में उच्चिष्ट के निर्माण से संबंधित था जिससे इसे अधिकतम अपसारिता के स्तर के होने की पुष्टि होती है और (5) विभिन्न दिवसों के वर्षा वितरण से यह प्रदर्शित होता है कि अधिकतम वर्षा चक्रवाती तूफान के गमनपथ के अग्रवर्ती अंचल में हुई।

ABSTRACT. A cyclonic storm formed in the Bay of Bengal in the first week of October 1983 and crossed the coast very close to Vishakhapatnam. This gave an opportunity to study the various development aspects of a post monsoon cyclonic storm by using satellite imageries, constant pressure charts, time sections of Vishakhapatnam and cross-sections through the station. It is found that :

(1) The initial development of the mid-tropospheric circulation and the low pressure area on the sea surface took place in the same area where a cloud cluster had formed in the previous day, (2) An intense warming was generated during the development process. The maximum in warming first appeared in the upper tropospheric levels of 300 hPa and 250 hPa. This phase later descended to the lower tropospheric levels. The warming was confined to Vishakhapatnam or its immediate surroundings on the south-north cross-section, (3) The maxima in temperature anomalies on the time and cross sections prepared, were overlain by the maxima in the geopotential height anomalies in the upper tropospheric levels in keeping with the hydrostatic phenomenon, (4) The maximum in the geopotential height anomalies on the cross section of 00 GMT of 3 October was associated with the formation of easterly wind maximum at the same level in its south-north section, confirming it to be the level of maximum divergence and (5) The rainfall distribution of different days showed that the maximum rainfall occurred in the forward sector of the cyclonic storm along its track.

1. Introduction

In October 1983, a cyclonic storm formed in the Bay of Bengal such that its intensification into depression and cyclonic storm took place over sea and it crossed the coast very close to Vishakhapatnam, a coastal Radiosonde/Rawin station. This gave an opportunity to study the development process of a cyclonic storm formed during post monsoon season. The study has been made with the help of vertical time and cross-sections, constant pressure charts and satellite imageries.

2. History of the storm

A cylonic circulation extending between 1.5 and 7.6 km asl developed over north Andaman Sea on 27 September. This development took place in response to the formation of a cloud cluster over the same area on 26 September (Ooyama 1982). Under the influence of this cyclonic circulation, a well marked low pressure area formed over Andaman Sea and neighbourhood on the evening of 29 September. This low pressure area moved northwestwards and concentrated into a depression centred near 19.5°N, 86. 5°E over northwest Bay at 0830 IST of 2 October. Moving southwestward it became a deep depression in the evening of 2 October and intensified into a cyclonic storm, probably, severe in the morning of 3 October and lay centred near 18.0° N, 84·0° E at 0830 IST. Thereafter moving in a westerly direction the cyclonic storm crossed north

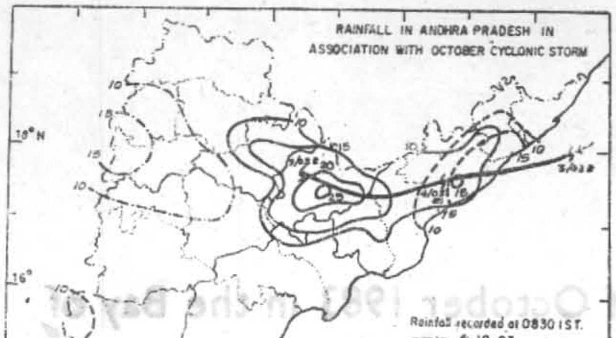


Fig. 1. Rainfall chart of Andhra Pradesh in association with October 1983 cyclonic storm

TABLE 1

Values of innermost isobar, 24-hr pressure departure from five days normals, distance from Vishakhapatnam and direction of the location of centre of the cyclonic storm, 2-5 October 1983

Date (Oct '83)	Time (GMT)	Stage of development	Innermost isobar (hPa)	Pressure departure (hPa)	Maximum core wind at 0.9 km (Dir. /kt)	Distance from Vishakha-patnam (km)	Direction (Deg.)	T. No
02	0300	Depression	998	4 to 6	NE/40 Bhubaneshwar	320	070	
02	1200	Deep depression	996	8	WNW/30 Vishakhapatnam	220	070	1.5
03	0300	Cyclonic storm	996	11 to 13	NW/45 Machilipatnam	100	070	3.0
03	1200	Cyclonic storm	994	11 to 12	NW/45 Machilipatnam	50	050	3.0
04	0300	Cyclonic storm	996	9 to 11	WNW/40 Machilipatnam	90	290	
04	1200	Cyclonic storm	996	10 to 11	WNW/30 Machilipatnam	150	290	
05	0300	Depression	998	10 to 11	W/40 Machilipatnam	250	280	
05	1200	Depression	996	10 to 11	NW/40 Hyderabad	250	280	

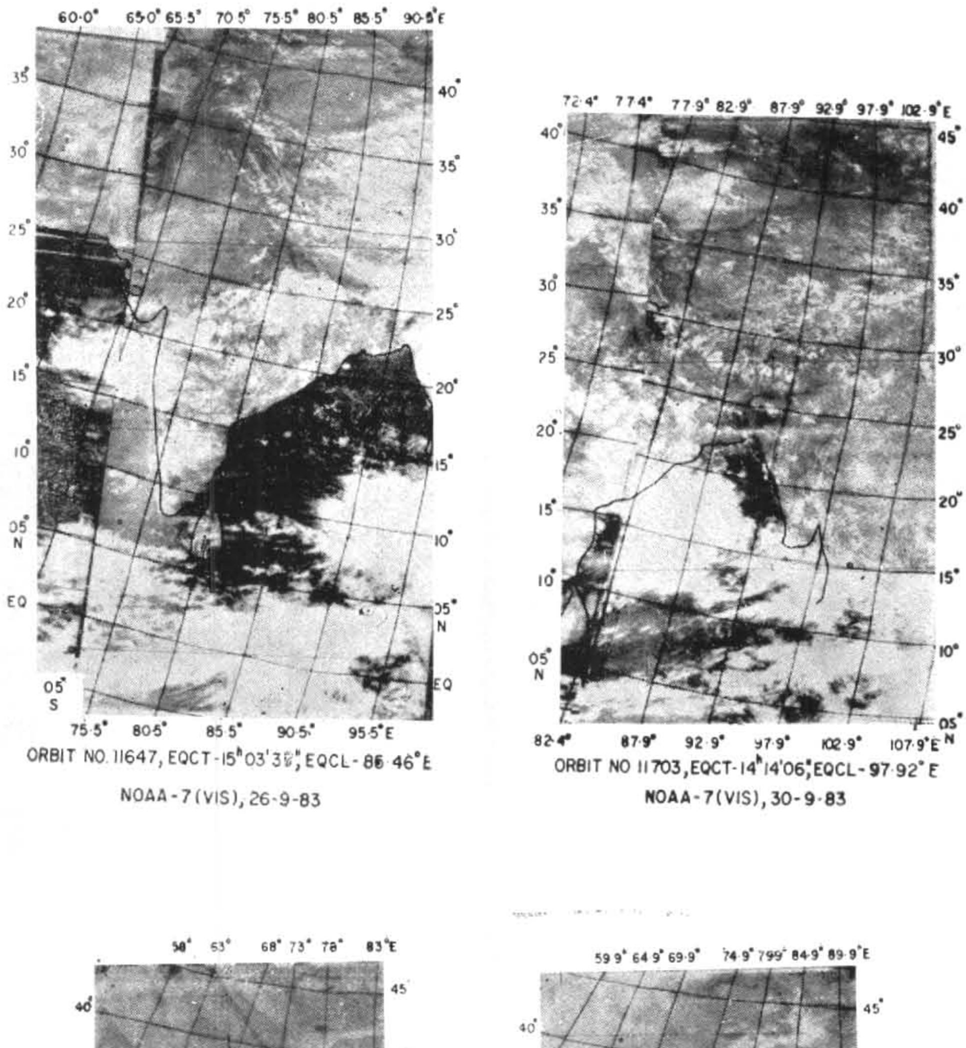
(1) The cyclone detection radar at Vishakhapatnam tracked the cyclone upto 0830 GMT of 3 October. The eye was seen only at 0500 GMT.

(2) As made out from the surface winds of Waltair storm crossed the coast to the north of Vishakhapatnam between 1800 and 1900 GMT. The lowest pressure at Waltair was 989.5 hPa at 0500 GMT.

Andhra coast, north of Vishakhapatnam in the early hours of 4 October. It weakened into a deep depression on 5 October and into a low pressure area over west Telangana and neighbourhood by 6th evening. The life history and the track of cyclonic storm are given in the rainfall chart of Andhra Pradesh (Fig.1). The distance and direction of the centre of the system from Vishakhapatnam for 00 GMT and 12 GMT on 2, 3 & 4 October, minimum central pressure and the 24 hours pressure departure from the normal at 03 GMT and 12 GMT of the day for these days are given in Table 1. As Vishakhapatnam was mostly located within the core of system during different stages of its development, the time sections of the station for different parameters may give the east-west cross-sections through the core of the system for these parameters.

3. Satellite view of the system from 26 September

A few NOAA-7 satellite visible cloud imageries received in the afternoon hours are consulted from 26 September onward when a cloud cluster C first appeared on the Andaman Sea (Figs. 2 a-d). This cloud cluster had the features of a well organised cloud mass with circular boundary. During its northwestward movement, the cloud mass preserved its distinct circular identity till it was finally declared depression on 2 October. On 00 GMT of 29 September when the



Figs. 2(a-d). Satellite pictures depicting the evolution of cyclonic storm between 26 September and 4 October 1983

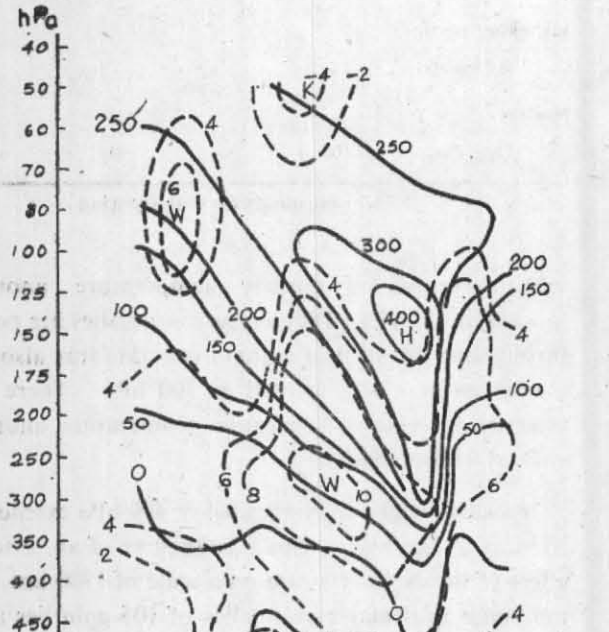


Fig. 3. Vertical time section of Vishakhapatnam for geopotential height and temperature anomalies at 50 hPa intervals of isobaric levels

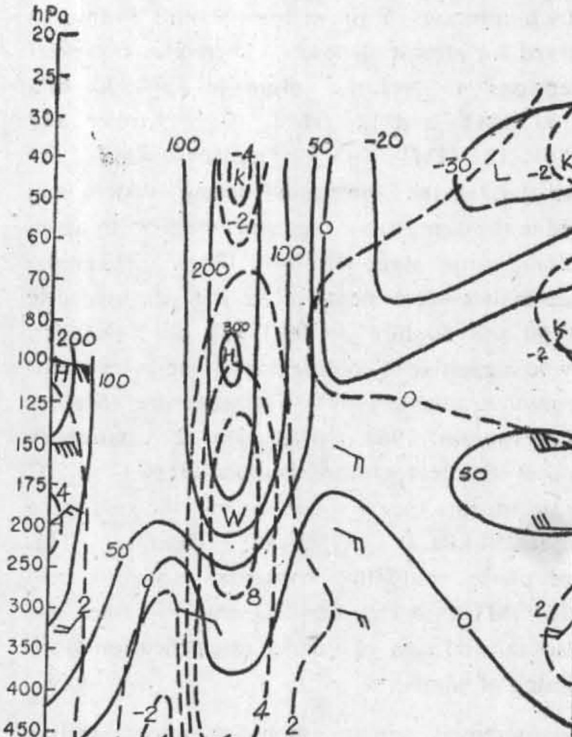


Fig. 4. Vertical north-south cross-section through Vishakhapatnam at 00 GMT of 3 October 1983

system passed over Port Blair, the wind reported at 850 hPa for the station was 250°/50 knots. The circular elliptical characteristics of cloud mass are normally associated with tropical depressions and have been reported as such in Atlantic and Pacific. Therefore, it could be possible that the system was infact a depression right from 29 September onward and missed naming so in the absence of data over sea.

4. Structure of the cyclonic storm

Different charts and vertical sections were prepared for various parameters through the storm. These are presented in the following paragraphs.

4.1. Time section of Vishakhapatnam for temperature and geopotential anomalies

This time section has been prepared from 00 GMT of 1 October to 12 GMT of 5 October (Fig. 3). The normals used were the mean values of temperature and geopotential heights prepared for 50 hPa height intervals based on radiosonde (audiomodulated A-type) data available upto 1975 separately for 00 GMT and 12 GMT observations. Positive temperature anomalies are observed for almost all levels. There are, however, two exceptions : (1) Negative anomalies at 950 hPa level at 00 GMT and 12 GMT of 2 October and again at 12 GMT of 3 October, which are suggestive that in the lowermost levels, system was cold cored in the depression stage and could be so again in its cyclonic storm stage (Holland 1984). (2) Temperature anomalies were negative in the stratospheric levels of 60 and 50 hPa on 00 GMT of 3 October. This may be suggestive of cooling due to the over shooting of cumulonimbus clouds into stratosphere (Malkus 1959, Koteswaram 1967, Mukherjee & Chaudhury 1979). From the temperature isolines drawn at 2°C intervals, it appears that a maximum in the warming appeared at 250 hPa at 12 GMT of 3 October. This maximum phase gradually propagated down to 850 hPa by 12 GMT of 4 October. During this time the storm also showed sign of further intensification from strengthening of winds.

The geopotential height anomalies were negative below 400 hPa and positive above. Their minimum lay in the lower troposphere centred around 900 hPa. Their maximum first appeared at 100 hPa with the formation of cyclonic storm. It later descended to 150 hPa with a significant rise of value (from 292 gpm to 422 gpm) on 12 GMT of 4 October. The maximum in gpm heights lies above the maxima in temperature anomalies. This is in keeping with the hydrostatic phenomenon.

4·2 *Cross-section of 00 GMT on 3 October 1983*

Fig. 4 gives the north-south vertical cross-section of the temperature and geopotential height anomalies through Vishakhapatnam. The core of the cyclonic storm is warm throughout the vertical column between 950 hPa & 700 hPa, with maxima in the warming lying at 250 hPa (+11°) in upper troposphere and at 800 hPa (+8°C) in lower troposphere. A relative maximum in warming lies in the mid-tropospheric levels of 600 hPa to 550 hPa (+4.5°C). The warming is mostly confined around Vishakhapatnam. It gives the suggestion that warming in a cyclonic storm is not an extensive phenomenon and may be visible only at a station lying within its core. The figure is similar to the Fig. 2.11 of Anthes, (1982), in which the warm core extends from 10 km to 30 km on either side of the centre of cyclonic storm

TABLE 2

Computation of outflow jet core wind at 100 hPa at 00 GMT of 3 October 1983

Station	Initial wind (m/sec)	Additional zonal velocity (m/sec)	Computed wind (m/sec)	Observed value of wind (m/sec)
Vishakhapatnam				
(17.7 Deg. N)	—10	—	—	—
Madras				
(13 Deg. N)	—10	—20	—30	—30

Minus sign stands for easterly wind

with maximum of positive temperature anomalies located at 250 hPa. Temperature anomalies are positive throughout the vertical column over Madras also, with maximum of 4.5°C located at 200 hPa. There is an intervening region of negative temperature anomalies over Machilipatnam.

Negative height anomalies below 400 hPa extend from Madras to Gauhati. This is suggestive of an extensive effect of the cyclonic storm on a scale of 1300 km. The minimum in negative anomalies of 105 gpm lies at 900 hPa over Vishakhapatnam. Positive anomalies are observed above 400 hPa with maximum of 300 gpm at 100 hPa over Vishakhapatnam. Over Madras positive anomaly maximum of 210 gpm lies at 125 hPa. Both over Vishakhapatnam and Madras the temperature anomaly maxima are over-lain by geopotential height maxima. But, whereas, the warming observed in the upper tropospheric levels over Vishakhapatnam at 250 hPa is due to convection, that observed over Madras at 200 hPa is due to subsidence.

4.3. *Outflow jet maximum over Madras*

Maximum positive anomaly of 300 gpm is observed over Vishakhapatnam at 100 hPa. This will, therefore, be the level of maximum upper air divergence over the cyclonic storm at 00 GMT of 3 October. A jet maximum forms from this outflow over Madras which can be explained with the help of conservation of angular momentum equation :

$$\triangle V = \frac{\Omega R\,(\cos^2\phi_1 - \cos^2\phi_2)}{\cos\phi_2}$$

when an air particle moves from the latitude of Vishakhapatnam (17°43′) N to the latitude (13° N) of Madras (Ranjit Singh 1985). The computed and observed values are given in Table 2. This jet core forms in the southwest

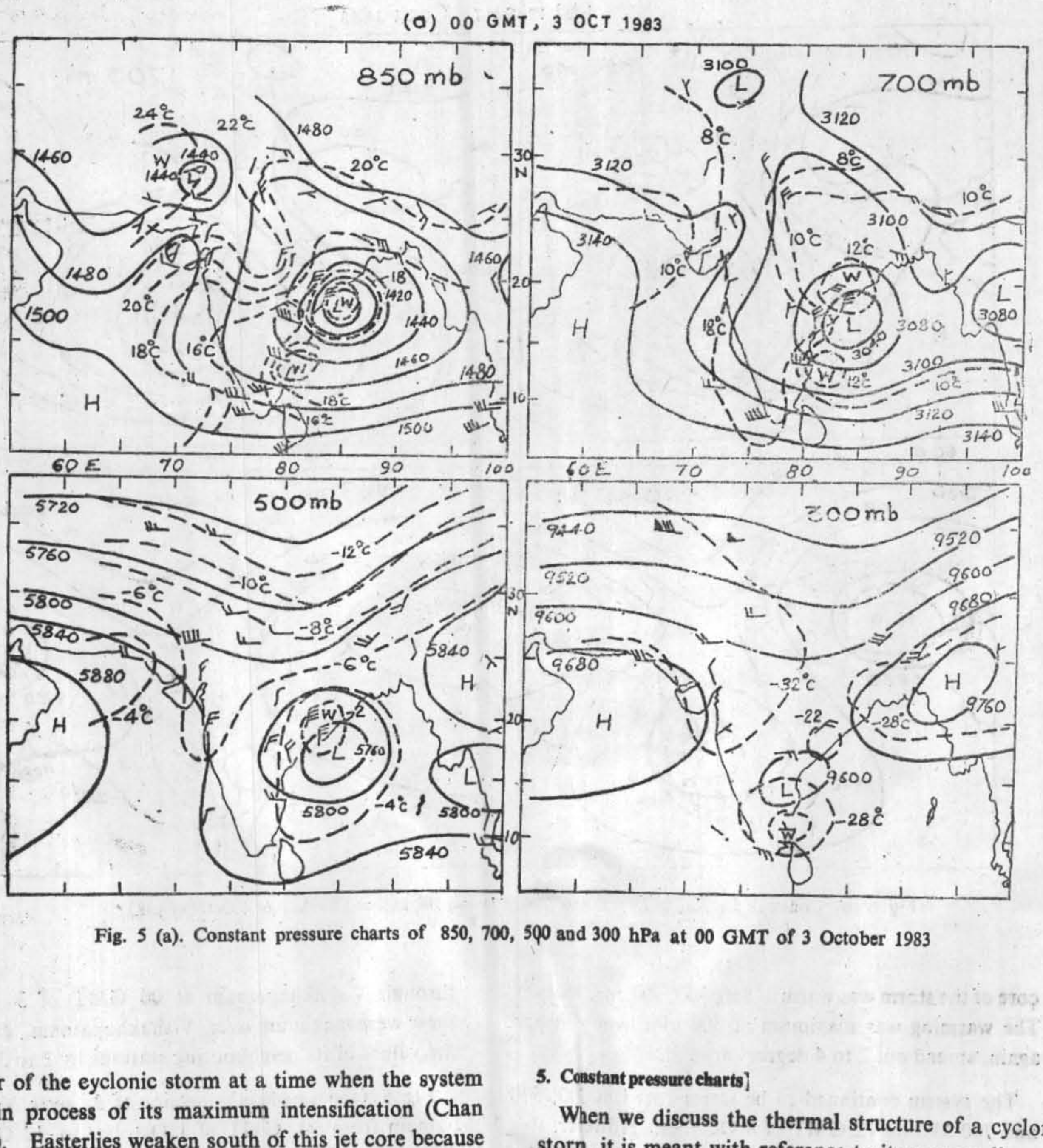


Fig. 5 (a). Constant pressure charts of 850, 700, 500 and 300 hPa at 00 GMT of 3 October 1983

sector of the eyclonic storm at a time when the system was in process of its maximum intensification (Chan 1985). Easterlies weaken south of this jet core because of the subsidence over Madras which is manifested by the rise of gpm height and temperature anomalies over the station. In a similar way westerlies increase in the northeast sector of the cyclonic storm at 00 GMT of 3 October. This increase in the westerlies occurs north of the subtropical anticyclone (STA). The STA strengthens under the subsidence arm of Hadley cell circulation, thereby increasing the outflow wind. The ridge axis in the anomalies slopes down both south and north *from Vishakhapatnam. The outflow wind* maxima are observed over Madras and Gauhati to lie over this ridge axis.

5. Constant pressure charts

When we discuss the thermal structure of a cyclonic storn, it is meant with reference to its surroundings on horizontal or constant pressure surfaces (Fig. 5). The system was a cyclonic storm from 00 GMT of 3 October to 12GMT of 4 October. It was warm cored at 850 hPa over sea at 00 GMT of 3 October. Warming was more concentrated to the northwest of system at 700 hPa and 500 hPa. The cyclonic circulation at 300 hPa was located south of Vishakhapatnam where a maximum warming (Temperature = —18°C) was observed north of the circulation compared to its surroundings. It was at this time that an outflow easterly jet core formed over Madras. The 12 GMT ascent of Vishakhapatnam on 3 October was a partial failure. At 00 GMT of 4 October

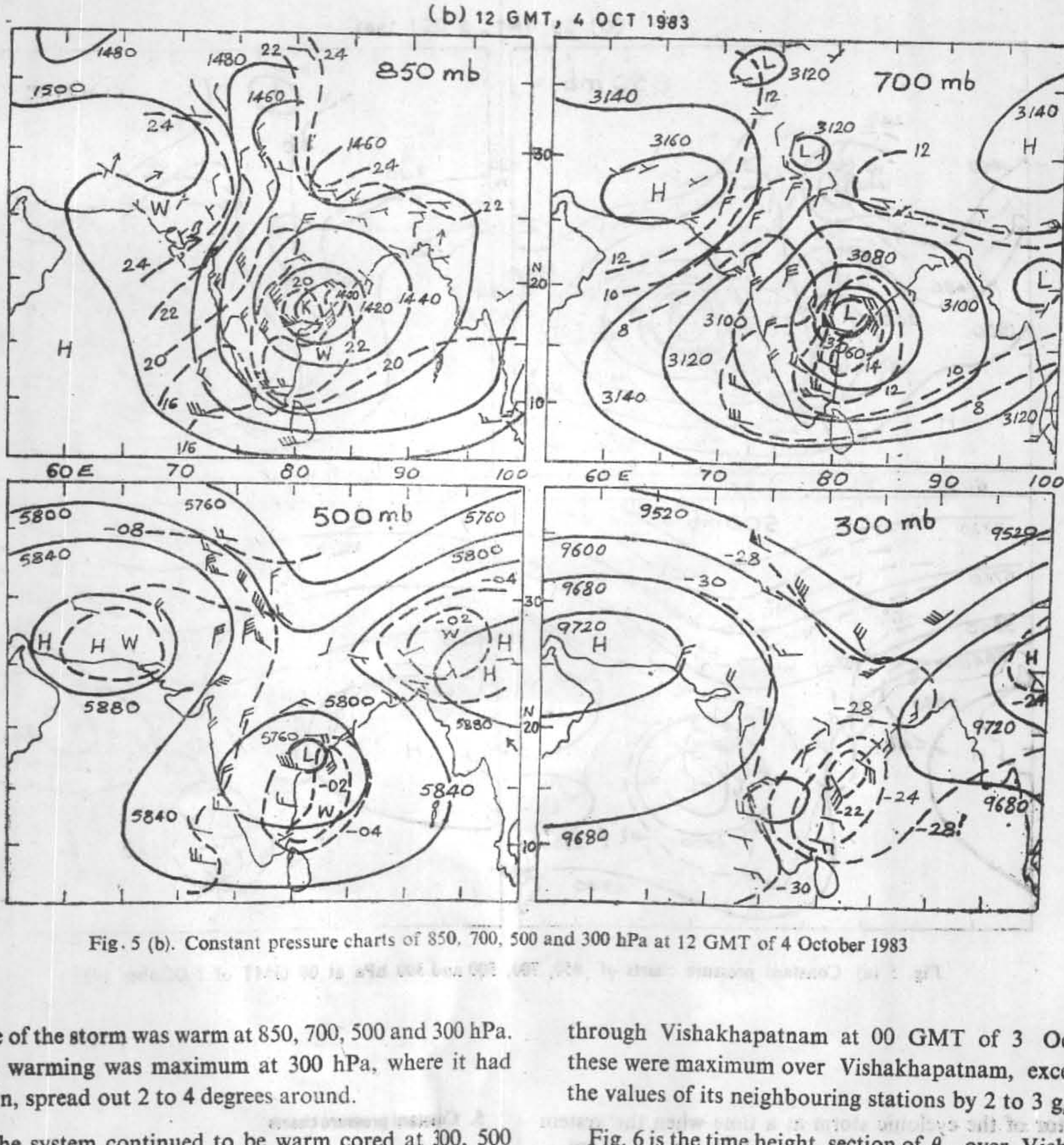


Fig. 5 (b). Constant pressure charts of 850, 700, 500 and 300 hPa at 12 GMT of 4 October 1983

core of the storm was warm at 850, 700, 500 and 300 hPa. The warming was maximum at 300 hPa, where it had again, spread out 2 to 4 degrees around.

The system continued to be warm cored at 300, 500 and 700 hPa on 12 GMT of 4 October. However, this warming spread out more to the south. At 850 hPa temperature field was distorted. Core became cold in its western sector where under thermal wind effect strong westerlies of 240°/65 knots and 280°/55 knots were observed at 850 and 700 hPa forming the low level jet (LLJ) core (Holland 1984).

6. Equivalent potential temperature

Equivalent potential temperature θ_e serves as a measure of heat of the parcel of air and depends both upon the temperature and mixing ratio of the parcel. On the south-north cross-section of mixing ratios through Vishakhapatnam at 00 GMT of 3 October these were maximum over Vishakhapatnam, exceeding the values of its neighbouring stations by 2 to 3 g/kg.

Fig. 6 is the time height section of θ_e over Vishakhapatnam from 00 GMT of 1 October to 12 GMT of 5 October. Two maxima in θ_e, one located in the lower tropospheric levels between 850 hPa & 700 hPa and the other in the upper troposphere located at 300 hPa level formed an important feature of the vertical distribution of θ_e between 00 GMT of 3 October and 12 GMT of 4 October. These were separated by a relative minimum in the mid-tropospheric levels of 600-500 hPa. Similarly on the north-south cross-section of θ_e through Vishakhapatnam (Fig. 7), there were two maximum of θ_e, one located at 800 hPa and the other at 300 hPa over Vishakhapatnam, the former being more pronounced than the latter. The occurrence of this feature

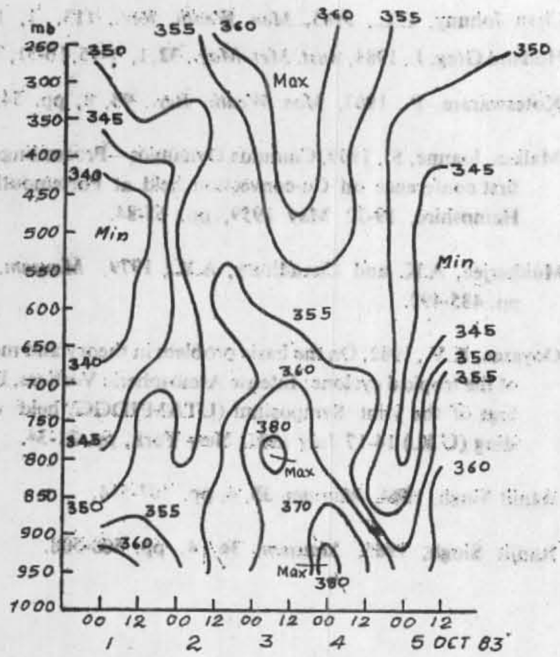


Fig. 6. Vertical time section of Vishakhapatnam for equivalent potential temperature, θ_e(°K)

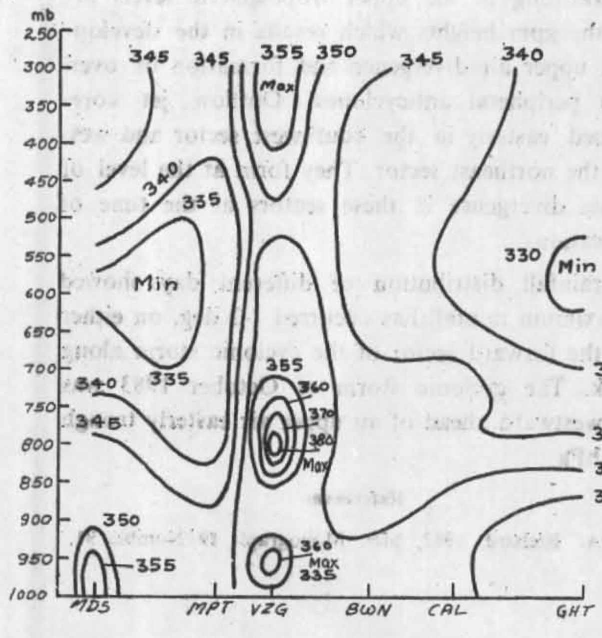


Fig. 7. North-south cross-section through Vishakhapatnam for equivalent potential temperature

with the level of minimum in θ_e in the middle troposphere is significant of the fact that the lower troposphere was convectively unstable at the time of intensification of the system into a cyclonic storm and a maximum transfer of energy took place from lower to upper troposphere at this time. Convective instability, therefore, forms the main mechanism of development for the cyclonic storms in tropics. The distribution of θ_e in Fig. 7 is also suggestive that the effect of the release of latent heat in the cyclonic storm was mostly confined to the immediate neighbourhood of the central region of the core. Both these Figs. 6 and 7 are very similar to the Fig. 2.13 of Anthes (1982).

7. Rainfall distribution and the steering current

The 24-hourly rainfall distribution as recorded at 03 GMT of 4, 5 and 6 October 1983 are shown in Fig. 1. 10-15 cm of rainfall was recorded at stations, 1-2 degree on either side of the track. Rainfall of 20-25 cm was recorded within ½-1 deg. on either side of the track. This area of maximum rainfall extended 2-3 degrees in the front sector along the direction of movement of system. Rainfall decreased when the system weakened into a depression. However, 10-12 cm of rainfall still occurred within 1-2 deg. on either side of the track with maximum concentration in the direction of movement of the depression. The cyclonic storm was steered westward ahead of an easterly trough at 200 hPa. Northerlies in the rear of westerly trough at 500 hPa and 300 hPa prevented it from taking a northerly course.

8. Discussion and conclusion

From the foregoing observations, it appears that the initial inception of a mid-tropospheric circulation and/or the low pressure area on the sea surface takes place in an area of a pre-existent cloud disturbance.

During the process of intensification, an intense warming is generated at the time of formation of cyclonic storm. The maximum in warming first appears in the upper tropospheric levels of 300 hPa and 250 hPa. The maximum phase gradually descends to lower tropospheric levels. The warming in the lower troposphere lowers the surface pressure and the gpm heights inside the core region, which favours an increased inward flow of the low-level air. The lower tropospheric circulatory winds, therefore, increase due to inward radial advection of angular momentum. The cyclonic circulation slopes southward with height in the upper tropospheric levels and is located in the relatively cooler region at 300 hPa. This southward displacement is due to the easterly component added up over station under thermal wind effect.

The warming in the upper tropospheric levels increases the gpm heights which results in the development of upper air divergence and formation of overlying or peripheral anticyclones. Outflow jet cores are formed, easterly in the southwest sector and westerly in the northeast sector. They form at the level of maximum divergence in these sectors at the time of intensification.

The rainfall distribution of different days showed that maximum rainfall has occurred 1-2 deg. on either side in the forward sector of the cyclonic storm along its track. The cyclonic storm of October 1983 was steered westward ahead of an upper air easterly trough at 200 hPa.

References

Anthes, A., Richard, 1982, Met. Monograph, 19, Number 91.

Chan Johnny, C.L., 1985, *Mon. Weath. Rev.*, 113, 1, 106-116.

Holland Greg, J., 1984, *Aust. Met. Mag.*, 32, 1, 1-15, 16-31, 33-46.

Koteswaram, P., 1967, *Mon. Weath. Rev.*, 95, 8, pp. 541-564.

Malkus Joanne, S., 1959, Cumulus Dynamics—Proceedings of the first conference on Cu-convection held at Portsmouth, New Hempshire, 19-22 May 1959, pp. 65-84.

Mukherjee, A.K. and Chaudhury, A.K., 1979, *Mausam*, 30, 4, pp. 485-492.

Ooyama, K.V., 1982, On the basic problem in theory and modelling of the tropical cyclone; Intense Atmospheric Vortices, Proceedings of the joint Symposium (UTAM/IDGG) held at Reading (U.K.) 14-17 July 1981, New York, pp. 21-34.

Ranjit Singh, 1984, *Mausam*, 35, 4, pp. 507-514.

Ranjit Singh, 1985, *Mausam*, 36, 4, pp. 503-508.