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Cyclone movement

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ABSTRACT. Utility of (1) isallobaric gradient from the storm centre and (2) warm advection in the lower troposphere in the storm field in guiding the direction of movement of two cyclonic storms in October and November 1971, when they were out at sea over the Bay of Bengal, is illustrated in this paper.

1. Introduction

Timely warnings based on correct tracking of cyclones which originate over the data gap sea areas and strike the coastal regions of our country is the most rewarding national duty of our meteorological services. Many a sophisticated method for tracking these storms, such as satellite pictures and aircraft reconnaissance reports are available for this purpose at the present times. These methods, no doubt, fix the centres of these systems at fixed times, but they have very limited forecasting capability based on meteorological data.

That low pressure systems move in the direction of maximum isallobaric gradient from their centres needs no emphasis. It is also well established that once formed, cyclones are largely maintained and steered by warm advection in its field in the lower troposphere (Sutcliffe 1947, Petterssen 1956). It is the purpose of this paper to illustrate simple methods for obtaining these two reliable guides for tracking the cyclones while they are over data gap ocean areas. Cases chosen for study are the two recent severe cyclones in the Bay of Bengal—Paradeep cyclone of 30 October 1971 and Chittagong cyclone of 6 November 1971. Their tracks are given in Fig. 1. The track of another cyclonic system which crossed north of Visakhapatnam in the afternoon of 15 October 1971 is also shown in this diagram.

2. Isallobaric field

The method for mapping out the 24-hour isallobaric field around the storm over the ocean area is direct and simple. After drawing the isobars around the storm/depression as accurately as possible, on the basis of all available data, the current chart is superposed over the chart 24 hours earlier and the value of the isobar on the earlier chart is subtracted from the isobar on the current chart at their intersection points. To maximise these values, isobars are drawn at 1 mb interval on both charts. The central pressure P_o (mb) of the system as obtained from Fletcher's (1955) formula $V_m = K\sqrt{P_e - P_o}$, where V_m is the maximum wind (knots) obtained from the nomogram for categorisation of the system by satellite picture, P_e is peripheral pressure and $K=16$, a constant for tropical areas, can be incorporated in the isobaric analysis, if desired. Isallobars are then drawn over the sea areas, taking into account these differences at the isobaric intersection points over the ocean area, as well as the 24-hour pressure changes reported by the coastal stations. Figs. 2 (a-c) and 3 (a-b) represent the isobars (full lines) and the corresponding 24-hr isallobars (dotted lines) at one millibar interval for some crucial dates/times in the case of Paradeep and Chittagong severe cyclones respectively. The dash-dot lines in Fig. 2(a) represent the isobaric field 24 hours earlier for the purpose of illustration of the method described above.

Isallobaric gradient — From the above charts, the direction of the isallobaric gradient is calculated by keeping the origin O of a finite difference grid of length $H = 200$ km shown in Fig. 4 to coincide with the 'low' centre. It will be seen that, if b is the isallobar,

$$\frac{\triangle b}{\triangle x} = -\frac{b_a - b_c}{H} \quad \text{and} \quad \frac{\triangle b}{\triangle y} = -\frac{b_b - b_d}{H}$$

so that θ, the direction of isallobaric gradient from the x-axis (east) is obtained from the relation :

$$\tan\,\theta = \left(\frac{\triangle b}{\triangle y}\right) \Big/ \left(\frac{\triangle b}{\triangle x}\right)$$

These values at the corresponding times are given in Table 1. The direction of the isallobaric gradient from the pressure centre at these hours, as given in Table 1, is indicated by short arrow heads alongside the tracks in Fig. 1. The correspondence of the direction of the isallobaric gradient at the above hours and the actual subsequent movement of the storms, as can be seen from Fig. 1 is striking.

Fig. 1 shows that the system which crossed north of Visakhapatnam in the afternoon of 15 October 1971 had a significant change of course, from NW to N as a depression on land from 03 GMT of 16th. Figs. 5 (a-b) show the 24-hr isallobaric field as reported by the land stations at 0300 and 1200 GMT respectively of this day. The directions of the isallobaric gradient from the corresponding pressure centres at these times, as given in the bottom rows of Table 1 a.e shown by short arrows in Fig. 1. The movement of the system in accordance with the direction of the isallobaric gradient from the pressure centres is as much convincing when this system was over land, as in the case of the Paradeep and Chittagong severe cyclones, while they were out at sea. This lends support to the dependability of the isallobaric field over the sea areas, obtained by the method outlined in para 2 above.

3. Warm advection

In an earlier study, the importance of warm advection as revealed by contour/thickness solencids at 500 mb surface for the steering of cyclones, was pointed out by one of us (George 1953). It was further confirmed in a subsequent study (Koteswaram and George 1958). In Figs. 6(a-d) and 7 (a-d), we present the vertical wind shears (thermal winds) between 0·9 km and 5·8 km a.s.l. for the Paradeep and Chittagong cyclones respectively, on certain days, when they were out at sea. Relative streamlines delineating warm/cold regions are drawn in full lines and the cyclonic wind circulation at 0·9 km a.s. l. around the pressure centres at the relevant times are shown by concentric circles in pecked lines. These provide a quick and ready method of assessing the zones of warm advection in the storm field. Areas of warm advection as revealed by the appropriate solenoids between these two sets of flow lines are shaded in these diagrams.

It may, however, be mentioned that the above areas of warm advection are only qualitative, in as much as the actual thickness gradient represented by the spacing of the relative flow lines of the shear wind is indicated only in a qualitative way; furthermore, the horizontal variation of wind speed in the actual circulation at 900 m a. s. l. around the pressure centre also has not been taken into account. In so far as these variables in a data gap ocean area can at best be only inferred as 'guess' values, it is highly improbable if the 'objective' numerical method of quantitative evaluation of the gradient of warm advection, would be more fruitful than the above qualitative assessment of warm advection. Nevertheless, it is clear that the storm moved into the region of warm advection from that of cold advection in its field.

4. Concluding remarks

We have shown how the cyclones moved in the direction of the isallobaric gradient from their centres while they were out at sea, as well as (by one confirmatory example), when the system was over land. This is a simple and practical method of forecasting movement of cyclone centres.

In the same way warm advection which feeds and maintains the cyclone and moves them both at sea and over land can be assessed when the system is over ocean areas by the method shown above. The authors hope that, these two forecasting tools for predicting cyclone movement will be found useful by the Storm Warning Centres.

As regards speed of movement of the cyclones based on kinematics, it was found that the magnitudes obtained were far too low to be encouraging, as the computation could be done only with the help of 24-hour isallobars in the above cases. However, except in cases of recurvature, simple extrapolation of the speed noticed earlier, modified as necessary by other prevailing meteorological factors, may not present much problem in this respect.

Acknowledgement

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TABLE 1

Direction of movement based on direction of isallobaric gradient from centre of pressure system

Date (1971)	Time (GMT)	$200\frac{\triangle b}{\triangle x}$	$200\frac{\triangle b}{\triangle y}$	$\tan\theta$	θ from x-axis	Direction of movement of pressure centre
28 Oct	0300	−1·0	2·3	−2·3	−66°	336° (NW)
	1200	−0·8	1·4	−1·7	−59°	329° (NW)
29 Oct	0300	−0·7	1·1	−1·4	−55°	325° (NW)
5 Nov	0300	−0·6	1·2	−2·0	−64°	334° (NW)
	1200	0·8	0·4	0·5	27°	63° (ENE)
16 Oct	0300	−0·8	5·0	−6·2	−81°	351° (NNW)
	1200	−0·1	2·4	−24·0	−88°	358° (N)

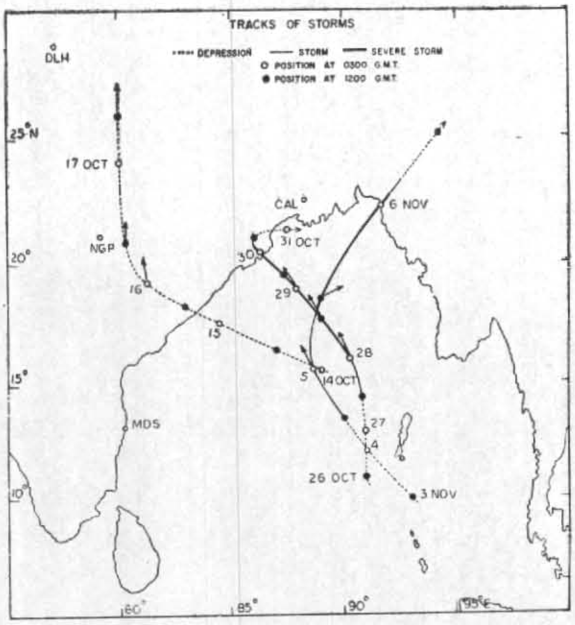


Fig. 1

Tracks of storms

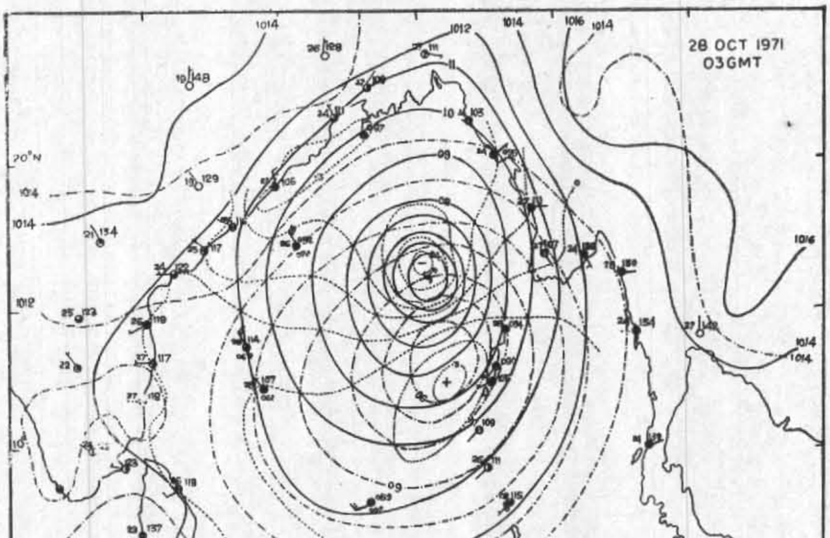


Fig. 2(a)

24-hr Pressure Changes at 03 GMT on 28 October 1971 (dotted lines), current isobars (continuous lines) and isobars 24-hr earlier (dash-dot lines)

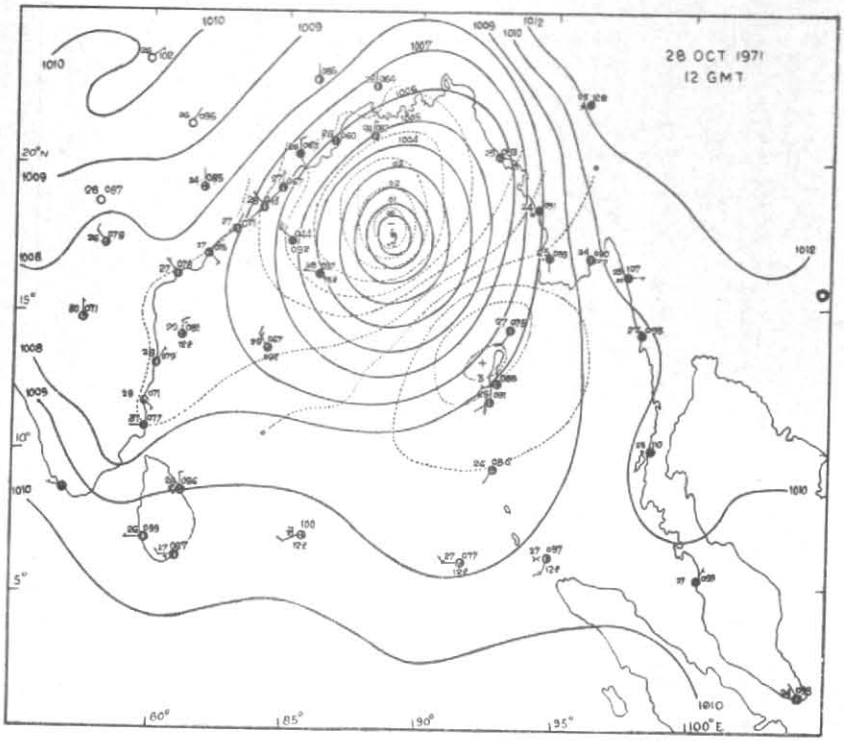


Fig. 2(b)

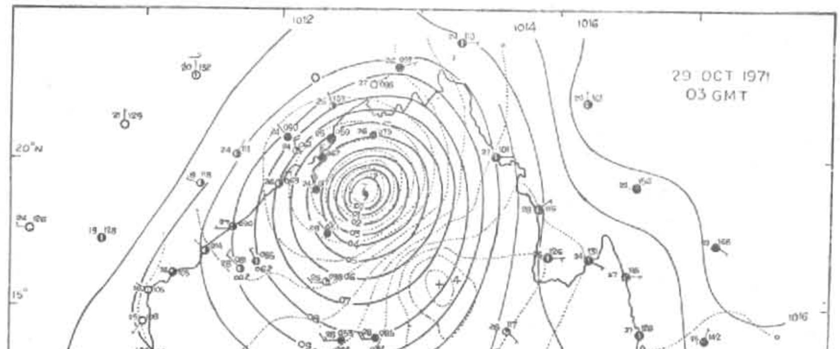


Fig. 2(c)

24-hr Pressure Changes (dotted lines) and current isobars (full lines)

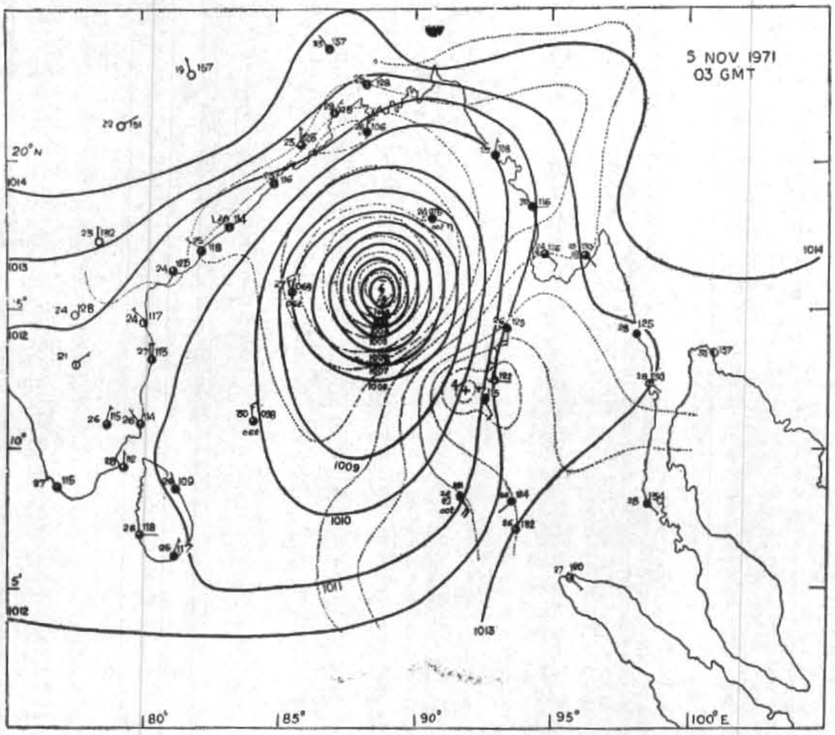


Fig. 3(a)

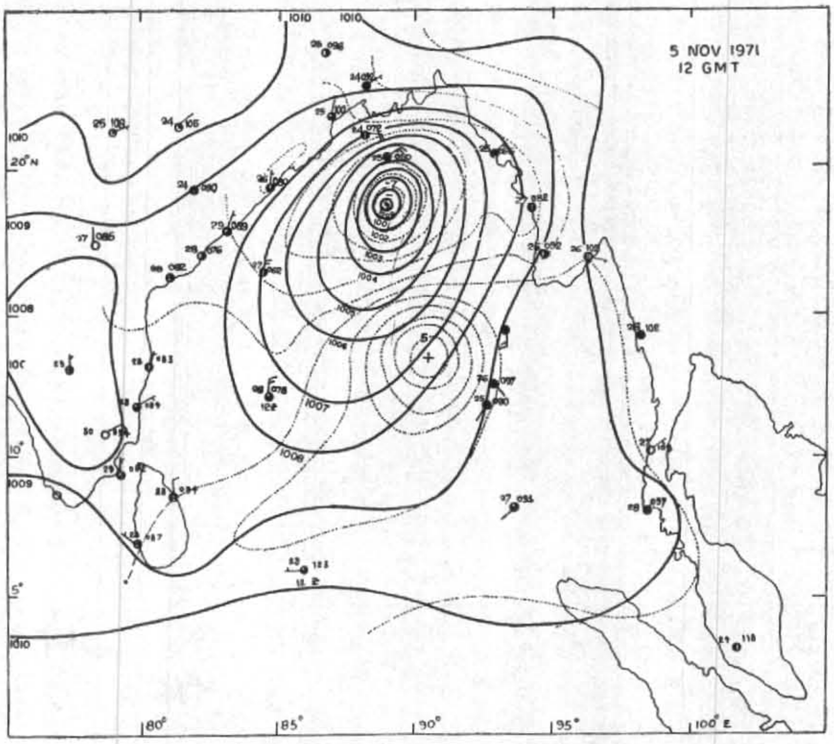


Fig. 3(b)

24-hr Pressure Changes (dotted lines) and current isobars (full lines)

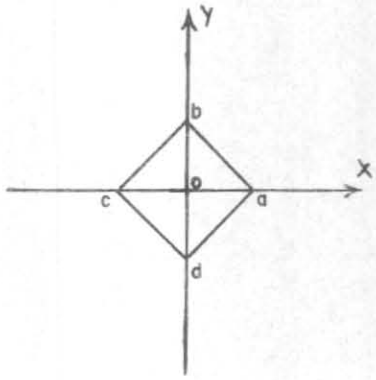


Fig. 4

Grid length $H=200$ km at Lat. 20° N on W3 Chart

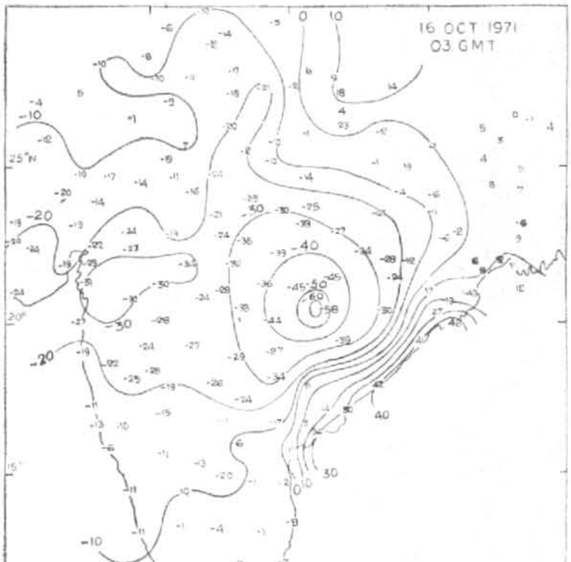


Fig. 5 (a)

24-hr isallobars

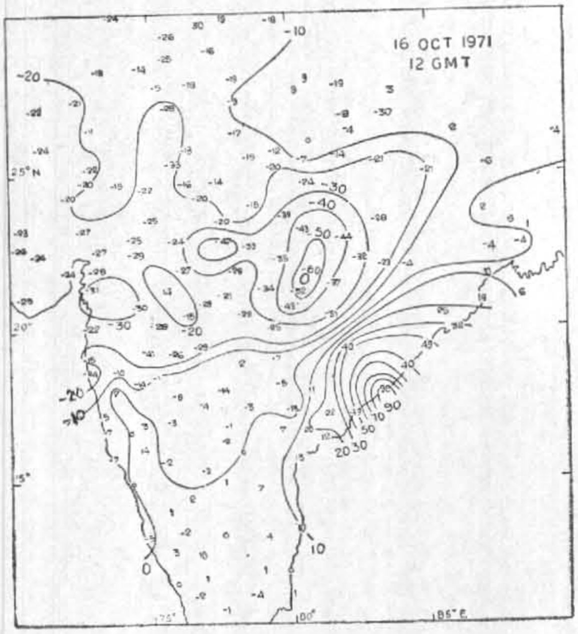
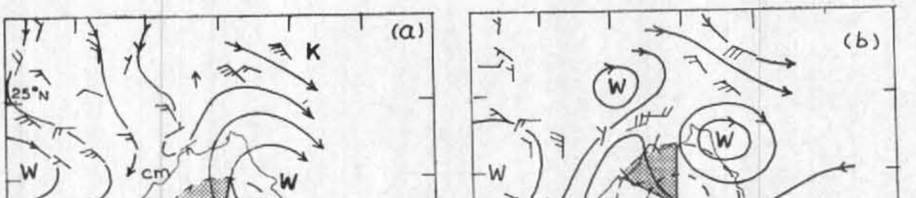


Fig. 5(b)

24-hr isallobars



28 OCT 1971, 00 Z

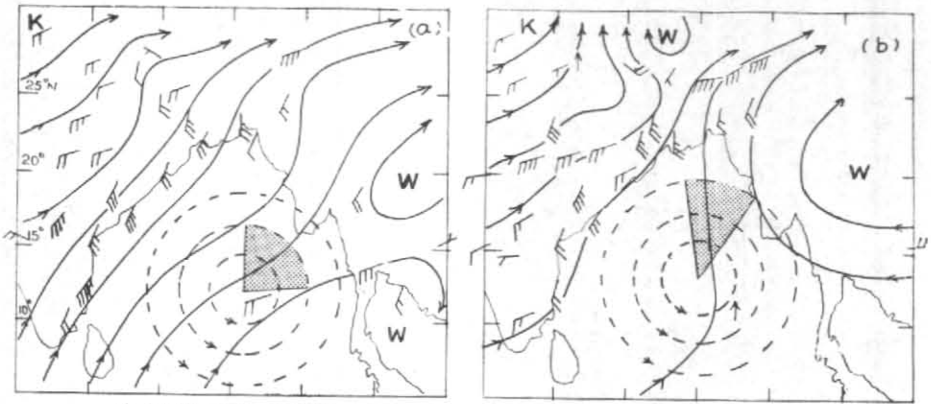
28 OCT 1971, 12 Z

29 OCT 1971, 00Z

29 OCT 1971, 12 Z

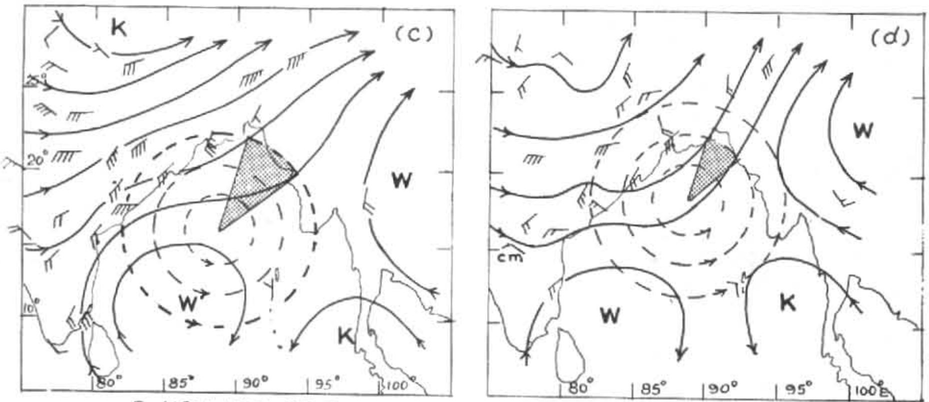
Fig. 6

0.9∼5.8 km Shear Wind



4 NOV 1971, 00 Z

4 NOV 1971, 12 Z



5 NOV 1971, 00 Z

5 NOV 1971, 12 Z

Fig. 7

0·9∼5·8 km Shear Wind