

# Can we utilise upper tropospherical winds for tracking storms in the Bay of Bengal ?

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**ABSTRACT.** In this study, the tracks of eleven cyclonic storms in the Bay of Bengal have been examined with a view to finding out if upper winds alone in the vicinity of the centre of cyclonic storms, could be useful in prognosticating the movement of these storms. By smoothed analysis of zonal ( $u$ ) and meridional ( $v$ ) components of the upper winds over various stations, the wind velocity for standard levels have been computed corresponding to the sea level position of the storm. The winds thus computed for various levels have been discussed from the point of view of their operational use in forecasting the movement of Bay storms. The limitations of such computations have also been brought out.

## 1. Introduction

One of the major responsibilities of a weatherman is to correctly and precisely track a cyclonic storm, and issue storm warnings. A number of techniques have been adopted in India and elsewhere to track the storms. Riehl (1954) has discussed in details, various methods of forecasting the movement of tropical storms. George and Datta (1965) has utilised a few techniques such as (a) high level steering, (b) warm tongue analysis, (c) troughs in mid-latitudes westerlies, and (d) shift of the rainfall belt, for depicting the movement of a tropical depression from the Bay of Bengal. Desai and Rao (1955) and Ananthakrishnan and Bhatia (1958) have emphasised the role of sub-tropical high pressure cell in deciding the movement of cyclonic storms. Koteswaram *et al.* (1960-61) have pointed out that the tracks of tropical depression over India (monsoon depressions) generally skirt the upper air anticyclone over north India and Tibet. Datta (1967) while discussing the May cyclonic storm in the Bay of Bengal has also highlighted the role of subtropical anticyclone in the upper troposphere. Ramaswamy (1967) has shown from synoptic examples how deep troughs in westerlies in the upper troposphere (300 mb) alter the configuration of the high over Tibet and northern India and consequently low latitude cyclonic systems which ordinarily move westnorthwestward curve to the north or northeast. Rai Sircar (1958) and Ray Choudhury *et al.* (1959) have given exhaustive climatology of storms in the Bay of Bengal and Arabian Sea respectively. Rai Sircar has also indicated the probability of movement of a tropical storm in a particular direction depending upon the location of the area of formation and

present position of the tropical storm for various months.

Objective methods based on non-divergent barotropic model and Estoque's baroclinic model have also been tried for tracking tropical depressions in the Bay of Bengal by Das (1958). To circumvent the difficulty caused by lack of geostrophic control at low latitudes Datta and Pradhan (1968) have utilised a graphic integration technique based on the equations of motion as suggested by Grimes (1958).

Sadler (1962) and Kulshreshtha and Gupta (1966) have utilised TIROS pictures for studying the movement of tropical storms in the Indian areas.

In the present study, keeping in view the limitations of availability of data in application of the various above mentioned techniques it is attempted to study the movement of the tropical storm in the Bay of Bengal based only on the upper wind data of the stations over the east coast of India, and coastal Burma and over Port Blair. In short the present paper is an attempt to study the utility of upper winds (though meagre) in forecasting the movement of tropical storms in the Bay of Bengal.

## 2. Data used

The present study has been confined to the life history of eleven storms (Table 1) in the Bay of Bengal. The number of storms and their period is just based on the convenience of the availability of data. The selection may be considered more of a random type. Upper winds for the

TABLE 1  
Cyclonic storms in the Bay of Bengal

Year	Period
1962	May 15—16
1962	Oct 28—31
1962	Nov 27—30
1963	Oct 20—21
1965	May 30—Jun 1
1965	Dec 31—Jan 3, 1966
1966	Sep 28—Oct 1
1966	Nov 2—3
1966	Nov 9—10
1966	Nov 19—22
1966	Nov 27—28

general levels corresponding to 500, 400, 300, 250 and 200 mb for Port Blair and other stations over the east coast of India and coastal stations of Burma have been utilised for the study. The track of the storms are based on *Indian Daily Weather Reports* published by India Meteorological Department. The relevant upper wind data has been taken from the scrutinised records of the India Meteorological Department.

### 3. Method of analysis

As already indicated the attempt in the present study is to make best use of upper winds which in a way means to locate the level (radially above the centre of the storm), the winds at which could guide in prognosticating the movement of the tropical storm. The upper wind chart for the various levels were prepared and for each level the approximate velocity of the wind corresponding to the centre of the storm at various levels was calculated by streamline and isotach analysis. To make this analysis less subjective, the zonal ( $u$ ) and meridional ( $v$ ) components of the winds at different levels were calculated. Based on the isolines of  $u$  and  $v$ , the wind corresponding to points vertically above the storm centre at various levels were computed for different synoptic observations. It was however found that in almost all the tropical storms circulation extended upto 400 mb or above and winds determined for levels 500 and 400 mb were in most cases unrepresentative of the corresponding movement of the storm. This may also explain the well known definition of steering level, which is defined as the height at which the cyclonic

circulation of the storm has virtually disappeared (Dunn 1960). Therefore, the description of levels 400 mb and below has been excluded in the present study.

### 4. Discussions

The tracks of the storms along with the spot winds computed for various synoptic observations radially above the positions of centres of storms for 300, 250 and 200 mb are plotted in three different sets of charts as shown in Figs. 1 to 5. In order to minimize the number of figures, tracks of more than one storm have been included in one figure wherever possible. It may be broadly seen that, in most of the cases one or the other of the three levels could be utilised in prognosticating the movement of the storm with a certain degree of success. To make the discussion a little more elaborate and to bring out limitations of such analysis because of lack of upper air data, the storms have been briefly discussed, separately in the following paragraphs.

4.1. *Storm of 15-16 May 1962*—The track of the storm along with the computed winds for the three levels are presented in Fig. 1. It may be seen that winds at all the levels suggest northwesterly movement of the storm whereas actually the movement had been westerly. On 00 GMT and 12 GMT of 15 May the computation of spot winds for these levels (300, 250 and 200 mb) was based on coastal winds except Madras, since the latter was not available above 400 mb. As the storm was centred nearer to Madras it is anticipated that the computations carried out in the absence of Madras winds could not give good results. For check purpose, if the computations are based on Madras observation of the next hour (00 GMT of 16th) as a first approximation along with the previous (12 GMT of 15th) observations of other coastal stations, 200-mb wind gives westerly movement (which is actual). Other levels (300 and 250 mb) give still northwesterly movement whereas the streamline analysis at these levels indicate a cyclonic circulation.

4.2. *Storm of 28-31 October 1962*—It may be seen from Fig. 1 that as far as the direction of movement of the storm before its recurvature is concerned, winds at all the three levels could be taken as good guiding factor in depicting the future movement of the storm. However after recurvature, viz., between 00 and 12 GMT of 29th, the winds at 300 mb fit in well in giving the actual movement rather than 250 or 200-mb winds. However after 00 GMT of 30th, observations at all the levels give a good fit.

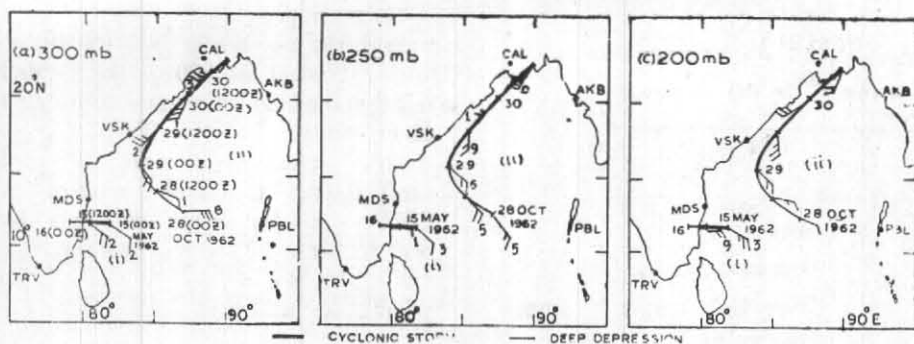


Fig. 1

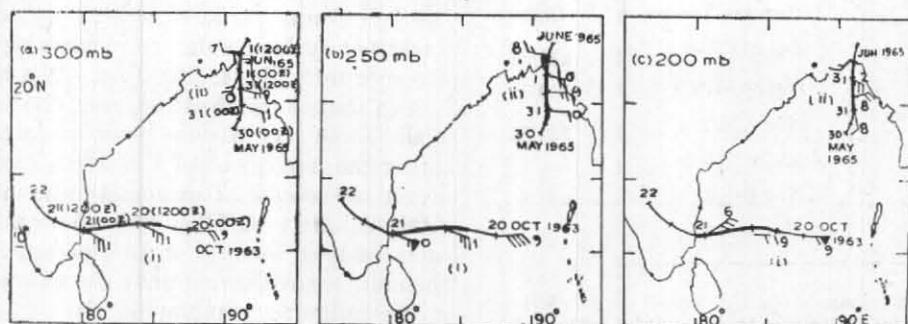


Fig. 2

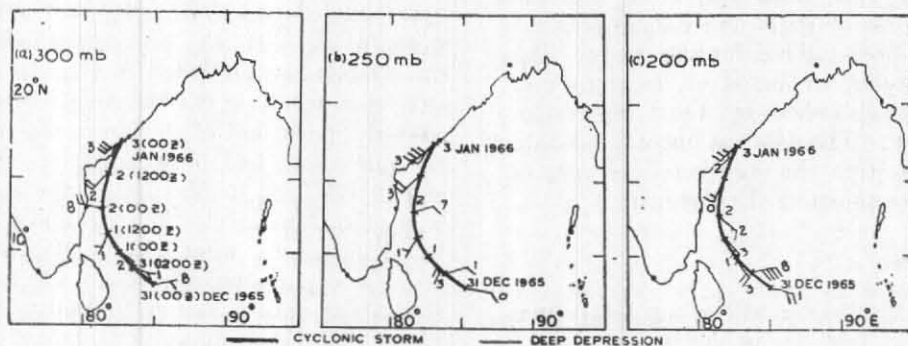


Fig. 3

4.3 *Storm of 27-30 November 1962*—It may be seen from Fig. 4 that based on observations of 00 GMT of 28th of the winds at 300 and 250 mb indicate the actual movement of the storm, whereas 200-mb winds would give some westerly movement. This is probably because of doubtful analysis at 200-mb level, since Port Blair ascent at this hour was not available above 400 mb and it was extrapolated upto 200 mb based on observations over Madras.

On 12 GMT of 28th and later when the storm was approaching east coast, 200 mb observation over Madras seems to guide the movement of the storm, whereas the observations for 250 mb and below would indicate some northward movement.

4.4. *Storm of 20-22 October 1963*—It may be seen from Fig. 2 that all the three levels give good indication of the direction of movement of the storm except the following anomaly. Based on

observations of 00 GMT of 20th the spot winds at 250 and 200-mb levels are 40 and 60 kt respectively, the speed is seem to be too high as compared to the speed of actual movement of the storm between 00 and 12 GMT of 20th. By critical examination it may be seen that for these hours, the computation was based on observations of Madras and Trivandrum only, Port Blair was not available above 400-mb level. Since the centre of the storm was far off from any of the stations for which data is available, the computation based on these data might not indicate the correct picture. The wind direction and speed on various levels based on later wind observations of 12 GMT of 20th and 00 GMT of 21st, when the storm was approaching the east coast, fit in well with actual movement of the storm.

4.5. *Storm of 30 May-1 June 1965*—It may be seen from Fig. 2 that till 00 GMT of 1st, winds at no level could indicate the proper movement

TABLE 2  
Winds (degrees/kt) at different pressure levels  
on 2 January 1966

	Time (GMT)	Winds at pressure levels (mb)		
		300	250	200
Trivendrum	00	270/04	160/10	160/26
	12	210/12	160/25	150/35
Madras	00	280/17	060/10	110/21
	12	210/18	220/13	070/12
Calcutta	00	250/29	270/38	260/57
	12	240/49	250/47	250/52
Port Blair	00	110/32	130/07	150/08
	12	190/31	180/22	090/29

of the storm. This may be probably because the analysis was based on the wind observations at Calcutta and Visakhapatnam which were far off from the centre of the storm. On and after 00 GMT of 1 June as the storm approached the coast, its movement could be indicated by upper winds over Calcutta which changed on all the levels from strong easterlies on 12 GMT of 31st to southerlies on 00 GMT of 1st (*viz.*, at 300 mb it changed from 100°/15 to 170°/17 kt; at 250-mb it changed from 090°/18 to 140°/17 kt and at 200 mb changed from 080°/16 to 140°/17 kt).

#### 4.6. Storm of 30 December 1965-3 January 1966

—As may be seen from Fig. 3 winds at all the three levels were generally indicating correct direction of movement of the storm except on 12 GMT of 31st for 250 and 200-mb levels and on 00 GMT of 2nd for all levels. The probable reason for the same is explained below—

(a) On 12 GMT of 31st the computed winds at 250 and 200-mb levels vertically above the centre of the storm is 080°/10 kt and 080°/40 kt whereas corresponding wind at 300 mb is 110°/5 kt. This may either indicate that 300-mb wind guided the movement or the analysis is doubtful for 250 and 200-mb levels in absence of Port Blair observations on 00 and 12 GMT of 31st.

(b) On 00 GMT of 2nd the direction of movement of the storm was northwards but the corresponding computed wind was 280°/18 kt at 300 mb, 080°/10 kt at 250 mb and 120°/20 kt at 200 mb. A marked change in the wind field on various levels between 00 and 12 GMT of 2nd (Table 2) is of interest in this connection.

Thus compared with the wind field on 00 GMT of 2nd, there was a general southerly sweep along the east coast at 300 and 250-mb levels on 12 GMT of 2nd and a marked anticyclone over Bay of Bengal on 200 mb. The unrepresentative directions indicated at various levels based on 00 GMT of 2nd may lead one to think that on 00 GMT of 2nd the system was in a transitory stage and the transition was complete by 12 GMT of 2nd. On and after 12 GMT of 2nd the upper wind observations at all the three levels indicated the correct movement of the storm.

4.7. Storm of 28 September-1 October 1966—The track of cyclonic storm with computed spot winds is shown in Fig. 4. It may be seen that the spot winds based on observations of 00 GMT of 28th to 00 GMT of 30th, do not indicate the actual movement of the storm for 300 and 250 mb. However 200-mb winds are found to be more representative. On 12 GMT of 30th, winds at all the levels are almost equally representative. From the general streamline analysis for various levels (not presented) it seems that in the earlier period the circulation extended right upto 300 mb with well marked trough at 250 mb in the area of tropical storm. At 200 mb, winds, specially over Visakhapatnam and Calcutta, indicate a marked anticyclonic circulation which has been steering the storm for the period.

4.8. Storm of 2-3 November 1966—The track of the storm and computed spot winds vertically above the storm centre are shown in Fig. 5. This storm moved at a high speed (about 20 kt) between 2 and 3 November. It may be seen from the figure that the winds at 250 and 200 mb gave good indication of the movement of the storm.

4.9. Storm of 9-10 November 1966—Track of the storm and computed winds at various levels corresponding to the centre of the storm are shown in Fig. 4. The speed of movement was about 12 kt from the stage of cyclonic storm. Winds at 250 and 200 mb levels explain its movement better, whereas 300 mb winds would have given a southwestward movement.

4.10. Storm of 19-22 November 1966—The storm track along with computed spot winds for levels 300, 250 and 200 mb corresponding to the storm centre are given in Fig. 5. It may be seen that the direction of movement after 00 GMT of 20th could be visualised well from 300 mb spot winds whereas 250 and 200-mb winds give predominantly more westward movement than the actual. After 12 GMT of 21st, however all the levels are quite representative. To understand, why 300-mb winds could better guide than 250 and 200 mb

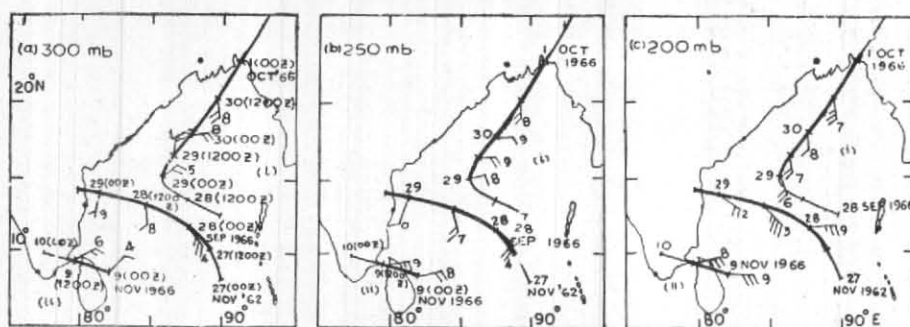


Fig. 4

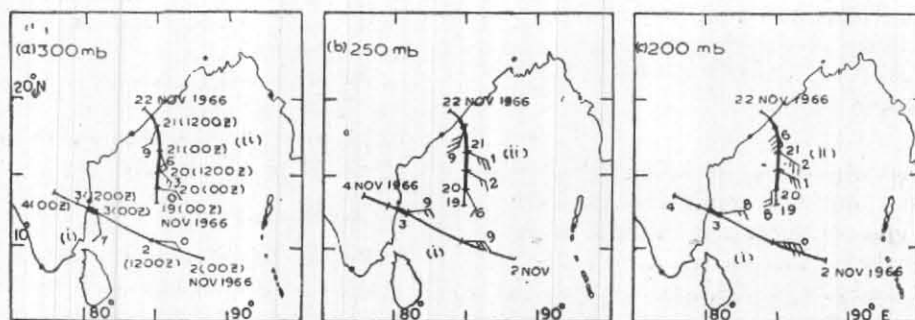


Fig. 5

Figs. 1-5. Winds computed for (a) 300 mb, (b) 250 mb and (c) 200 mb levels radially above the sea level position of cyclonic storms

The corresponding tracks of the storms have also been given;

The computed winds have been plotted according to the standard practices;

The middle figure of the direction in degrees has been indicated at the head of the shaft

in the initial stage, it would be interesting to study the wind variation for various synoptic hours. 300-mb wind at Visakhapatnam continuously veered from  $010^{\circ}/20$  kt on 00 GMT of 20th to  $100^{\circ}/20$  kt on 12 GMT of 20th to  $150^{\circ}/15$  kt on 00 GMT of 21st. Wind at Calcutta backed from  $250^{\circ}/25$  kt to  $230^{\circ}/15$  kt and again to  $200^{\circ}/10$  kt between 00 GMT of 20th and 00 GMT of 21st. Wind at Madras backed from  $330^{\circ}/12$  to  $180^{\circ}/7$  kt and again  $170^{\circ}/8$  kt between 00 GMT of 20th and 00 GMT of 21st. Thus between 20th and 21st there had been a general change of wind pattern giving a complete southerly sweep at 300-mb level, thereby suggesting a more northward movement, which was actually the case. This southerly sweep seems to have been maintained till 12 GMT on 21st and by 00 GMT of 22nd, with the weakening of the system, the wind field again changed giving westerly winds over Visakhapatnam and southwesterly over Calcutta. The wind field at 250 and 200 mb seems to have not been affected at Visakhapatnam with the approach of the storm. It continued to be predominantly easterly upto 00 GMT of 21st. The same holds good for winds at Madras. The change at these levels was however quite marked on 12 GMT of 21st, when the wind flow right from Madras to

Calcutta became predominantly southerly. Since the winds at 250 and 200 mb were not affected by the approach of the storm till 00 GMT of 21st, probably these levels could not give correct indication of the movement of the storm. However, on and after 12 GMT of 21st, when the changes were marked at all the levels (300, 250 and 200 mb), all the levels gave good indication of movement of the storm, 200 mb being the best fit. This may perhaps lead one to think that the first level in the upper troposphere, which shows marked variation, with the approach of a cyclonic storm proves to be a good steering level.

4-11. Storm of 27-28 November 1966—Almost all the levels indicated the correct movement of the storm, 300 mb spot winds however gave a better fit (figure not presented).

##### 5. Conclusions

Although the recent investigations of other workers suggest that steering concept itself needs a fresh thinking (Koteswaram 1967) but still from the brief study of these eleven storms, it is interesting to note that, only upper tropospheric winds upto 200 mb, if available for stations in the vicinity of centre of the storm, can be used at an

operational centre as a first step in prognosticating the movement of the storm in Bay of Bengal. The computation and analysis for three levels for the purpose hardly takes 15 to 20 minutes.

Certain other special features which have been noted in the present study are detailed below :

(i) It is seen that the level in the upper troposphere which shows marked variations first, with the approach of a cyclonic storm indicate a good steering for the future movement of the storm. This is seen in the case of the storm of 19-22 November 1966 (Fig. 5) when 300-mb level was apparently acting as a steering level and not 250 or 200-mb levels. A study of few more such cases is however necessary.

(ii) In cases where the circulation extends upto 300 or 250 mb the winds at these levels do not seem to give correct indication about the movement of the storm; whereas the next higher level give a good guidance in deciding the movement of the storm. This is marked in storm of 28 September—2 October 1966 (Fig. 4) where only 200 mb

wind could indicate the correct movement of the storm.

(iii) It has been noticed that on the occasions when spot winds at various levels could not depict the correct movement of the storm, the main handicap had been the non-availability of wind data for the stations in the vicinity of the storm centre upto 200 mb. In this type of study, besides the coastal stations, the observations over Port Blair are obviously of great importance especially when the storms are in the mid sea, far away from any of the coastal stations. The study also reveals that it may also be essential to take more frequent high rawin ascents (say after every 6 hours), for the stations in the vicinity of the storm, to catch up the transitory state for getting the correct movement as was the case between 00 and 12 GMT of 2 January 1966 (storm of 30 December 1965—3 January 1966).

#### 6. Acknowledgements

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