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Letters to the Editor

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SOME ASPECTS OF WIND STRUCTURE OF BAY CYCLONE OF MAY 1990

There have been very few studies on the wind structure of cyclonic storms over the north Indian Ocean mainly due to the absence of aircraft reconnaissance flights over the region and due to the non-availability of conventional data source over the sea area. The surface wind data from ships plying in the sea area within the storm's circulation field and the upper air wind observations from coastal rawinsonde/rawinwind stations (provided the storm moves close to the coast for a sufficient period of time), can be utilised to generate wind composited data set. This compositing technique has been used by many workers in India and abroad for several years. The Machilipatnam hurricane of 5-11 May 1990 gave an unique opportunity to use this method as there were a good number of ship observations particularly from the one called "*Vishwamohini*" which moved right up to the 'eye' of the storm. Moreover, the storm moved more or less parallel to the coast at a distance of 200 to 300 km for a considerable stretch of time. Some of the interesting features of wind structure of the storm based on wind compositing method are discussed and presented in the note here.

2. The Machilipatnam cyclone of May 1990 was one of the most severe cyclones to occur over Bay of Bengal in recent years. It began its life as a low pressure area on 4 May over SE and adjoining SW Bay of Bengal, became depression on the same day, moved northwestward and intensified into a cyclone in the evening of 5th, severe cyclone on 6th morning and finally into a severe cyclone with a core of hurricane winds at about 0900 UTC of 6th. The system subsequently moved in northnorthwestward direction and maintained more or less same intensity till it crossed the coast of Andhra Pradesh at the mouth of river *Krishna* at about 1330 UTC of 9 May. The storm was tracked by four Cyclone Detection Radars situated at Karaikal, Madras, Machilipatnam and Visakhapatnam. INSAT-1B tracked the storm for the complete period of its life time. The ship "*Vishwamohini*" recorded the lowest sea level pressure of 912 hPa and the estimated maximum sustained wind of the order of 135 kt.

Fig. 1 shows the composites of winds based on ship observations. Total 27 ship observations were available for the preparation of this diagram. Isotachs are also drawn on this composite. It may be seen from this figure that besides the maximum wind speed of the order of 135 kt (250 kmph) in the eyewall region (~25 km from the storm centre), 90 kt (~180 kmph) wind speed was reported by a ship in the NE sector of the storm at a radial distance of about 100 km. Merrill (1984) has defined the size of the storm as the radius to 17m/sec (~35 kt) gale force wind or as the radius of outermost closed isobar (ROCI). The 35 kt isotach drawn in Fig. 1 shows that the present storm has the size of about 200 km indicating strong gale force winds in the outer core region of the storm.

With the help of composited data, mean tangential winds across the storm field were computed and plotted in Fig. 2(a). The figure shows strong winds ranging from 150 kmph (~35 m/s) to 250 kmph (~65 m/s) within the area between the radius of maximum surface winds ($R_{\max}$) and 100 km radius (R_{100}) of the storm. Winds beyond 300 km radial distance decrease exponentially. The magnitude of wind at 300 km is about 60 kmph (~15 m/s). The size and outer core strength (OCS) are also shown in Fig. 2(a).

Using Merrill's (1984) definition, the outer core wind strength of the storm has been obtained by computing area weighted mean winds within the radii of 100 km and 300 km [Fig. 2(a)]. The value of OCS for May 1990 storm comes to be around 20 m/sec (40 kt). This value is comparable with those obtained by Weatherford and Gray (1988) for Pacific typhoons.

In a similar manner, the mean wind strength (by combining inner and outer core strengths) of the storm can be obtained by integrating the wind profile $V(r)$ shown in [Fig. 2(a)] for the storm area from radius of maximum sustained wind ($R_{\max}$) to 300 km radius. The formula for the same may be given as :

$$\bar{V} = \frac{\displaystyle\int_{r = R_{\max}}^{r = 300\text{ km}} V(r)\, r\, dr}{\displaystyle\int_{r = R_{\max}}^{r = 300\text{ km}} r\, dr} \tag{1}$$

As the wind profile varies from storm to storm depending on its size and strength, a simpler formula can be used in which mean wind within radial distances of $R_{\max}$-100 km, 100 km-200 km, 200 km-300 km

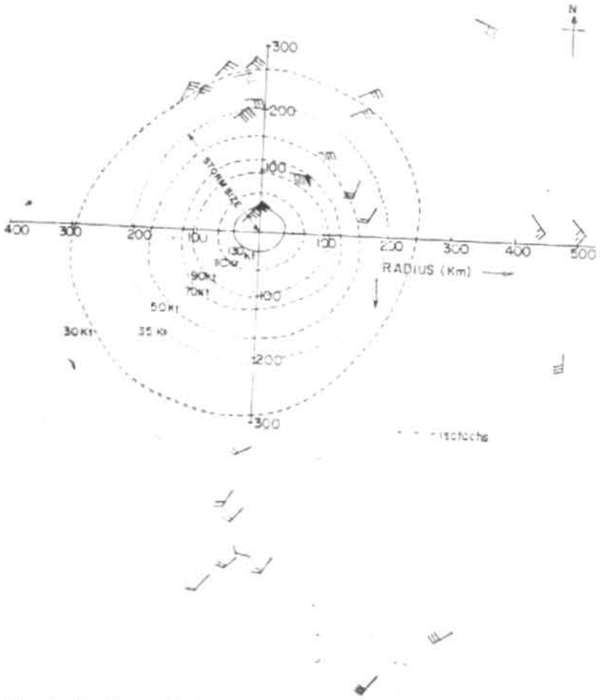
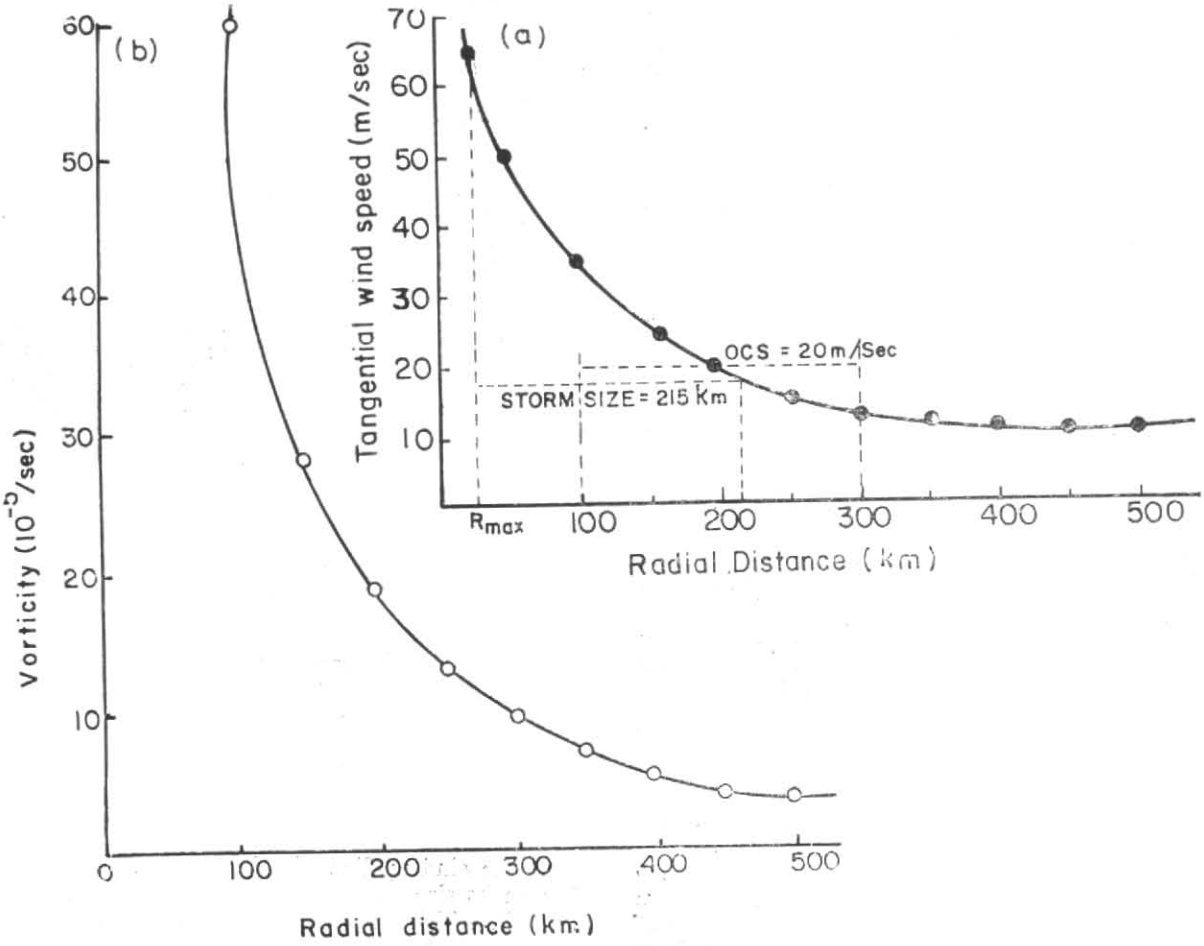


Fig. 1. Surface wind composite based on ship data of 7-9 May 1990



Figs. 2 (a & b). Profile of the : (a) Surface tangential wind (m/sec), and (b) Relative vorticity ($\times 10^{-5}$/sec) based on ship data of 7-9 May 1990

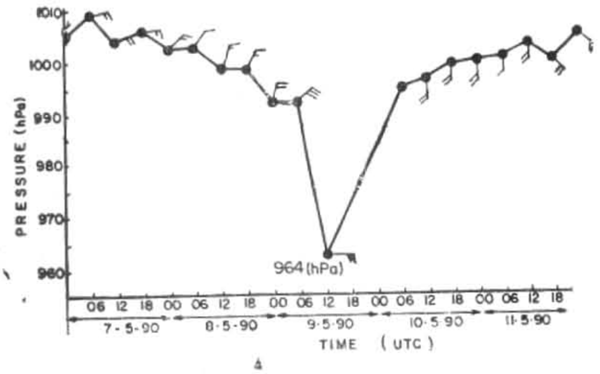


Fig. 3. Surface pressure and wind changes at Machilipatnam during 7-9 May 1990

may be used. Moreover, for a typical storm R_{max} may be taken as 25 km. Eqn. (1) thus simplifies to:

$$\bar{V} = \frac{V_{25-100}\int_{r=25}^{r=100} r\,dr + V_{100-200}\int_{r=100}^{r=200} r\,dr + V_{200-300}\int_{r=200}^{r=300} r\,dr}{\int_{r=25}^{r=300} r\,dr} \qquad (2)$$

This reduces into a simple equation:

$$\bar{V} = 0.1\,V_{25-100} + 0.34\,V_{100-200} + 0.56\,V_{200-300} \qquad (3)$$

The mean wind strength of the storm ($\bar{V}$) may be a good parameter for estimation of the actual wind potential of the storm as far as wind damage is concerned. The storm size and outer core strength will obviously be reflected in this parameter. In the case of May 1990 cyclone the value of V comes to be around 24 m/sec (~48 kt).

Relative vorticity values are calculated for various radial distances from the storm centre based on Fig. 2(a), and profile of the same has been drawn in Fig. 2(b). A steep fall in the magnitude of relative vorticity is seen between 100 km and 150 km radial distances. The values decreases exponentially beyond this distance. This is in agreement with the results of Riehl (1954).

Fig. 3 is prepared based on the observations recorded by the anemograph and barograph available at the Cyclone Detection Radar Station, Machilipatnam. The figure shows that the pressure has fallen initially at a rate of 8 hPa per day from 1010 hPa at 06 UTC of 7th to 994 hPa at 06 UCT of 9th. At this time (06 UTC of 9th) the storm was about 120 km southsoutheast of the station. The pressure subsequently fell at the rate of 4 hPa per hour, from 994 hPa at 06 UTC to 978 hPa at 12 UTC of 9th. The storm at this time (12 UTC of 9th) was about 50 km south of Machilipatnam indicating an average pressure gradient of about 0.35 hPa/km within the radial distances of 120 km and 50 km. Similarly wind observations at Machilipatnam as shown in Fig. 3 indicate that northeasterly winds of the order of 30 kt prevailed at 06 UTC of 9th which became easterly 55 kt at 12 UTC.

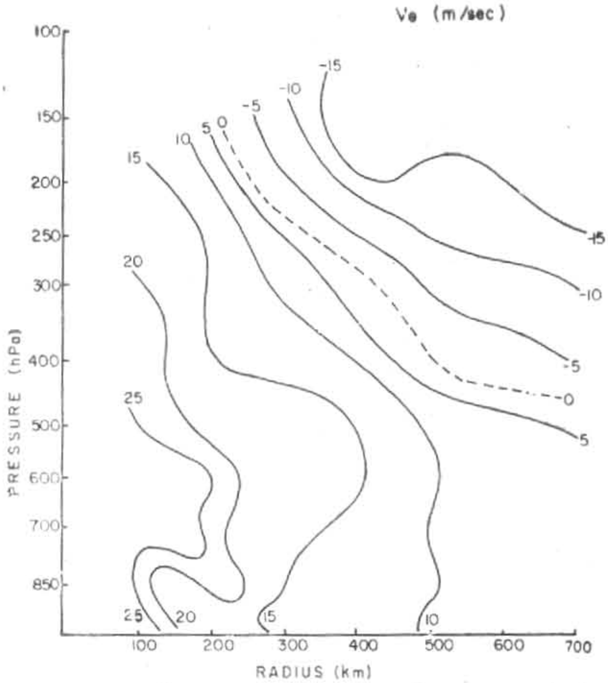


Fig. 4. Two dimensional cross-section of tangential winds (V_θ). Positive done cyclonic flow

The upper air data from 4 RS/RW coastal stations, *viz.*, Karaikal, Madras, Machilipatnam and Visakhapatnam are used for the preparation of wind composites and computation of tangential and radial wind components at various upper levels. For the preparation of two dimensional structure of the storm compositing has been performed on a cylindrical grid with 10 vertical levels up to 100 hPa. The cylindrical grid consists of various radial bands of 100 km width, *e.g.*, 0-100 km, 100-200 km and so on. Using this method the two dimensional structures of tangential and radial winds across the storm field are prepared. Fig. 4 and 5 show the two-dimensional structures of these two components. It is evident from Fig. 4 that maximum values of cyclonic tangential winds lie between 700 and 600 hPa levels within 200 km radius. Negative tangential wind components have maxima above 200 hPa level beyond 400 km radius. These results are more or less in agreement with those of Lee *et al.* (1989) for north Indian Ocean cyclones, Frank (1977) for typhoons over northwest Pacific and Gray (1979) for hurricanes over north Atlantic.

However, features displayed by the two dimensional structure of radial winds shown in Fig. 5 are very interesting. The maximum inflow was seen at 500 hPa level within

100-200 km radial distance. This is somewhat unexpected as normally maximum inflow is observed close to the ground level. These results are not in agreement with those reported by Frank (1977) for northwest Pacific Ocean and Gray (1979) for north Atlantic where maximum negative radial winds have been observed at around 950 hPa level within 2° radius. But, the results of Pant and Rao (1989) for the Bay storm of 1985 are relatively close to the results of the present study. Their study has shown that maximum inflow of 10-15 m/sec is observed between 700 and 500 hPa levels within 200-300 km radius. This aspect requires to be investigated further by taking more number of cases over NIO region. Fig. 5 also shows that the maximum outflow in the storm dominates the levels above 300 hPa beyond 300 km radius. This, of course, in agreement with other studies.

Although the results presented in this study are more, or less consistent with the results reported elsewhere the data set used in this study was not adequate enough to bring out very accurate results. Moreover, the study is confined to only one storm. Further study combining similar cases of NIO region may bring out more accurate and generalised results.

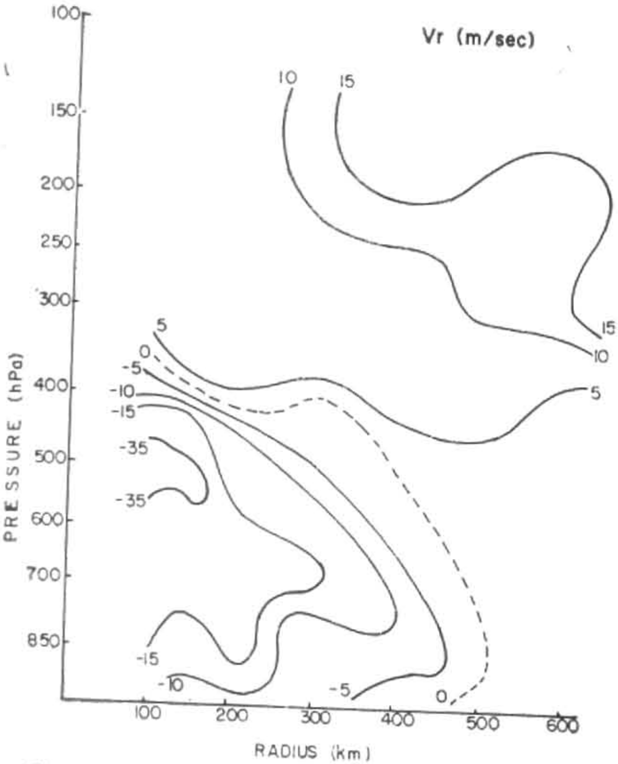


Fig. 5. Two dimensional cross-section of radial winds (V_r). Positive number denote divergence

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