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### SOME SALIENT FEATURES OF THE BAY OF BENGAL SUPER CYCLONIC STORM OF OCTOBER 1999

1. A super cyclone hit Orissa coast in the forenoon of 29 October 1999. The system from the Gulf of Thailand emerged into north Andaman Sea as a well-marked low-pressure area on 25 October and later intensified into a super cyclone. Throughout its course in the Bay of Bengal for more than three days the system moved mainly in a northwesterly direction and crossed Orissa coast close to Paradip between 0400 and 0630 UTC on 29 October and caused extensive damage to life and property. INSAT-1D tracked the system throughout its course in the Bay of Bengal. Coastal radar at Paradip also tracked the system when it came within its range. The track of the system, its central pressure, associated gale force winds, storm surge and the damage caused by the storm are discussed in IMD/RSMC report (2000) and IMD (2000). Douglas Le Comte (2000) has also discussed some of the above aspects.

Paradip lies in Cuttack district of Orissa. Available records show that during the last 109 years (1891-1999) four cyclonic storms crossed this district in the post monsoon months and all of them were severe cyclonic storms with wind speeds exceeding 150 kmph. It is further seen that in the past, two cyclonic storms crossed this district in the month of October. In this paper salient features of the super cyclonic storm have been studied and the results are presented.

1.1. *History of super cyclonic storm* - A well-marked low-pressure area over gulf of Siam and neighborhood on 24 October emerged into north Andaman Sea and concentrated into a depression and lay centred at 1200 UTC of 25 near  $12.5^{\circ}$  N/ $98.0^{\circ}$  E. It moved in a west northwesterly direction and intensified into a cyclonic storm and lay centred at 0300 UTC of 26 near  $13.5^{\circ}$  N/ $95.5^{\circ}$  E. It further intensified into a severe cyclonic storm at 0300 UTC of 27 and lay centred near  $16.0^{\circ}$  N/ $92.0^{\circ}$  E. Moving in a northwesterly direction it further intensified into a very severe cyclonic storm at 1500 UTC of 27 near  $17.0^{\circ}$  N/ $90.5^{\circ}$  E. It became a super cyclonic storm at 1800 UTC of 28 near  $19.3^{\circ}$  N/ $87.0^{\circ}$  E. It crossed Orissa coast near Paradip on 29 between 0400 and 0630 UTC. After crossing the coast it weakened into very severe cyclonic storm and lay centred at 1200 UTC of 29 near  $20.5^{\circ}$  N/ $86.0^{\circ}$  E near Cuttack. It remained practically stationary and further weakened into a cyclonic storm and lay centred at 0300 UTC of 30 near  $20.5^{\circ}$  N/ $86.0^{\circ}$  E very close to Bhubaneswar. It then weakened into a depression

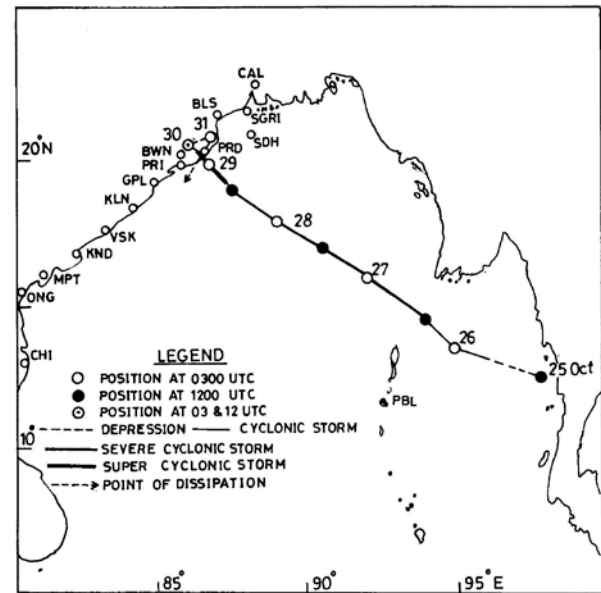


Fig. 1. Track of the super cyclonic storm in the Bay of Bengal 25-31 October 1999

at 0300 UTC of 31 near  $21.0^{\circ}$  N/ $87.0^{\circ}$  E when it was very close to Chandbali. Drifting southward it further weakened into a well marked low pressure area over coastal Orissa, north coastal Andhra Pradesh and adjoining sea areas of northwest Bay of Bengal by the morning of 1 November. The track of the storm is shown in Fig. 1.

2. *Data* - In addition to INSAT-1D Paradip radar data has been used. Synoptic data of Gopalpur, Puri, Bhubaneswar, Paradip, Chandbali, Balasore and Calcutta have been utilized for the study. Upper air observations of Karaikal, Chennai, Machilipatnam, and Visakhapatnam have also been considered.

3.1. *Satellite and radar observations* - Satellite observations show that initially the system intensified gradually and attained the intensity of T 2.0 by 0000 UTC of 26. At 1200 UTC of 26 system intensified to T 3.0 and the intensity at 1500 UTC of 27 was T 4.0. In the next 24 hours the system intensified to the stage of T 6.0. At 28/1800 UTC the storm intensified to T 7.0. NOAA-12 satellite view of the cyclone at 2332 UTC on 28 October is shown in Fig 2. Well-defined eye and dense circular overcast area could be seen in the picture.

Paradip radar tracked the system from 0600 UTC of 28. The 'eye' was visible from 28/0800 UTC to 29/0200 UTC after which due to logistic problem observations could not be continued. Radius of maximum wind (RMW)

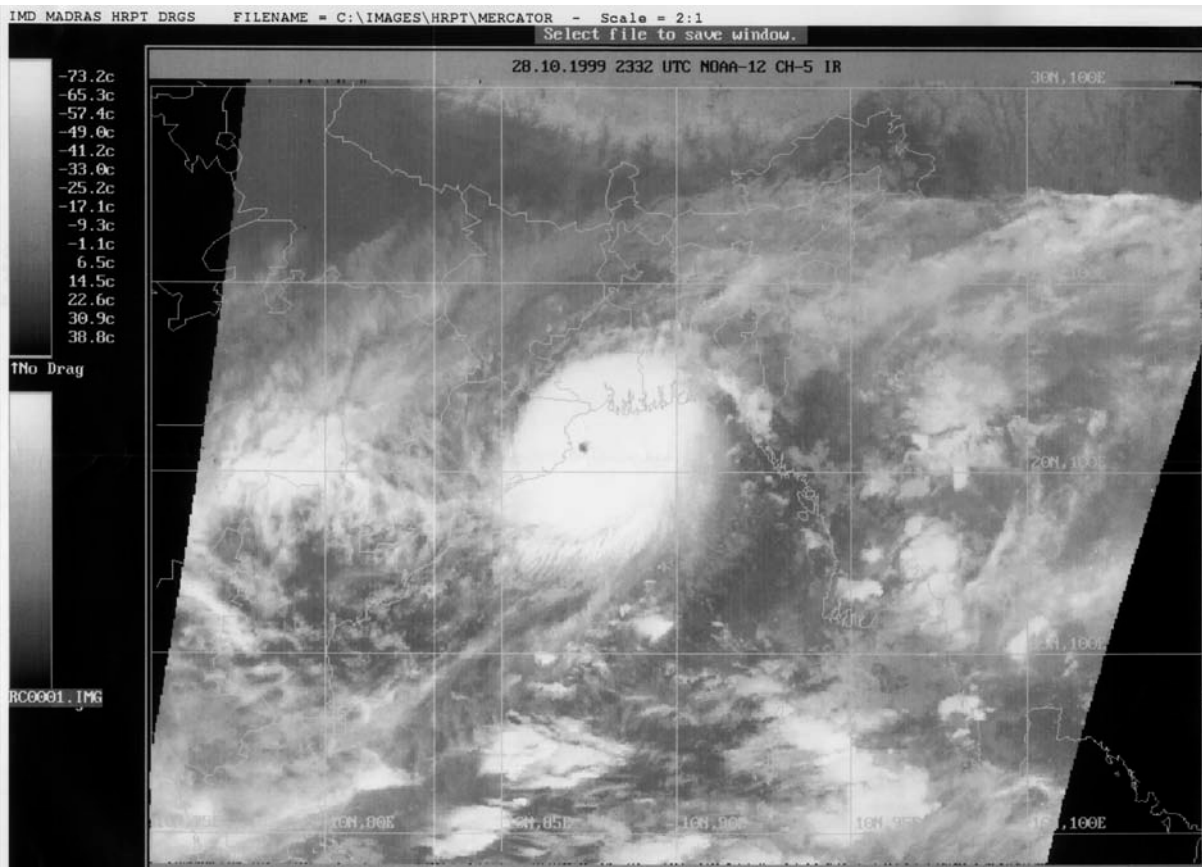


Fig. 2. NOAA 12 satellite view of super cyclone at 2332 UTC on 28 October 1999

as reported by Paradip radar from 1000 UTC of 28 to 0200 UTC of 29 is shown in Fig. 3. Corresponding satellite T No. is also shown in the same figure. It can be seen that as the storm intensified the RMW decreased which is in agreement with the conclusion made by Raghavan *et al.* (1989) based on their study of the Bay of Bengal cyclone of November 1984. While calculating the correlation between T No. and mean value of RMW during the period of same intensity (T No.) it is found that the value works out to 0.64, which is a significant correlation. Radar observations indicated that the diameter of the eye varied between 15 km and 40 km and it was less than 20 km just before crossing the coast.

3.2. *Pressure and wind aspects*—Pressure values recorded from 28/0600 UTC to 30/0900 UTC at Puri, Bhubaneswar and Paradip are shown in Fig 4. It can be seen that the lowest pressure was reported by Bhubaneswar, which is an interior place. This suggests that the centre came close to Bhubaneswar than other two places. Further it can be seen that the pressure did not increase after reaching the

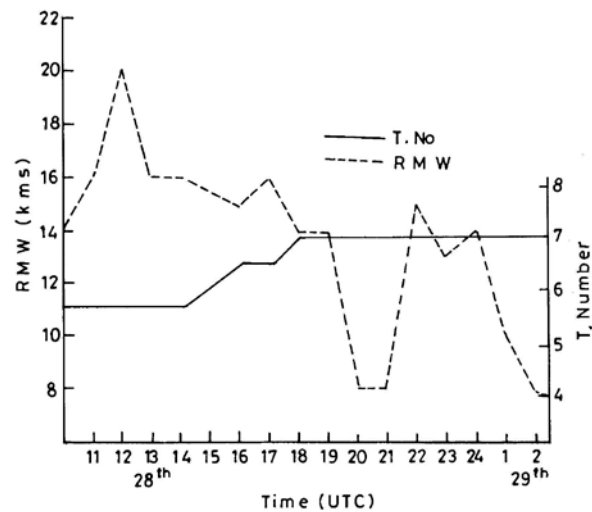


Fig. 3. Radius maximum wind and T No. of super cyclonic storm October 1999

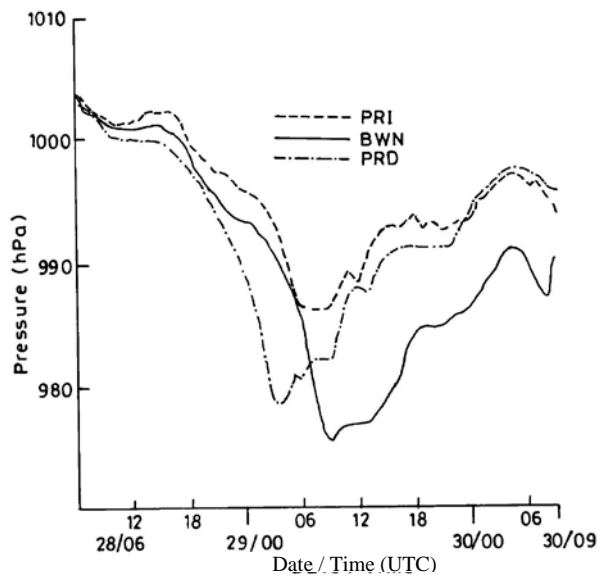


Fig. 4. Pressure recorded at Puri, Bhubaneswar and Paradip from 28/0600 UTC to 30/0900 UTC

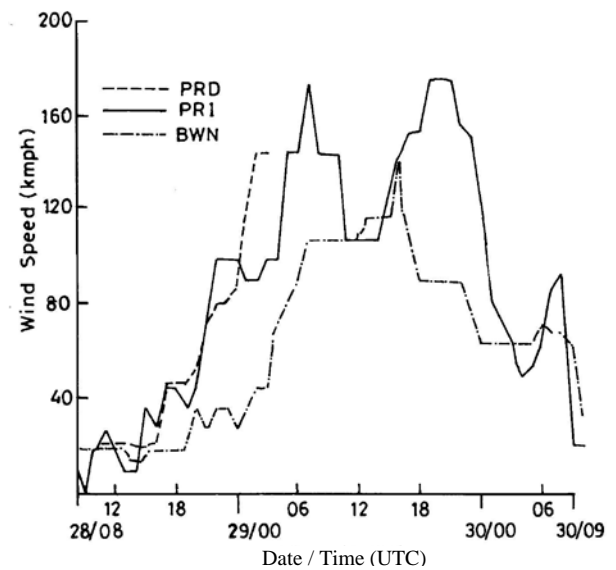


Fig. 5. Wind speed recorded at Puri, Bhubaneswar and Paradip from 28/0600 UTC to 30/0900 UTC

lowest value as quickly as it decreased while the storm approached the station. This may be due to slow weakening of the system after crossing the coast. The lowest pressure recorded at Paradip was 978.4 hPa at 0400 UTC of 29 at Puri it was 986.1 hPa at 0800 UTC and at Bhubaneswar 975.3 hPa at 0900 UTC. If we assume the lowest estimated central pressure in this cyclonic storm as 912 hPa (Mausam, 2000) corresponding to T- number of 7.0, then the pressure gradient at Paradip (near the eyewall) would be 1.5 hPa/km. At the time when the lowest pressure was recorded at Bhubaneswar the pressure gradient was 1.6 hPa/km.

Fig. 5 gives the wind speed recorded at Paradip, Bhubaneswar and Puri. At Puri the recorded maximum wind speed was 180 kmph at 0700 UTC of 29 and then it decreased to 110 kmph from 1100 to 1400 UTC on 29. After that the wind speed started increasing and reached 180 kmph at 1900 UTC. Even after 15 hours after the landfall, the wind speed was as high as 180 kmph at Puri. The highest windspeed recorded at Bhubaneswar was 148 kmph at 0700 UTC of 29 October. The persistence of strong wind coupled with heavy rain for several hours resulted in heavy loss of life and substantial damage to property.

The hourly observations of Gopalpur to Calcutta recorded during the storm period were composited. For this purpose wind speeds were estimated at different distances upto 300 km from the storm centre. The inverse

polynomial of the form  $V = a/(r^2 + br + c)$  was found to be a good fit for estimating the wind speed in terms of radial distance from the system centre. The constants a, b, c can be arrived at by applying three values of wind speed and distance close to the storm centre and solving the three simultaneous equations. The Chi-square test also confirms the suitability of this equation for estimating the wind profile. The estimated and actual wind speeds at different distances from the storm centre are shown in Fig. 6. It is seen that considerable increase in wind speed is noticed towards storm centre only from a distance of 200 km. Beyond this distance the wind speed was almost steady. The maximum wind speed at radius of maximum wind can be estimated from the inverse polynomial. Assuming radius of maximum wind to be at a distance of 20 km from the system centre, the estimated maximum wind speed comes out to be 260 kmph.

3.3. *Speed of movement of the storm* - The six hourly average speed of movement of the system at various stages of intensities is shown in Fig. 7. It is seen that when the storm was at lower intensity it moved faster *vice versa*. The average speed of the storm was 21.7 km/hr when it was of depression stage, it then decreased to 18.7 km/hr when it became cyclonic storm and it was 17.2 km/hr when it reached severe cyclonic storm intensity. The speed of the storm was 15.3 kmph when it became very severe cyclonic storm / super cyclone. After crossing the coast it almost remained stationary for about 42 hours.

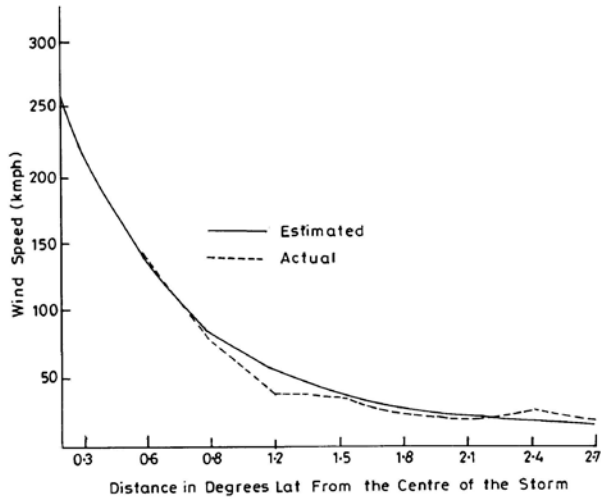


Fig. 6. Actual and estimated wind speed at various radial distances in the storm field

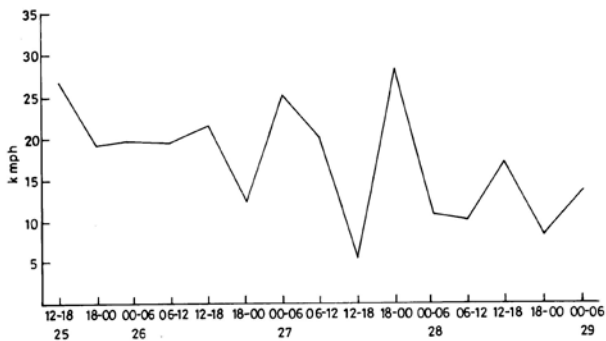


Fig. 7. Six hourly averaged speed of movement of super cyclonic storm during 25/1200 UTC to 29/0600 UTC

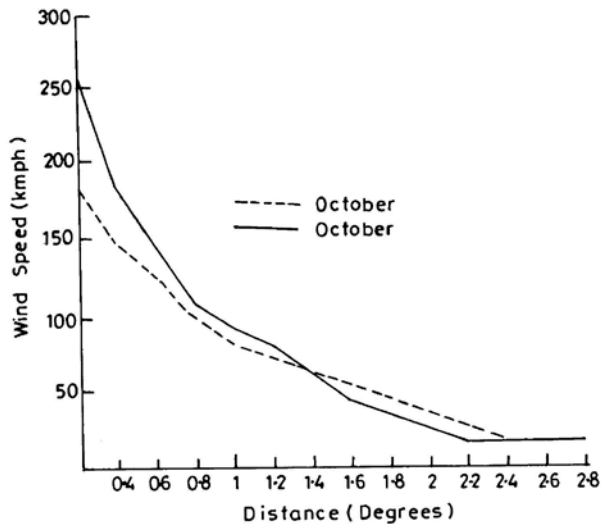


Fig. 8. Wind speed recorded/estimated in October 1971 cyclone and October 1999 super cyclonic storm

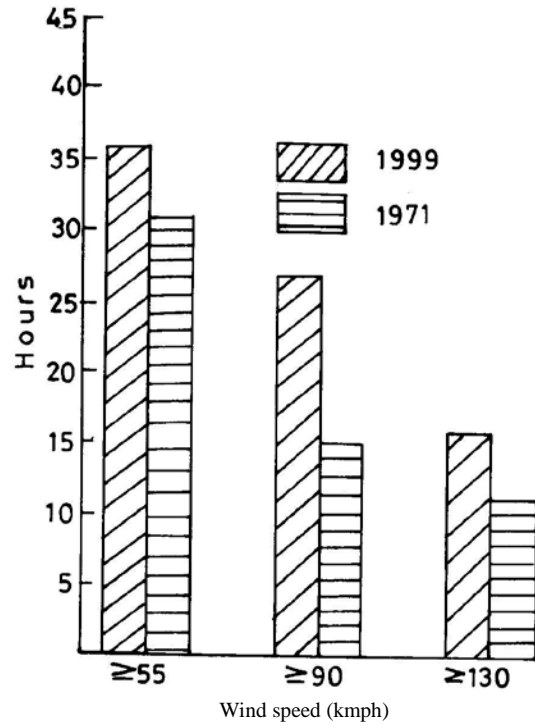
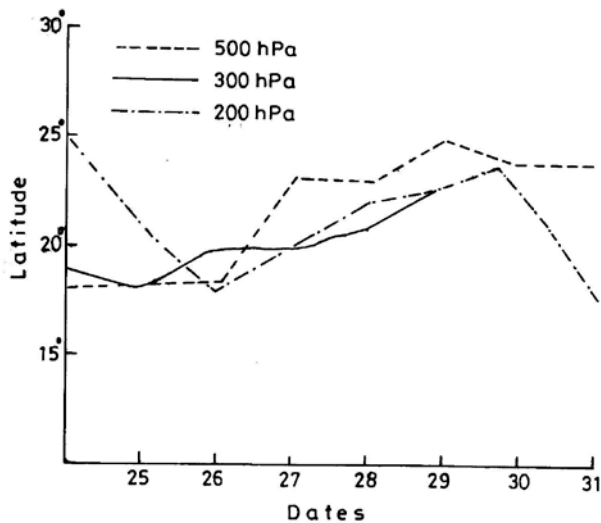


Fig. 9. Duration of different wind speeds in October 1971 storm and October 1999 super cyclonic storm

3.4. *Comparison with earlier storms that crossed Cuttack district in October* – Prior to this cyclone two severe cyclonic storms had crossed Cuttack district near Paradip in the month of October 1967 and 1971. The 1967 storm was a very small storm with the eye diameter of 5 km. The 1971 storm crossed Paradip port on 31 October and the reported maximum wind was of the order of 185 kmph. In association with this storm the reported surge height was 6 m above normal tide level and seawater inundation extended up to 30 km inland. In the case of present storm, surge height was of the order of 7 m and seawater inundation was reported upto 35 km inland. Fig. 8 gives the wind profile of 1971 and 1999 storms. It can be seen that though core of 1971 storm was slightly larger than present one, the intensity of the former was less. Fig. 9 gives duration of wind speed recorded at Paradip and Puri in different ranges for the storms of 1971 and 1999 respectively. In the case of 1999 storm since wind speed at Paradip was not available after 0300 UTC of 29, wind speed recorded at Puri has been considered and the study has been restricted to wind speed  $\geq 130$  kmph. It is seen that in all ranges of wind speed the duration is more in October 1999 super cyclone. The estimated maximum wind in 1999 super cyclone was as high as 260 kmph. The present storm may hence be considered as one of the most intense cyclonic storms in the north Indian Ocean in this century in terms of wind speed and surge height.



**Fig. 10.** Ridge position at different levels around 80° E during the storm period

3.5. *Ridge position* – Fig. 10 gives the ridge position around 80° E at different (500, 300 and 200 hPa) levels from 24/0000 UTC to 31/0000 UTC. It can be seen that the ridge position at all levels shifted southward at the initial stage of development of the system and moved northward with the intensification of the storm and its movement towards northwest. After the system crossed the coast ridge position at 300 and 200 hPa level once again shifted southward.

4. The Bay of Bengal super cyclonic storm of October 1999 after crossing the coast remained stationary for about

42 hours and weakened slowly resulting in strong gale force winds persisting for a long period of time. Inverse polynomial relation is found to be a good fit for estimating the wind profile in the cyclone field. Based on wind and surge observations the super cyclonic storm of October 1999 may be classified as a system of unprecedented intensity in the north Indian Ocean.

5. Authors are thankful to the Deputy Director General of Meteorology, Regional Meteorological Centre, Chennai for the support provided to this study and to S/Shri M. Bharathiar and N. Selvam for drafting the figures.

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