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**TORNADOES ASSOCIATED WITH BAY OF BENGAL  
CYCLONE OF 8-10 NOVEMBER 1995**

Tornadoes associated with cyclonic storms are common in the maritime states of United states. Extensive studies are made about occurrence of tornadoes at various stages of a cyclonic storm with the data spread over a few

decades. Hurricane BEULAH of 1967 had 115 tornadoes associated with the system was studied by Orton (1970). The track of these hurricanes some times extended over tens of kilometers causing damage along its path. Gentry (1983) reviewed the genesis of the tornadoes associated with hurricanes. The results showed that most of the tornadoes develop in a preferred area of within 100 km from hurricane centre and between azimuths of  $20^\circ$  and  $120^\circ$ . They occurred when there is a strong vertical shear

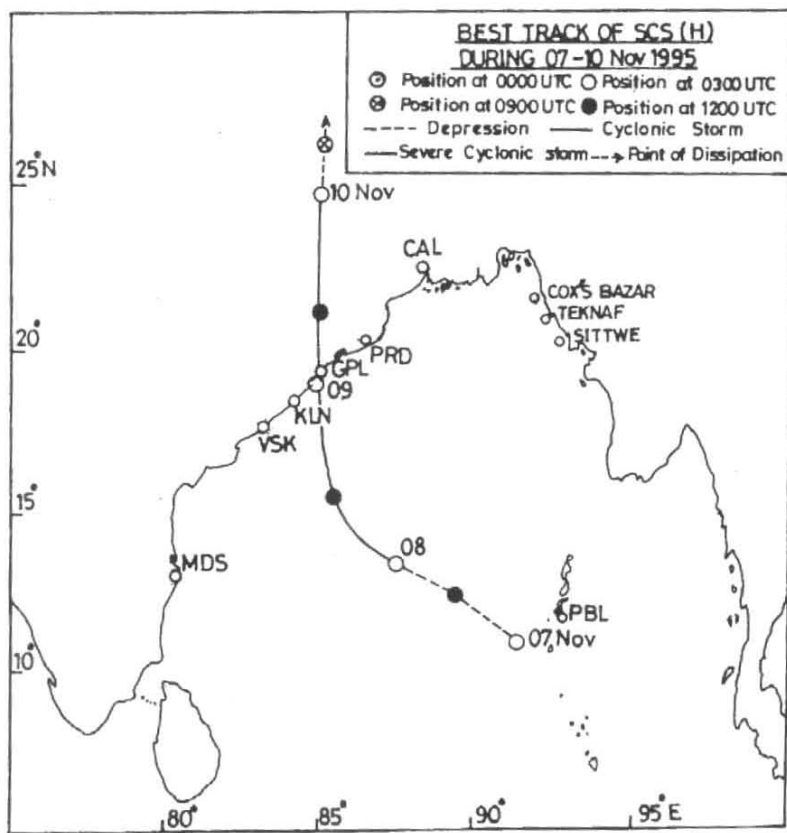
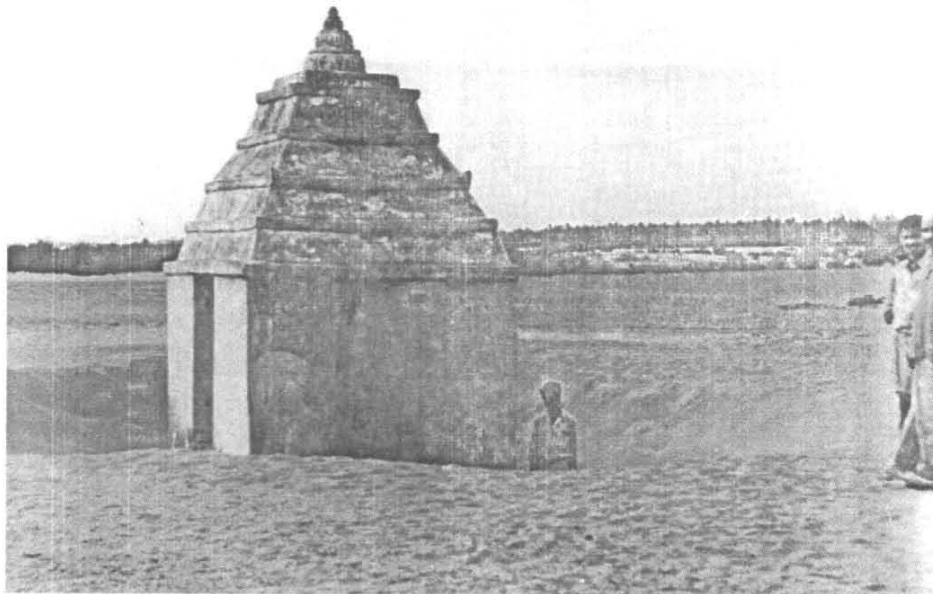


Fig. 1. Track of the severe cyclonic storm with a core of hurricane winds in Bay of Bengal which crossed the North Andhra coast between Kalingapatnam and Gopalpur by 0500 UTC of 9 November 1995



**Fig. 2.** Evidence of tornadoe seen with the excavated sand around a temple of 10 m height. The depth of the sand can be estimated from a person standing in the trench at Kambalarayudupeta village situated 50 km northeast of Kalingapatnam



**Fig. 3.** Three coconut trees separated at about 15 m apart seen fallen in various directions in Peddaballi- puttuku, about 120 km northeast of Kalingapatnam



Fig. 4. The twisted cashew tree branches seen due to another tornadoe near Kaviti village situated at about 150 km northeast of Kalingapatnam

in the horizontal component of the horizontal wind and hence strong gradient in vertical component. Obviously, they occurred whenever there was intense convergence. These situations normally developed in the northeastern sector of a northerly or northwesterly moving storm. Mostly they occurred whenever 850 hPa winds were stronger than those at the surface. Mc Caul(1991) studied the composite profiles of temperature moisture and wind of hurricane-tornadoes environment. It was concluded that vertical wind shear at lover troposphere and wind had high correlation for cyclone-tornadoes outbreaks.

Such occurrences may be a few in India as the storms crossing Indian coast are only 1-2 in a year. Also due to the lack of extensive survey soon after the storm crossed the coast, probably marked the evidence of such tornadoes occurrence for a detailed study.

Recently, an occasion arose where there is a strong evidence of tornadoes occurrence was inferred from post cyclone survey conducted for a severe cyclonic storm with a core of hurricane winds which crossed north Andhra coast, south of Gopalpur on 9 November 1995.

The system originated as a low pressure area over Andaman sea in adjoining southeast Bay of Bengal on 6 November, concentrated into a depression on 7th morning. It intensified into a cyclonic storm on 8th morning and became severe cyclonic storm on the same day evening. INSAT classified the system as T 4.0 at 1500 UTC of 8th from 08/1500 to 09/0200 UTC. The peak intensity of

T 4.5 occurred when the vortex was centered near  $18.5^{\circ}$  N/ $84.5^{\circ}$  E at 0300 UTC of 9th while crossing the coast.

At 09/0300 UTC Gopalpur reported a pressure of 989.8 hPa with a negative departure from normal about 23.3 hPa with estimated wind of 50 kts. Visakhapatnam reported a maximum wind of 40 kts at 08/1850 UTC. The system crossed the coast between 0400-0500 UTC on 9 November (Fig.1).

During post cyclone survey, it was noticed that, at Kambalara-yudupeta, a small village located about 50 km northeast of Kalingapatnam, a temple situated at beach showed a clear excavation of sand around the temple. The sand around the temple lifted up from a depth of about 2 metres wthin a diameter of 10 m around the temple. This is clearly seen from the Fig 2. Similarly, yet another place called Peddaballiputtiku, situated at about 70 km northeast of Kambalarayudupeta gave another evidence of probably another tornadoes occurrence. Here the coconut trees fell in all directions with their heads cut-off and thrown away at a few metres distance. Fig 3. shows a clear evidence of two coconut trees fallen at about 15 m apart.

Fig 4. also shows yet another evidence of the twisted cashew tree near Kaviti village situated about 150 km northeast of Kalingapatnam. A detailed enquiry from local people revealed that this was due to a whirlwind phenomenon which was observed in the early hours of 9th.

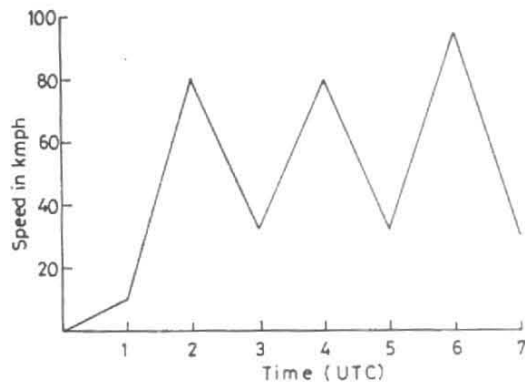


Fig. 5. The hourly speed of the storm centre plotted during 0000-0700 UTC of 9 November 1995 from the INSAT inferred centres

From the storm centre at a distance of 100 to 200 km tornadoes probably would have occurred in the northeastern sector. Since the morning of 8 November the storm centre continued to move along  $85^{\circ}$  E longitude till 9th evening. The storm even after crossing the coast continued to maintain a track along  $85^{\circ}$  E. From the analysis of fallen trees in Srikakulam district of North coastal Andhra Pradesh where the storm crossed the coast and moved northwards indicate that most of the trees were fallen towards southwest to westwards. The Cyclone track fitted from the wind data indicate that the observed tornadoes at Kambalarayadupeta, Peddaballiyuttiku and Kaviti fall into the right of the track. With respect to storm centre they are located in northeastern sector. From the intensity of the storm it was estimated at T 4.0 when the tornadoes occurred in the northeastern sector of storm centre.

Analysis of upper winds at Visakhapatnam showed on 08/0000 UTC a wind speed of 24.5 mps (47 kts) at 850 hPa. The data were not available on 08/1200 and 09/0000 UTC. The wind speed on 07/1200 UTC was at 12.0 mps (23 kts) while on 09/1200 UTC it was 9.1 mps at this level. This shows large increase of wind speed almost double the value occurring ahead of the storm centre in the northern sector. Malkin and Galway (1953) reported strong evidence of tornadoes occurrence whenever wind field at 850 hPa was 45 kts. Also it was observed that the humidity of 15.5 gm/kg at the site. Coinciding with these values specific humidity increased from 7.8 gm/kg on 07/0000 to 15.6 gm/kg on 08/1200 UTC. Fig. 5 shows the speed of the storm centre plotted from 09/0000 UTC to 09/0700 UTC, the average value was around 50 kmph corresponding to 25 kts.

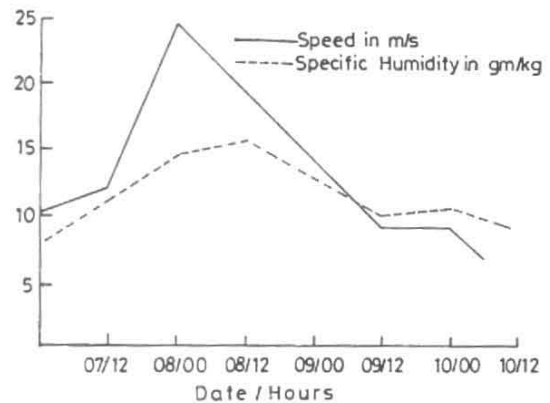


Fig. 6. Hourly values of specific humidity and wind speed at 850 hPa observed at Visakhapatnam

Malkin and Galway (1953) while studying hurricane-able observed a humidity value of 15.5 gm/kg in the layer 840 to 870 hPa in the neighbourhood of the tornadoes. They also observed wind speed of 45 kts at 850 hPa. Both these conditions appeared to be similar in the present observations. They also reported that the speed of the storm centre a value of 16 kts, which is lesser than the 25 kts observed in the present case.

Fig 6. shows the variation of 850 hPa wind speed and specific humidity. Since wind data were not available on 08/1200 UTC and 09/0000 UTC the peak value was appearing to be at 08/0000 UTC which may be slightly different to that at 1200 UTC. However, the evidence of maximum winds at 850 hPa to trigger tornadoes activity was clear. The specific humidity of 15.6 gm/kg well coincided with 08/1200 UTC observation triggering a higher convection for triggering the tornadoes Mc Caul(1991).

Hill *et al.* (1966) while surveying tornadoes associated with tropical cyclones, observed that the tornadoes were seen on the forward sector of the cyclone. They observed that the tornadoes activity at all stages of the storms, including that of developing or decaying stages. It was also seen that the tornadoes occurred in the rainbands of tropical cyclones as seen from the radar pictures. In the present case, the tornadoes rightly occurred in forward sector of the storm of fully matured storm. This observation similar to the clustering of tornadoes in the right front quadrant (Mc Caul 1991) for tornadoes in U.S coasts.

From the above study an evidence for the occurrence of three tornadoes over extreme North coastal Andhra Pradesh occurred under the following conditions viz.

- (i) When the cyclone was at a hurricane stage and moving northward;
- (ii) The upper wind data at Visakhapatnam, a station situated in the forward sector of storm centre showed a peak value of 47 kts at 850 hPa while the specific humidity was at 15.6 gm/kg.
- (iii) The tornadoes occurred in northeastern sector of storm centre while storm centre was moving with a speed of the order of 25 kts.

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