MONITORING OF HIGH WIND SPEED BY NEW STATE-OF-THE-ART HIGH WIND SPEED RECORDING SYSTEM DURING RECENT DECEMBER 2003 MACHILIPATNAM CYCLONE

By

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A B S T R A C T

The accurate measurement of wind speed and direction will provide a greater help to the weather man, particularly during cyclone time. It will also help in tracking the cyclone accurately and to estimate its devastating potential.

India Meteorological Department has recently installed 20 High Wind Speed Recorders (HWSR) along the East and West Coasts of India. HWSR is having a solid-state sensor with no moving parts. It is capable of providing uninterrupted data in cyclone prone coastal areas in severe weather conditions including high winds and heavy rains. The system is capable of measuring wind speeds up to 0-65 mps with an accuracy of 1.5 per cent rms and a resolution of 0.01 mps.

The system has monitored high wind speed during December 2003 Machilipatnam cyclone. A complete description of HWSR system and the wind data as observed during the cyclone is presented in this paper.

1. INTRODUCTION

Tropical cyclone is an atmospheric system in which very strong winds prevail over a large part. It also consists of a huge mass of revolving moist air. Within this system there is an annular zone close to the earth's surface, sea or land where wind speeds of 25 to 50 mps are encountered. On rare occasions wind speed can be as high as 65 mps with gust superposed. The winds are weaker towards the centre as well as towards the periphery of the system. The sense of rotation of this large mass of air is anticlockwise in the northern hemisphere. This large revolving mass of moist air has a deficiency of atmospheric air pressure throughout the system. The deficiency of pressure at the centre is often about 2% below the normal. The amount of pressure deficiency at the centre determines the severity of the cyclone. The horizontal pressure gradient from the periphery to the centre is small almost half the way and thereafter it becomes steep. This rapid decrease of pressure with horizontal distance coupled with forces brought into play by the rotation of earth around polar axis gives rise to the very strong winds of 25 to 50 mps or even more. The revolving system moves as a whole and the direction of displacement in the Indian latitudes is between West-North-West and East-North-East.

Besides strong winds and large deficiency of atmospheric pressure, a tropical cyclone is characterized by heavy cloudiness and heavy to very heavy rainfall over wide areas.

In many cyclones, particularly the severe ones, there is a cloud-free, almost circular area, at the centre called the 'eye'. Here, the atmospheric pressure is the lowest. The winds are very weak; often it is calm.

The number of Cyclonic Storms/Severe Cyclonic Storms which have crossed different states of Indian coasts, (for the period 1891 –2000) is presented below:

State	Total Nos.
West Bengal	69
Orissa	98
Andhra Pradesh	79
Tamil Nadu	62
Karnataka	02
Maharashtra	18
Gujarat	28
Kerala	03

2. THE NET WORK OF HWSR STATIONS

IMD has recently installed state-of-the-art instruments for monitoring the high winds associated with cyclonic storms on the East and West Coasts of India, at 20 stations (Fig. 1).

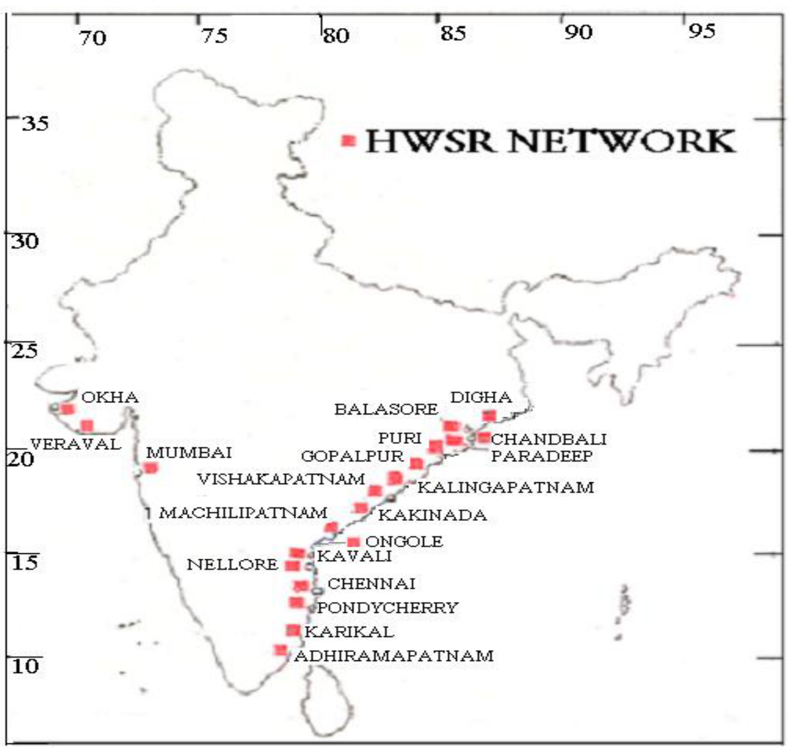


Fig.1: HWSR Network.

3. SYSTEM DESCRIPTION

The High Wind Speed Recorder System mainly consists of an Ultrasonic wind sensor, which has no moving parts; it consists of display unit with an easy read-out of wind information, a data logger with 22-bit A/D converter, a strip chart recorder with selectable recording speed and a PC for downloading the data from data logger. The system is also provided with 48 h back-up power supply (UPS). It has a lightning protection for the sensor. A block diagram of the system is given in Fig. 2.

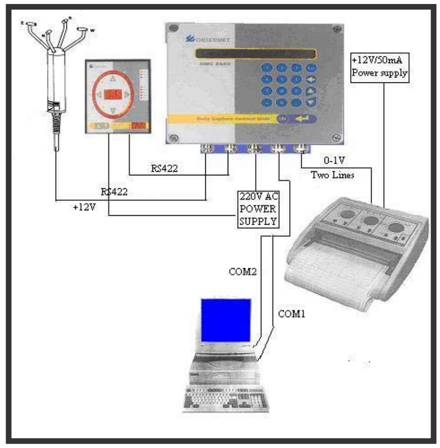


Fig.2: Signal flow diagram of High Wind Speed Recorder

COM1→ Live wind data to the computer COM1 port every 1s either from the display unit or the ADAM card (RS422 to RS232 converter) of the data logger Unit decided by the mechanical switch at back of the data logger.

COM2 → Logged data from the data logger to the PC COM2 port in the interactive mode.

3.1 Wind sensor & its Calibration:

The two-axis (x, y) wind sensor uses the ultrasonic technology with no moving parts. The system does not need any expensive calibration tools. IMD carried out calibration of ultrasonic wind recording sensors in its wind tunnel.

The tunnel is of the open circuit type having a square test section of 60cm x 60cm. It has a contraction ratio of 9 and honeycomb and screens at inlet. The maximum speed in the test section with a 15 HP electric motor drive is about 45 mps smooth and continuous variation of speed is provided over a wide range (4.5 to 45mps) by means of an aerodynamic speed control (flap) mechanism combined with variable speed drive of electric motor.

The true wind speed is calculated using a projection manometer reading using the formula $3.8245\sqrt{diff}$, mps, where *diff* is manometer readings (original – actual after attaining the desired speed).

The wind sensor works on 9 to 30V dc with a current consumption of 60 mA max. It has a wind speed reporting range from zero to 65 mps and possess uniform rate for the entire range. The accuracy for 0 to 5 mps is better than ±3% and for >5 mps it is better than 2%. The response time is better than 1s and threshold is 0.5 mps or better. It has a very high resolution i.e. ±0.01mps.

In case of wind direction, it is reporting in the range from 0 to 359 degrees, with an accuracy better than ±2% for <25 mps and better than 1% for >=25 mps. The output of sensor is in serial mode with RS-422 full duplex with selectable baud rate from 300, 1200, 2400, 4800, 9600, 19200 and 38400 bauds.

3.2 Working principle:

The two-axis ultrasonic sensor works on the principle of travel time taken by the 40 kHz ultrasonic sound pulse between the trans-receivers located in E-W and N-S direction separated by a distance of 115 mm. The travel time is detected & measured by the processor circuit in the sensor. From the travel times TE-W (sound pulse travel time between east transreceiver to west transreceiver) and TW-E (sound pulse travel time between west transreceiver to east transreceiver) are sampled from E-W. Similar measurements of the travel time done by the N-S transreceiver and TN-S, TS-N are measured. The processor in the sensor takes 40 samples of these travel times per second.

40 Samples are averaged for 1 s interval both north and east component of the wind is computed by the processor inside the sensor. The processor further calculates the wind direction and actual wind speed in the polar co-ordinates. Finally sends wind speed and direction for 1 s average in the form of a telegram in RS 422 format.

There are two modes of operation for the system (1) measurement mode – which is normal mode of operation (by default) from power up onwards. The other mode is (2) Interactive mode – which allows the anemometer to be set up and interrogated.

3.3 Sensor Installation:

Ultrasonic sensor was set to point North, using North alignment indicator on the base of the instrument. Separate earthing was provided for the sensor in order to protect it from the lightning. A typical photograph where sensor is installed with lightning protection is given in Fig. 3.

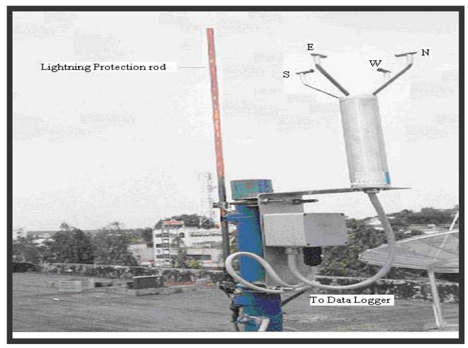


Fig. 3 →

3.4 Wind Display:

Incoming RS 422 serial data (9600 baud, 8 data bits, 1 stop bit, parity-none), from the wind sensor via a surge protector enters the display unit through Data Logger unit. The processor PCB in the display unit converts this incoming serial data into parallel mode, which is given to the display driver unit for the display of both wind direction and wind speed.

Wind speed is displayed in 3 digits, seven segment LED display of 14.3 mm height. The gust display is three digit 7-segment display 10.1mm height. The direction is indicated by 36 LEDs circularly placed having amber colour. The scale selection option in knots, mph, mps and kmph is available on a press of the button.

3.5 Data Logger:

It basically consists of four analogue input channels, with 22-bit analogue to digital converter. It has 1 MB cyclic memory and averaging interval programmable from 1 minute onwards.

The D/A converter in the unit converts incoming wind speed data to analogue voltage in the range from 0-1V for 0-65 mps. The converter also converts the wind direction signal for 0-400° to analogue voltage in the range 0-1V and feeds to the memory module of data logger. These outputs can also be connected to an analogue recorder for continuous recording of wind speed and direction.

It has a provision for telephone modem housed inside the logger casing for down loading the data remotely. It has RS 232 connectivity for computer and also for satellite transmitter.

3.6 Strip Chart Recorder:

The strip chart recorder works on the principle of comparing the input voltage against the derived variable voltage. In a comparator, the output of the comparator drives the DC motor till the variable voltage is equal to the input voltage. The recording pen is connected to the motor by mechanical means. The pen records continuously for the varying input voltage. The magnification/scaling can be adjusted by magnification of the variable voltage source.

4. SEVERE CYCLONIC STORM THAT CROSSED MACHILIPATNAM

A trough in the easterlies over the Andaman Seas and the adjoining southeast Bay became a low pressure area by 11 Dec. Its subsequent developments are given in the following Table 2:

TABLE –2

DEVELOPMENTAL STAGES OF THE SYSTEM

Date	Time (IST)	Location		State of the pressure system
		Lat. (°N)	Long. (°E)	
11.12.2003	-	-	-	Low pressure
11.12.2003	1730	4.5	90.5	Depression
12.12.2003	0830	6.0	89.0	Depression
12.12.2003	1730	7.5	88.0	Depression
13.12.2003	0830	9.0	87.5	Deep depression
13.12.2003	1730	9.5	87.0	Cyclone
14.12.2003	0830	11.0	85.0	Cyclone
14.12.2003	1730	12.0	83.5	Severe cyclonic storm
15.12.2003	0830	14.0	81.5	Severe cyclonic storm
15.12.2003	1730	15.5	81.0	Severe cyclonic storm 80km south of Machilipatnam.
16.12.2003	0230	-	-	Cyclonic storm
16.12.2003	0830	-	-	Deep depression

Maximum intensity of the system as given by Satellite Kalpana-1 was T3.5 between 1730 h of 14 and 2030 h of 15 December, 2003. The track of this cyclone is presented in Fig. 4. Satellite pictures about the movement of this cyclone are given in Figs. 5-7 and the radar pictures as observed by Cyclone Detection Radar installed at the station in Fig. 8.

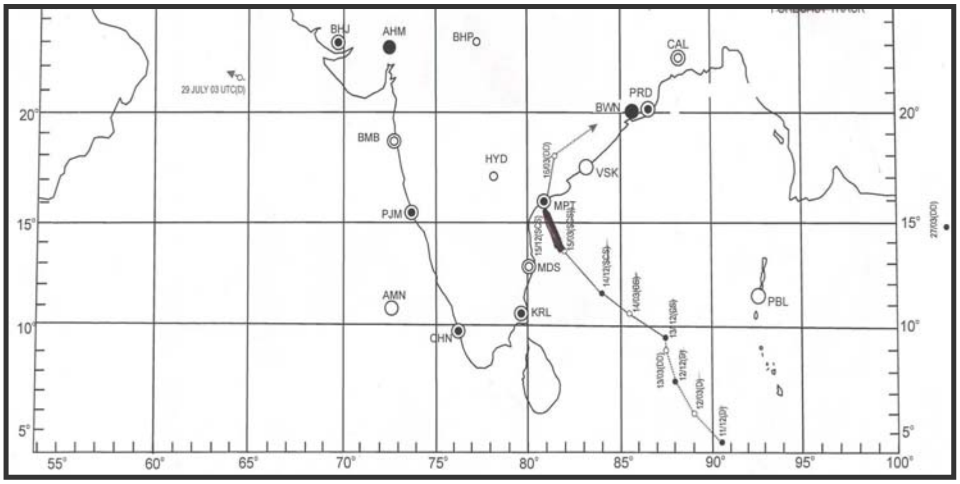


Fig. 4: Track of the cyclone crossed Machilipatnam during December 2003.

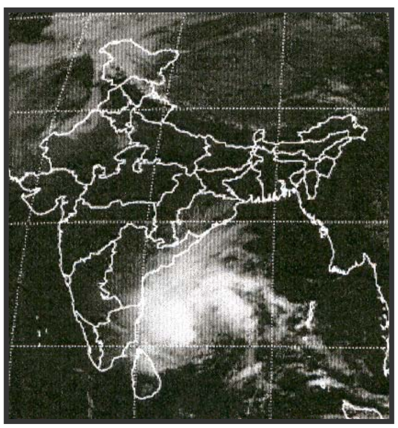


Fig. 5: Satellite image (2030h. IST – 14 Dec.) before the cyclone crossed the Coast

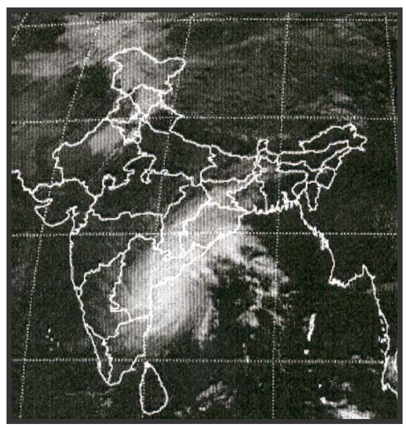


Fig. 6: Satellite image (1730h. IST – 15 Dec.) during the cyclone crossing the Coast

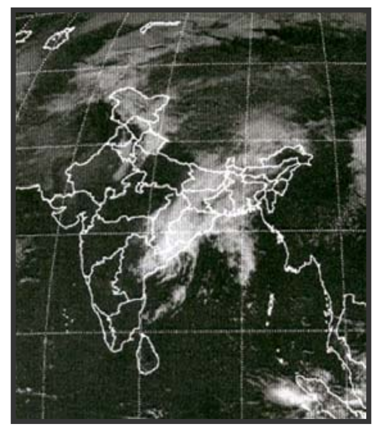
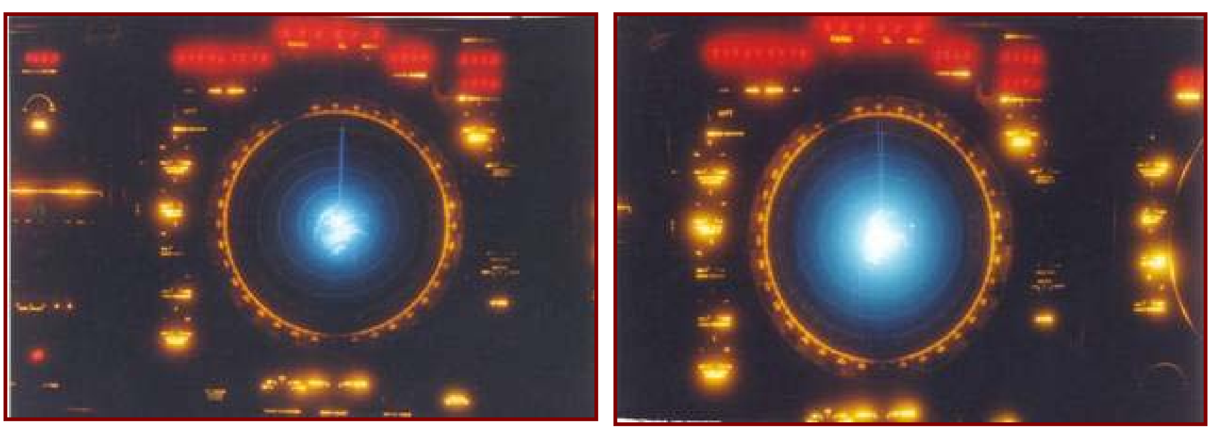


Fig. 7: Satellite image (0830h. IST – 16 Dec.) after the cyclone crossed the Coast



11:30 h. (IST) – 15 Dec., 2003. **15:30 h. (IST) – 15 Dec., 2003.**

Fig. 8: Radar pictures as obtained by the Cyclone Detection Radar of Machilipatnam.

4.2 Damages caused by the cyclone:

- ❖ Eight people died due to heavy wind and rainfall.
- ❖ About 2000 buildings were destroyed completely and more than 7000 were partially damaged.
- ❖ Overhead telecom lines were disrupted.
- ❖ About 2 lakh hectares of agricultural land was submerged in the associated heavy rainfall.
- ❖ Total cost of all damages was estimated to be about Rs.240 crores.
- ❖ Ship M.V. Nandak was severely disabled and it sank near Machilipatnam. All the crew members were, however, rescued by Coast Guards.

4.3 Chief amount of rainfall in cm (16 Dec.):

Repalle	-	19
Bhemodele & Kodia	-	17
Nuzvid & Tenali	-	15
Machilipatnam & Kakinada	-	15
Gannavaram	-	13

5. DISCUSSION

The variations in wind direction and wind speed are presented in the following graphs while the cyclone was crossing the coast. 1-hour average wind speed (in mps) as recorded by the system from 1600 h. of 15 Dec. to 1700 h. of 16 Dec. are shown in Graph-2.

The peak wind speed was observed between 1800 h. and 1900 h. Hence 10-minute average wind speeds (in mps) as recorded by the system between 1830 h. and 1930 h. are given in Graph-3.

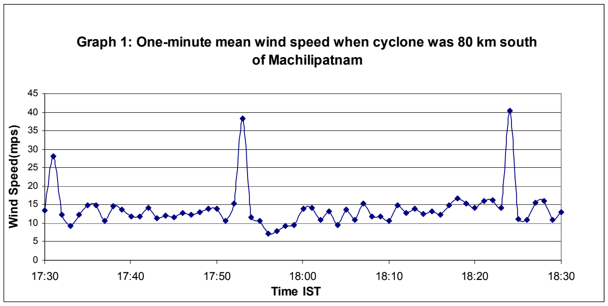
1-minute average wind speeds (in mps), as recorded by the system, between 1830 and 1930 h. is presented in Graph-4.

1-minute average wind speeds (in mps), as recorded by the system, when cyclone was 80km south of Machilipatnam are presented in Graph-1.

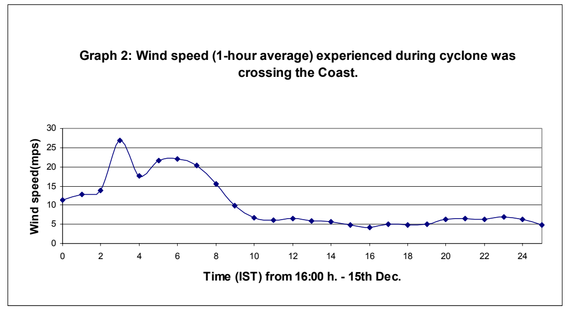
1-minute average wind speeds (in mps), as recorded by the system, after the cyclone crossing the coast is presented in Graph-6.

Similarly, changes in wind direction (in degree), as observed before during and after the cyclone crossed the coast, are shown in Graphs 7-9.

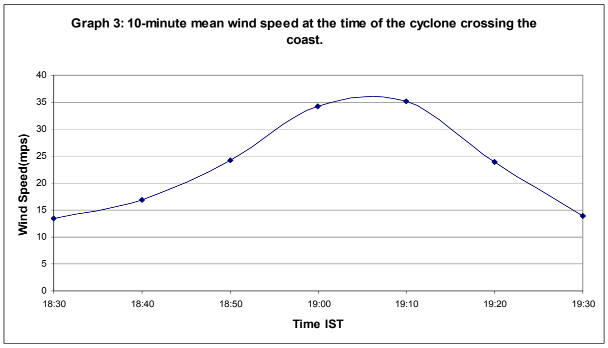
Changes in wind direction and wind speed with reference to critical time when cyclone was crossing the coast are presented in Graph-5.



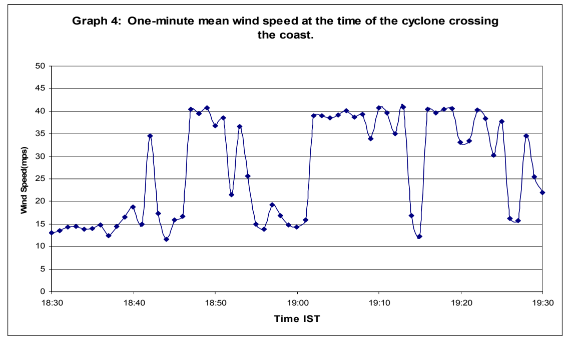
Graph 1: One-minute mean wind speed when cyclone was 80 km south of Machilipatnam



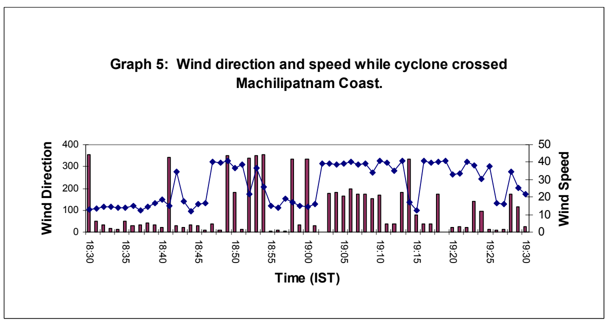
Graph 2: Wind speed (1-hour average) experienced during cyclone was crossing the Coast.



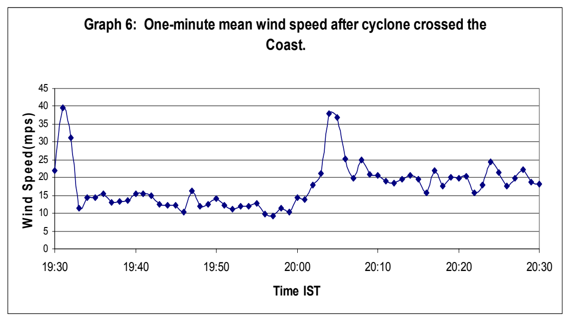
Graph 3: 10-minute mean wind speed at the time of the cyclone crossing the coast.



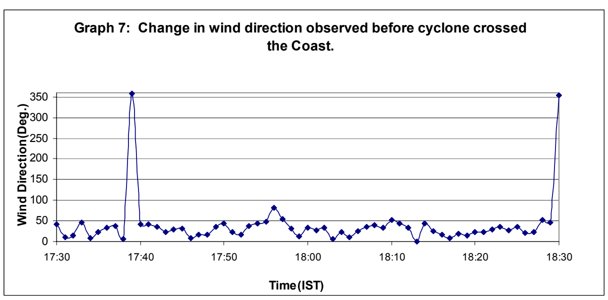
Graph 4: One-minute mean wind speed at the time of the cyclone crossing the coast.



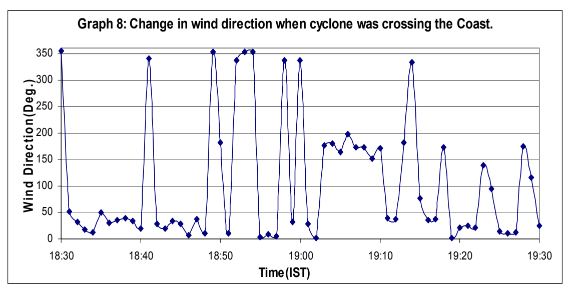
Graph 5: Wind direction and speed while cyclone crossed Machilipatnam Coast.



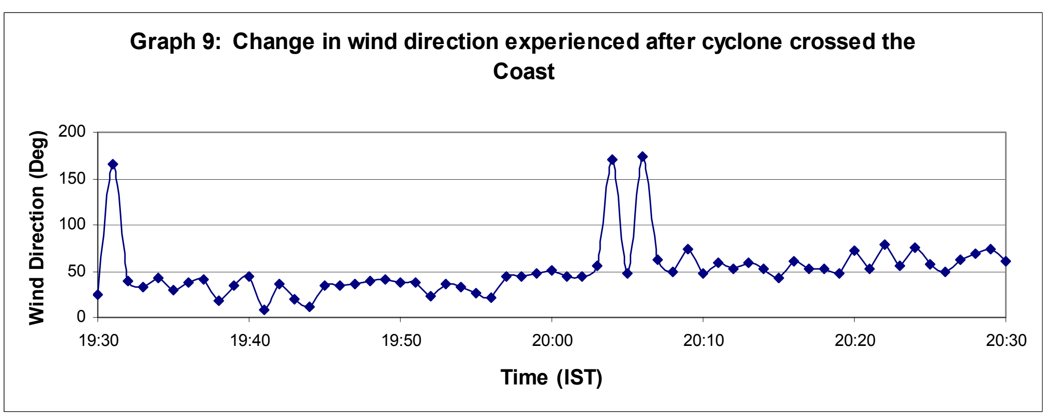
Graph 6: One-minute mean wind speed after cyclone crossed the Coast.



Graph 7: Change in wind direction observed before cyclone crossed the Coast.



Graph 8: Change in wind direction when cyclone was crossing the Coast.



Graph 9: Change in wind direction experienced after cyclone crossed the Coast

The wind speed/wind direction with time when cyclone was about 80 km south of the station shows no significant variation. However, when cyclone was crossing the coast, following variations in wind speed and wind direction are observed:

- A sharp increase in wind speed from 14 mps to 27 mps between 1800 h. and 1900 h. and from 2000 h. and 2100 h.
- A sharp decrease in wind speed in between these two peaks, i.e. between 1900 h. and 2000 h.
- The peak hourly average wind speed recorded is of the order of 27 mps between 1800 h. and 1900 h.
- The peak 10-minute average wind speed recorded is of the order of 36 mps during 1900 h. and 1910 h.
- The peak 1-minute average wind speed recorded is of the order of 40 mps from 1847 h. and 1853 h. and again between 1902 h. and 1925 h.
- The change of wind direction from 'NNE' to 'southerly' is experienced between 1902 h. and 1930 h.
- The significant changes both in wind direction and wind speed is recorded between 1830 h. and 1930 h. of 15 Dec., 2003. The cyclonic wind experienced is seen to be for a very short duration and weakened immediately after crossing the coast.

6. CONCLUSION

A large number of environmental factors influence the formation, development, movement, areal extent and structural features of a cyclone. However, due to non linear nature of the atmosphere the assessment of these environmental factors in an operational mode remains practically difficult causing uncertainty in landfall forecast. The accurate and continuous wind information is possible with the help of high wind speed recorder system installed at the station. With the help of radar system available for cyclone tracking, exact position of the cyclone in the sea is known well in advance.

The performance of the HWSR system was satisfactory during the cyclone and it has provided vital information of wind when the cyclone was crossing the coast.

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