Use of Simulation, Spatial Data and Real Time Observation on Natural Disaster HUDHUD Cyclone - A Case Study

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Abstract

Tropical Cyclone, one of the most destructive of all the natural disasters, are capable of causing loss of life and extensive damage to property. The Bay of Bengal is potentially energetic region for the development of cyclonic storms and about 7% of the global annual tropical storms form over this region with two cyclone seasons in a year. Tropical cyclones have great socio-economic concern for the Indian subcontinent. Precise forecasting of tropical cyclone intensity and track are important for the countries bordering the Bay of Bengal, India, Bangladesh and Myanmar due to significant socio-economic impact. In recent past there has been remarkable improvement in forecasting of the tropical cyclones with the better predication systems.

In this study the tropical cyclone HUDHUD, based on IMD forecast track and wind speed has been used for simulations such as Delft 3D-flow, Real Time System (RTS) existing with APSDPS. From these models Storm Surge inundation, Maximum Damaging Wind Speeds, Wind Damage to Crops, Houses, Road, & Rail Network etc., can be estimated .The results obtained by these models in the case of recent cyclone were regularly conveyed, in Real Time to the Disaster Managers who found them very useful in Disaster Mitigation measures. In addition Rainfall, MSLP, Wind Speed & Direction, Local Pressure etc are obtained by running WRF Model. They are plotted for Real Time analysis. The vulnerable areas which are likely to be affected after running the models here were conveyed to the District administrators from time to time for their necessary actions.

Key Words: *APSDPS, Tropical cyclone, District Administrators, Damage &Vulnerable.*

Introduction

Storm surges associated with severe tropical cyclones constitute the world's worst coastal marine hazard. Storm surge disasters cause heavy loss of life and property, damage to the coastal structures and the losses of agriculture, which lead to annual economic losses in affected countries. Death and destruction arise directly from the intense winds characteristics of tropical cyclones blowing over a large surface of water, which is bounded by a shallow basin. As a result of these winds the massive piling of the seawater occurs at the coast leading to the sudden inundation and flooding of coastal regions.

Disasters like drought, storm surges and floods. This is so because 77 cyclones crossed the coast from 1891. AP is at a risk of at least one cyclone each year, and this occur maximum during the month of October and November. Cyclone with an intensity of moderate to severe occurs every two to three years which results in a huge damage to the state.

According to Government of AP 2.9 million people are vulnerable to cyclones and 3.3 million people are located within 5 kms distance from the coastline, which shows that even a storm surge with small wave height from the sea level results in effecting thousands of people.

The very severe cyclonic storm to cross India in the last year (2013) was 'PHAILIN' cyclone with a wind speed of 200 – 210 kmph; it was second strongest cyclonic storm after Odisha cyclone in 1999. This cyclone made landfall in Gopalpur, Odisha. It affected both Odisha and AP.

1. DATA INPUT FOR SURGE PREDICTION MODELS

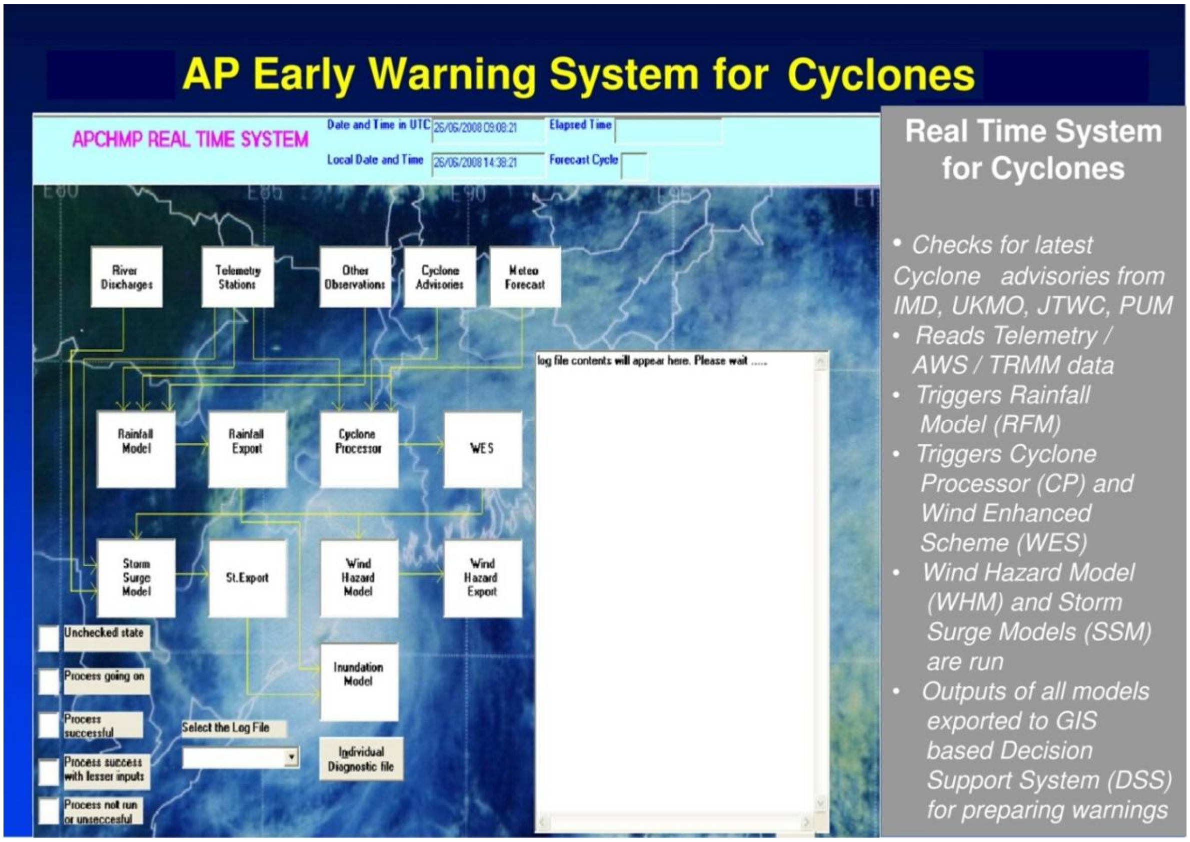
In order to achieve greater confidence in surge prediction in the Indian Seas one should have the good knowledge of the input parameters for the model. These parameters include the oceanographic parameters, meteorological parameters (including storm characteristics), hydrological input, basin characteristics and coastal geometry, wind stress and seabed friction and information about the astronomical tides. It has been seen that in many cases these input parameters strongly influence the surge development.

Most of the northern Bay of Bengal is very shallow and is characterized by sharp changes in seabed contours. The shallowness of water may considerably modify the surge heights in this region. Therefore, accurate bathymetry maps are needed for improved surge prediction.

The precise computation of wind field in a cyclone is an essential prerequisite for the realistic computation of storm surges. Meteorological fields characterizing the cyclone, viz., the pressure drop (i.e. difference between pressure at the centre of the storm and ambient pressure surrounding the storm), maximum sustained winds, and radius of maximum winds can be obtained from satellite imagery. Computation of cyclone wind field, for which the cyclone model requires the above mentioned cyclone specific meteorological fields as input. Thus, more efforts are required to see whether replacing the above developed by meteorologists would be a good alternative to get accurate cyclone wind field.

Real time System for cyclones:

All the models to forecast Cyclone tracks, wind, rainfall, storm surge will run in a sequential manner in an automated mode for real time operation as shown in the figure 1. The RTS check for the latest data received from different sources from the data server and identifies the model to be run and stores all the data in predefined directories for further analysis using Decision Support System (RTS). This model will be running continuously on an uninterrupted basis to trigger cyclone alerts and to run the required models to forecast the impact of the approaching cyclone.



Natural hazards like hydro-meteorological events occur in all parts of the world, although some regions are more vulnerable than others. Hazards become disasters when people's lives and livelihoods are destroyed. Further, human and material losses caused by disasters are a major obstacle to sustainable development. By developing a system of issuing accurate forecasts and warnings in a form that is readily understood, lives and property can be protected. The WMO coordinates the efforts of national meteorological services to mitigate human and property losses through improved early warning services, risk assessments and to raise public awareness on the risk and vulnerability for TCs Very focused sensitive experiments in this direction need to be done. The other cyclone variables such as vector motion of the cyclone, place of landfall, and duration of the cyclone is usually provided by the national weather services.

HUDHUD CYCLONE

This year AP experienced a very severe cyclonic storm "HUDHUD" with a wind speed of 181.6kmph. The cyclone made a landfall on 12th October, 2014 near Visakhapatnam. 4 districts namely Visakhapatnam, Vizianagaram, Srikakulam and East Godavari are majorly affected. The huge wind speed and rainfall had a serious effect on agriculture, horticulture, fisheries, livestock's, infrastructure like roads, communication, buildings, water supply, etc. The early prediction helped in reducing the loss of lives through evacuating nearly 1.35 lakh people in low lying areas but the damage to infrastructure couldn't be prevented. The area resulted in effect on livelihood of people, uprooting of trees, damaged electric and mobile towers, roofs of huts were swept away, damage to crops, disruption to rail & road traffic, etc. During 1995 cyclone made landfall in Visakhapatnam, after that Hudhud was the cyclone which made land fall after 19years.

Very severe cyclonic storm HUDHUD made landall on Andhra Pradesh coast on Sunday (12 October 2014) triggering heavy downpour in the coastal regions of A P. inundated areas near anakapalle, Vishakhaptanam.

3. SYNOPTIC SITUATIONS OF CYCLONE HUDHUD:

A low pressure system that formed over Tenasserim coast and adjoining North Andaman Sea in the morning of 6th October, 2014. It intensified into Depression (T.No- 1.5) at 0300 UTC of 7th October 2014 near latitude 11.50 N and longitude 95.00 E. It moved northwestwards and intensified into a Deep Depression (T.No- 2.0) at 1200 UTC of 7th October, 2014 near latitude 12.00 N and longitude 94.00 E, its continued to move in northwestwards and intensified to Cyclonic storm(T.No- 2.5) at 0300UTC of same day and crossed Andaman Island close to Long Island between 0300 – 0400 UTC. Then it continued to move west northwestwards with same Intensity. The Cyclonic storm, HUDHUD at 0300UTC of 9th October, 2014 had intensified into Severe Cyclonic Storm (T.No- 3.5) near 13.80 N and longitude 89.00 E about 750 km southeast of Gopalpur and east-southeast of Visakhapatnam. It further moved in northwest direction with same intensity. In the afternoon 0900UTC of 10th October, 2014 it concentrated into Very Severe Cyclonic Storm (T.No- 4.0) near 15.00 N and longitude 86.80 E. It continued to intensify while moving northwestwards and reached maximum intensity (T.No- 5.0) in the early morning of 12th October about 260 km southeast of Visakhapatnam and 350 km southsoutheast of Gopalpur with a maximum sustained wind speed (MSW) of 180 kmph over the West Central Bay of Bengal off Andhra Pradesh coast. Very Severe Cyclonic Storm (T.No- 5.0) , HUDHUD crossed north Andhra Pradesh coast over Visakhapatnam (VSK) between 1200 and 1300 hrs IST of 12th October with the same wind speed. About 48hours HUDHUD remained as Very Severe Cyclonic Storm. After the landfall it weakened gradually into Severe Cyclonic Storm at 1200UTC near latitude 18.00 N and longitude 82.70 E and moved northwestwards and as Cyclonic Storm evening at 1500UTC near latitude 18.30 N and longitude 82.50 E. On early hours of 13th it weakened into Deep Depression near latitude 19.50 N and longitude 81.50 E and into Depression at 1200UTC near latitude 21.30 N and longitude 81.50 E. Thereafter, it moved nearly northward and weakened into a well-marked low pressure area over East Uttar Pradesh and neighbourhood in the evening of 14th Oct. 2014.

Thermal Energy:

The thermal energy of Bay of Bengal is between 60 to 100KJ\CM2.

Wind Speed:

The wind speed is 15 to 80Knots around the system in Bay of Bengal.

Sea Surface Temperature:

Sea surface temperature of Bay of Bengal is between 28 to 300C.

Cloud Top Temperature:

The cloud top temperature is varied between -75 to -800C.

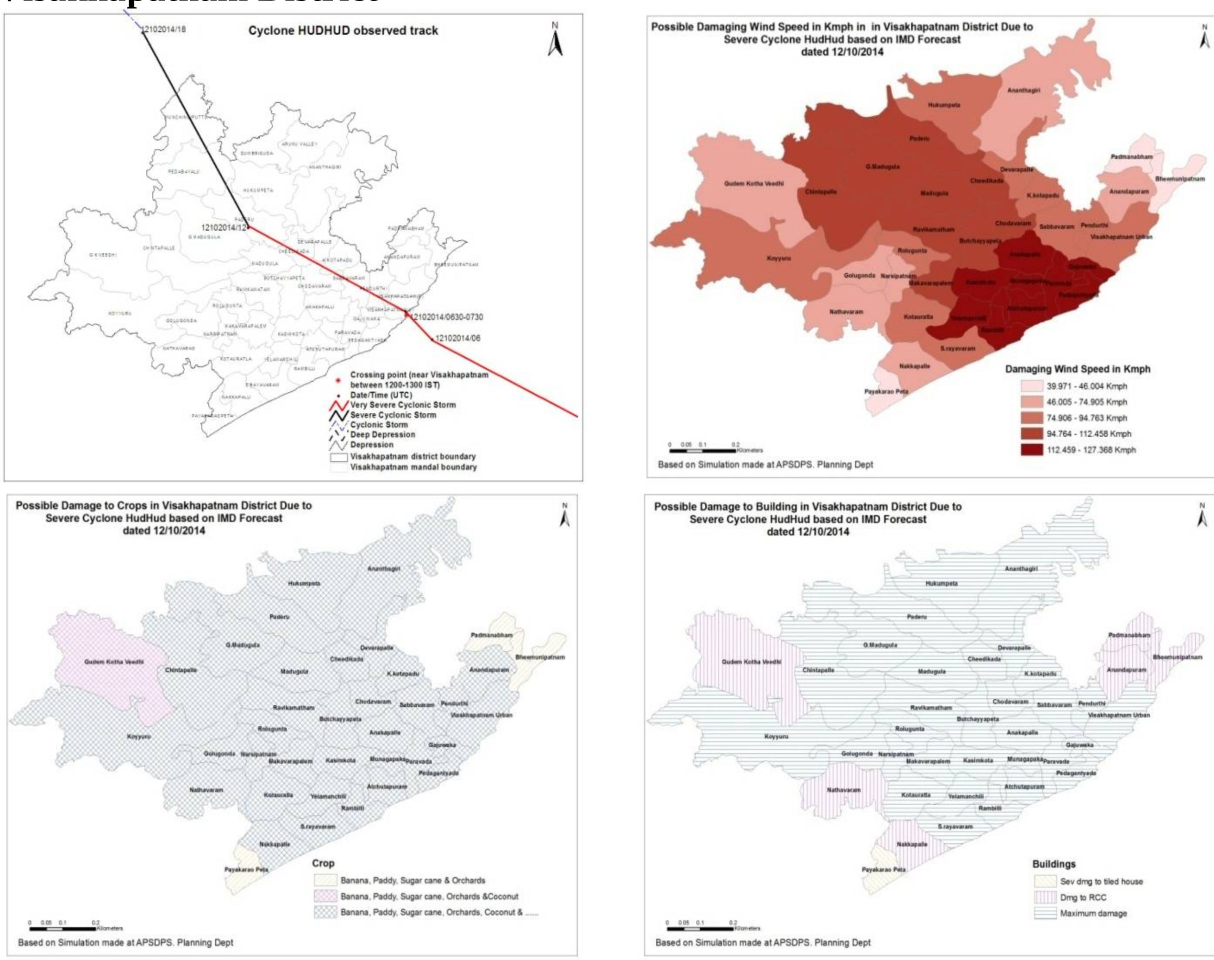
Mean Sea Level Pressure:

On 6th morning the well marked low pressure area was seen over Tenasserim Coast and adjoining North Andaman Sea, intensified into depression at 0300 UTC of 7th October 2014. It moved northwestwards and intensified into a deep depression at 1200 UTC on same day and further intensified into a cyclonic storm, HUDHUD at 0300 UTC of the 8th. The cyclonic storm continued to move in northwesterly direction and intensified into Severe Cyclonic Storm (T.No. 3.5) at 0300 UTC of 9th October, subsequently intensified into Very Severe Cyclonic Storm at 0900 UTC of 10th October, 2014. At 0300 UTC of 11 October 2014 the continued to move northwesterly direction towards and crossed coast near Visakhapatnam at between 0630 and 0730 UTC of 12th October 2014. The system maintained same intensity for two and half hours later after crossing the coast then it weekend into a Severe Cyclonic Storm then to Cyclonic Storm on 12th and into deep depression on 13th at 0000 UTC then to Depression and weakened into a well marked low pressure area over East Utter Pradesh and neighbourhood.

Intensity Variation of HUDHUD Cyclone.

The variation of satellite intensity in terms of T.No. is given in Fig below. The T.Nos are shown on the ordinate while the date and time are given on abscissa. The System attends the maximum intensity of 5.0 and remained so from 0600 UTC of 11th till 0600 UTC of 12th (about 27hr).

Map No. 3- Hudhud track in Visakhapatnam District



Mandals Damaged in Visakhapatnam district due to wind speed, Crop and Houses for Very Sever Cyclonic Storm HUDHUD

DATA ANALYSIS

Mandals along the cyclone are considered and changes they recorded according to local pressure, rainfall, wind direction and wind speed are observed on the day of landfall, before and after the landfall is made are looked into.

Table 1 - Day wise Rainfall data in Hudhud route

	Vishakhapatnam (U)	Gajuwaka	Anakapalli	Sabavaram	Chodavaram	K.Kotapadu	Devarpalle	Hukumpeta	Pendurthi	Paderu	Atchutapuram	Yelamanchili
10/10/2014	0	0	0	0	0	0	0	0	0	0	0	0
10/11/2014	97.25	N.A	25.5	37.5	13.5	14.25	24.25	20.75	3.25	19.25	29.75	21.75
10/12/2014	11.75	N.A	176	106.5	79.25	76.5	N.A	116.25	N.A	54.5	527.25	343.75

Table 2 – Day wise - Pressure data in Hudhud cyclone route

	Vishakhapatnam (U)	Gajuwaka	Anakapalli	Sabavaram	Chodavaram	Atchutapuram	Bhoghapuram	Rambilli	Yelamanchili	K.Kotapadu	Devarpalle	Hukumpeta	Pendurthi
10/10/2014	1004.97	1002.47	998.4	1000.44	999.41	998.05	998.41	1010.17	1012.87	998.05	994	911.54	1001.11
10/11/2014	999.67	997.56		995.65	995.14	999.7	993.09	1012.87	N.A	993.28	989.4	907.79	996.13
10/12/2014	N.A	N.A	1000.75	N.A	990.08	N.A	1000	N.A	N.A	979.16	N.A	N.A	979.03

Table 1 - Day wise Wind Speed data in Hudhud route

	Vishakhapatnam (U)	Gajuwaka	Anakapalli	Sabavaram	Chodavaram	Atchutapuram	Bhoghapuram	Rambilli	Yelamanchili	K.Kotapadu	Devarpalle	Hukumpeta	Pendurthi
10/10/2014	4.82	8.99	12.5	12.27	2.18	19.33	9.34	8.01	20.56	8.79	2.59		13.76
10/11/2014	9.34	11.17	23.94	17.46	7.22	80.88	56.69	0	81.46	8.16	16.93	30.8	15.85
10/12/2014	N.A	N.A	N.A	N.A	N.A	N.A	8.86	N.A	N.A	N.A	N.A	N.A	1.29

Table 4 - Day wise Wind Direction data in Hudhud cyclone route

	Vishakhapatnam (U)	Gajuwaka	Anakapalli	Sabavaram	Chodavaram	Atchutapuram	Bhoghapuram	Rambilli	Yelamanchili	K.Kotapadu	Devarpalle	Hukumpeta	Pendurthi
10/10/2014	354.2	343.6	350.5	263.8	327.3	333.5	272.3	348.7	352.2	87.9	269.5	348	308.9
10/11/2014	358	336.7	142.2	262.2	327.3	345.9	355.9	352.2	360	87.8	235.8	265.7	N.A
10/12/2014	N.A	268.6	254.2	N.A	338.1	N.A	111.6	N.A	N.A	N.A	235.8	N.A	N.A

Source: APSDPS, Automatic Weather Stations (AWS)

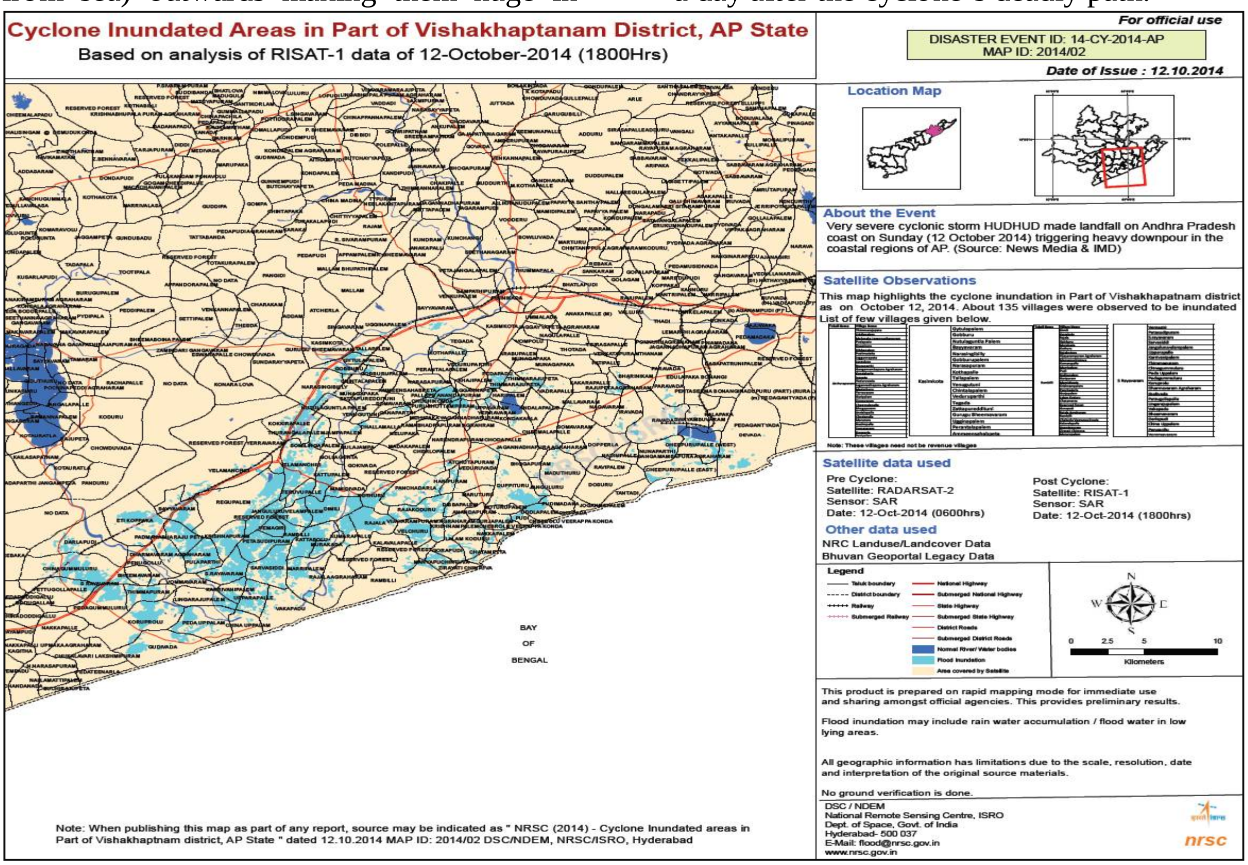
Inference: On 10th of October - Pressure was high in Yalamanchili, low in Hukumpets and equal for all other places. On 11th of October - Slight decrease in pressure was noted compared to 10$^{th.}$ The local Pressure in the cyclone route is almost similar with slight change from Vishakhapatnam (U) to Devarpalle; this change might be due to distance of the mandals from cyclone eye. 10th of October - wind direction was 354.2 degrees, there was change to 263.8 degrees, which further changed to 87.9 degrees and increased to 348 degrees.

- 11th of October – Wind direction in Vishakhapatnam was 358 degrees which changed to 87.8 then finally changed to 265.7
- 12th of October - Chodavaram had 327.3 degrees; Wind direction was not available to 5 mandals.

Wind direction here is counter clockwise, so the direction of wind recorded depends on the location of mandals in the path / track of the cyclone.

- 10th of October – wind speed was 4.82 in Vishakhapatnam (U) which increased to 12.5 in anakapalli and dropped to 2.18 in chodavaram, then slightly increased and further decreased.
- 11th of October - wind speed was 9.34 which increased to 23.94 in Anakapalli, 80.88 in Achutapuram and dropped to 8.16 and again rose to 30.8 in Hakumpet then dropped to 15.85 in Pendurthi.
- 12th of October – Data not available except for Pendurthi having a speed of 1.29 kmph.

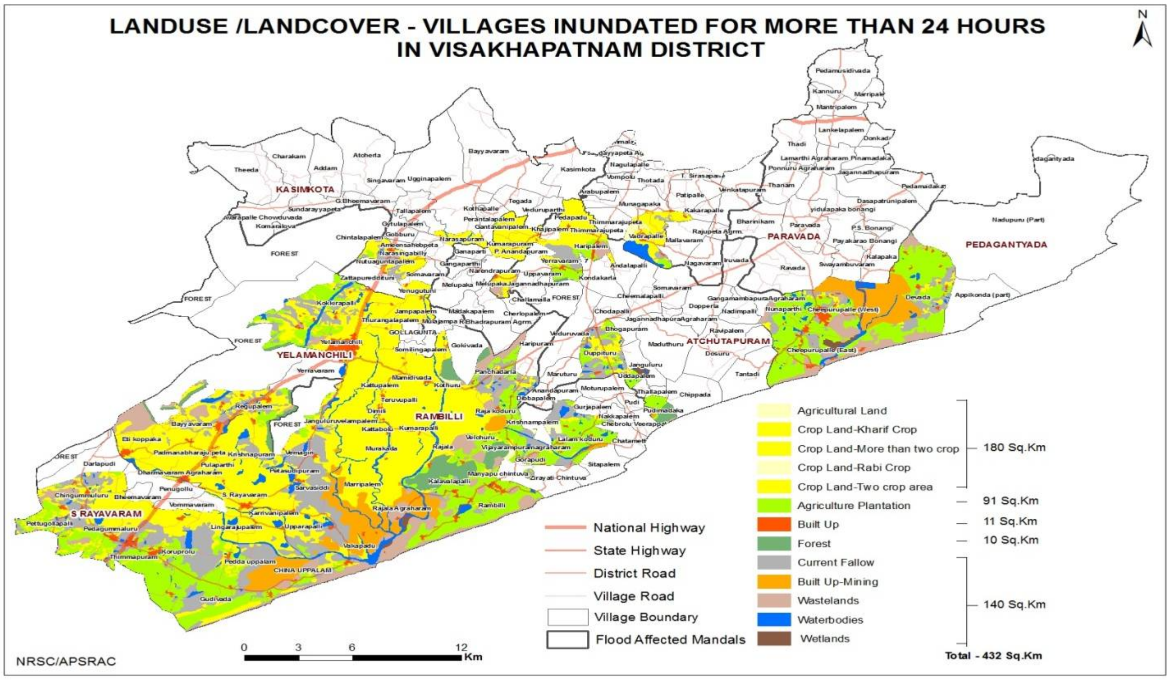
Wind speed depends on the radii of the eye as speed is low at the centre and increases while moving outwards to the eye wall. Wind speed also depends on wind direction and distance of mandals. As Hakumpet is far from cyclone eye wall it recorded high speed compared to other mandals. Wind speed depends on the radii of the eye as speed is low at the centre and increases while moving outwards to the eye wall. Wind speed also depends on wind direction and distance of mandals. As Hakumpet is far from cyclone eye wall it recorded high speed compared to other mandals. In the cyclone route rainfall is highest in Achutapuram Mandal and other mandals have low rainfall with slight change before the landfall is made; this change might be due to outward spiraling winds which carry clouds and air (with moisture absorbed from sea) outwards making them huge in volume and leaving the eye area dry and this depends on the distance. On 12 October 2014, the category 3 tropical cyclone Hudhud made landfall on the coast of Andhra Pradesh, near the city of Visakhapatnam (also known as Vizag). At the time of impact, the wind force was approximately 200 km/h, and height of the waves up to 3 meters. The city of Visakhapatnam was heavily damaged, including the airport, a number of buildings, electrical and telecommunications supplies and roads. Similarly, districts of Visakhapatnam, Srikakulam and Vijayanagaram have encountered damages to infrastructure, communication, shelter and livelihoods. Light 'kutcha' 1 houses (mud and/or thach) have been particularly badly damaged. According to the latest media reports, the latest death toll amounted to 22, a day after the cyclone's deadly path.



Cyclone inundated areas in part of Visakhaptnam District

According to initial government information, a total of 248,004 people in 320 villages have been affected by the cyclone and as many as 135,262 people have been evacuated and accommodated in 223 relief camps 2. Access to many affected villages is still difficult, and full extent of damage will be known in the next 24 to 48 hours. The cyclone landed exactly one year after cyclone Phailin, which affected Odisha and caused heavy damages and subsequent flooding. This time, Odisha was largely spared as the cyclone’s path took a slightly different direction.

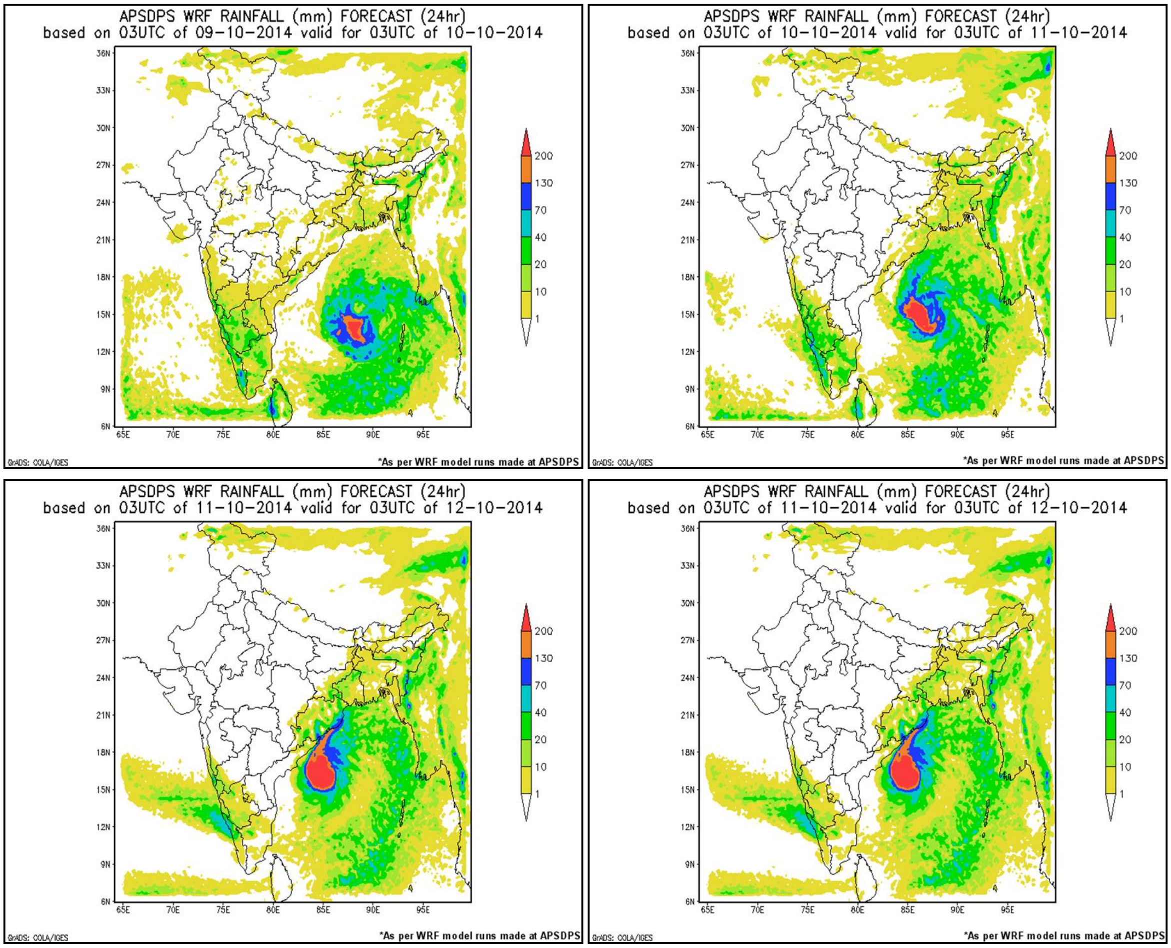
The Indian Meteorological Department (IMD) confirmed that the cyclone has lost most of its speed since last night, and has weakened into a deep depression. As a result, heavy rain is expected in Jharkhand, Bihar and parts of Madhya Pradesh and West Bengal in next 24 to 48 hours, and state authorities are on flood alert. Heavy rain is however not expected in Odisha.



Map showing land use land cover data in inundated areas

APSDPS has started experimental 24 hours, 48 hours and 72 hour forecast for India using mesoscale Weather Research and forecasting (WRF) model. This forecast is over 20 km X 20 km grid. At present we are upgrading and expanding the observational network to improve the forecast. The experimental forecast is under validation the predicted meteorological fields are being kept in graphical form five surface parameters are displayed.

- Humidity: is in percentage
- Rain: is last 24 hour and 48 hour accumulated rain and is in mm. Range: (0.0-0.4) - No Rain, (0.5-7.5)- Light, (7.6-64.4)- Moderate, (64.4+)- Heavy
- Temperature: is in Celsius
- Wind Direction: is in degree, and follows meteorological convention. 0 degree corresponds to Northerly wind
- Wind Speed: is in m/s.

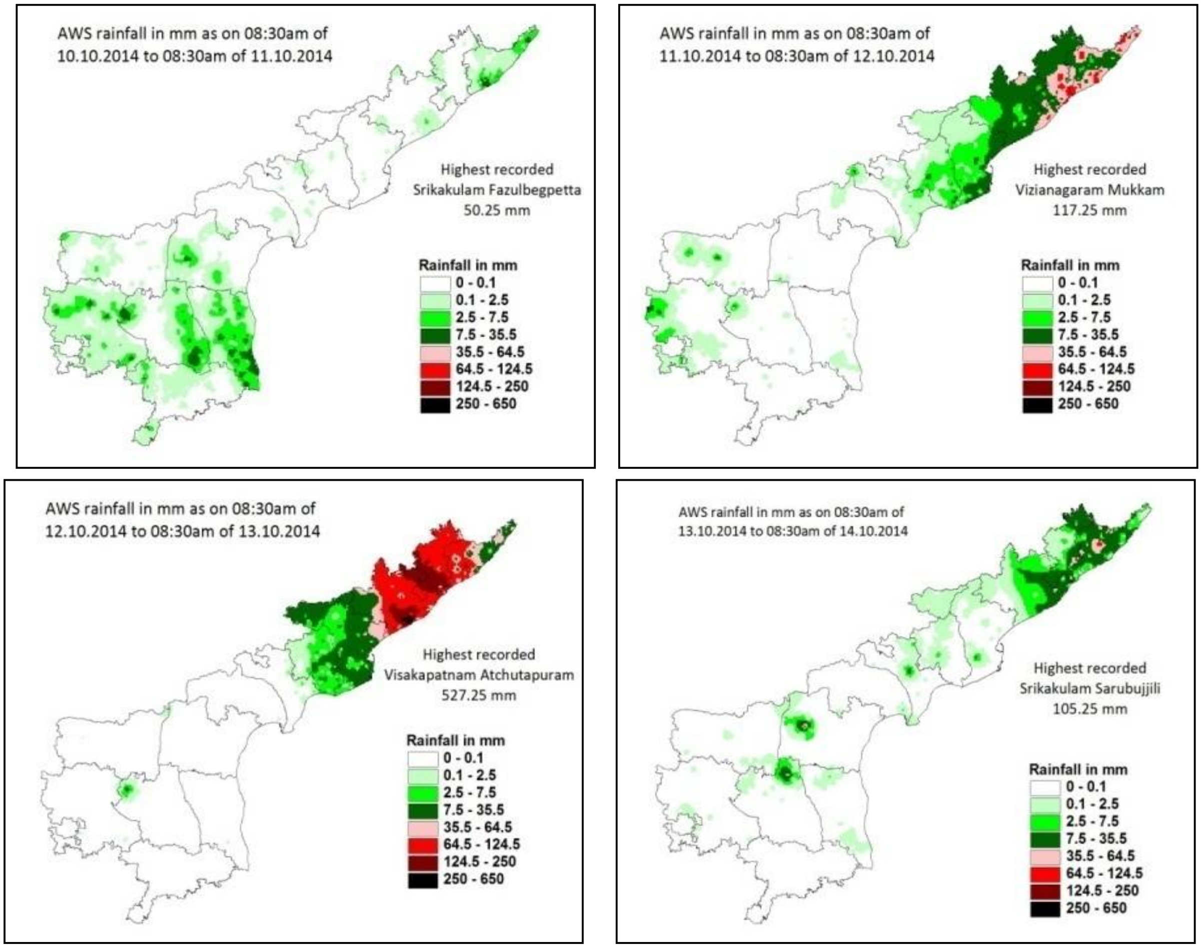


24 hr Rainfall Forecast of WRF-APSDPS model based on 03 UTC of 9th to 03 UTC of 12th October 2014

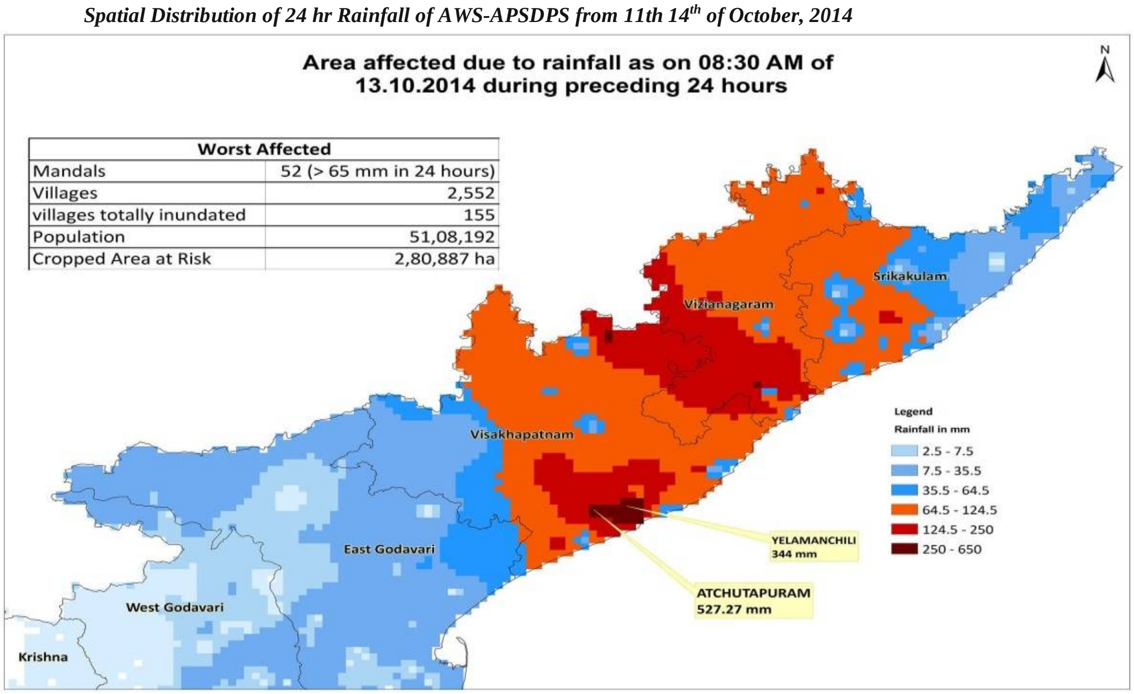
The actual rainfall recorded by the Automatic Weather Stations of APSDPS, rather heavy to heavy rains in the Visakhapatnam district, Atchutapuram mandal about 527mm on 0830am of 12th to 0830am of 13th October 2014.

Achuthapuram mandal (Visakhapatnam district) Automatic Weather Station hourly recorded rainfall, Local Pressure, Wind Speed and Wind Direction from 0830am of 11Oct, 2014 to 0830am of 13thOct, 2014.

As on 3pm of 12th Oct, recorded rainfall is about 139mm, Local Pressure 958mb and Wind Speed 81kmph.



Spatial Distribution of 24 hr Rainfall of AWS-APSDPS from 11th 14th of October, 2014



Spatial Distribution of 24 hr Rainfall of AWS-APSDPS from 12 th of October, 2014

Summary and conclusion

The recent developments in the storm surge forecasting for the Bay of Bengal is described. A real time storm surge prediction systems is proposed, which can be run in a few minutes on a personal computer. The forecasting system is based on the vertically integrated numerical storm surge model of Dube et al (1985). A dynamic storm model developed by Jelesnianski and Taylor (1973) is used for computation of surface winds associated with cyclonic storms. Only meteorological inputs required for the model are positions of the cyclone, pressure drop and radii of maximum winds at any fixed interval of times. The system is operated via a terminal menu and the output consists of the 2-D and 3-D views of peak sea surface elevations with the facility of zooming the region of interest. The system can handle multiple forecast scenarios.

The model results reported for several case studies are in very good agreement with the available observations and estimates of the surge. The model has extensively been tested with severe cyclonic storms of the last three decades, which have affected the coastal regions in the Bay of Bengal.

The cyclone had developed from a low pressure area which lay over Tenasserim coast and adjoining North Andaman Sea in the morning of October 6 and concentrated into a depression in the morning of October 7th. Moving west-northwestwards, it finally crossed north Andhra Pradesh coast over Visakhapatnam between 12 noon and 1 PM on October 12 with the wind speed of 180 km per hour. It finally weakened into a well-marked low pressure area over east Uttar Pradesh and neighbourhood on October 14 evening. Cyclone HUDHUD is the first cyclone which is formed in this year (2014) and crossed Visakhapatnam after 1995 cyclone. The intensity of the HUDHUD is same as phailin, with maximum wind speed is about 195kmph. Achuthapuram mandal of Visakhapatnam district received highest cumulative rainfall of about 527mm on 0830am of 12th to 0830am of 13th October 2014 by Automatic Weather Station. As on 3pm of 12th Oct, recorded rainfall is about 139mm, Local Pressure 958mb and Wind Speed 81kmph.

Uprooting hundreds of trees and bringing down power lines by the storm, it has since weakened but continues to deliver high winds and drenching rain. The WRF and Delft models provided good guidance with respect to its genesis, track, intensity and damage Mandal wise. These bulletins are mailed and send messages to district Collectors and CPO's.

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