ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 10 , October 2016

Precipitation Data Visualisation of Tropical Cyclone along Coastal Belt Districts of Bay of Bengal using Remote Sensing Based Web Tools

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ABSTRACT: IMD warned on 10th October 2014 at 12:30 PM. heavy to very heavy rainfall may occur in districts of North Andhra Pradesh including East Godavari, Visakhapatnam, Vizianagaram and Srikakulam Districts. The very severe cyclonic storm is located over the west central Bay of Bengal has moved North-Westwards during the past 6 hours and is located at about 420 km South East of Visakhapatnam and 450 Km South of Gopalpur gusting winds of about 100-110 km/hour along and off the coast of Odisha and Andhra Pradesh. The state has made all arrangements to evacuate people in low lying areas of coastal districts, Railways has cancelled certain trains, alerted coastal district administrations, control rooms are being opened in district collectorates and mandal offices, distant cautionary signal number 2 kept hoisted in all major ports, fishermen advised to return, the leaves of employees are cancelled, control room set up in district offices round the clock, Eastern naval command has kept 30 naval teams, one column of Army have been kept standby at Visakhapatnam, Disaster Rapid Action Force, NDRF, Fire services deployed in areas expected to be hit, state government in Full Alert to deal with any emergency, Hon'ble Prime Minister will chair a high level meeting, the moment comes to destroy steel city and its surrounding districts along the sea coast of Bay of Bengal in the name of 'HUDHUD' on 12th October 4. This paper focus on the precipitation data visualisation of cyclonic storm along the coastal districts along Bay of Bengal Visakhapatnam, Vizainagaram, srikakulam and East Godavari using Remote sensing based NASA web tools. The precipitation prediction from Skymet, IMD-India has lower rainfall depth values are recorded comparatively from NASA web tools of Giovanni. The precipitation data visualisation from GFMS shows nearly match with weather reports from Skymet and IMD-India.

KEYWORDS: HudHud, MODIS, NASA, Giovanni

I. INTRODUCTION

One third of the natural disasters are in the world can be attributed due to cyclone events. Globally, cyclones and tropical storms are the most expensive hazards during the last 100 years. The cyclone disasters are major challenges and these are to be effectively addressed and efficiently managed in order to have sustainable development and poverty alleviation particularly in developing countries like India [1]. Cyclones over the Bay of Bengal usually move westward or northward and cross the east coast of India or Bangladesh. When this happens, it brings strong winds and high rainfall to the coastal region, causing damage to property and loss of life [2]. Tropical cyclones in particular are the most devastating on natural disasters due to the loss of human life they cause and economic losses they induce. "A non frontal synoptic scale low pressure system originating over tropical or sub tropical waters with organized convection and definite cyclonic surface wind circulation" is called a tropical cyclone[3]. In India, the state of Andhra Pradesh (AP) is the second most impacted state, just after Orissa, which is also a coastal state lying immediately North of AP [4]. On 12 October 2014, the category 3 tropical cyclone made landfall on the coast of Andhra Pradesh, near the city of Visakhapatnam with severe cyclonic storm namely 'HUDHUD'. The name for the severe cyclonic storm 'HUDHUD' is contributed by Oman. It is an Arabic word. It is Hoope Bird which is called Hudhud in Arabic. Because a procedure is followed while naming cyclones over this part of the Indian Ocean, and countries are allotted turns to name cyclones. Care is taken that no community's sensitivities are hurt while giving names since cyclones are destructive. Accordingly, Oman named it Cyclone Hudhud [5]. 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 Vizainagaram have encountered damages to

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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infrastructure, communication, shelter and livelihoods [6]. According to sources HUDHUD if compared to Cyclone Phailin, the wind speed is much lower. Cyclone Phailin had speeds going up to 200kph, but the categories of both the systems are same [7]. On October 7, 2014, a low pressure area over Andaman Sea was upgraded to a depression by the India Meteorological Department (IMD). On October 8, when it made a landfall over an island in the Andaman, it was classified as a cyclonic storm. On October 10, Cyclone Hudhud was upgraded to a "very severe cyclonic storm" in intensity, at 2:30 pm it was cantered near latitude 15.0º North and longitude 86.8º East, around 470 km east-southeast of the coastal city of Visakhapatnam. From there, the storm system was predicted to move in a direction west-north-westwards. The next day, on October 11, large-scale evacuation of people from the coastal areas of Odisha and Andhra Pradesh was underway. On October 12, 2014 Cyclone Hudhud made landfall near Pudimadaka, some 50 km from Visakhapatnam in Andhra Pradesh at around 11.30 A.M. The sequential movement of Hudhud cyclone as shown in Fig.1

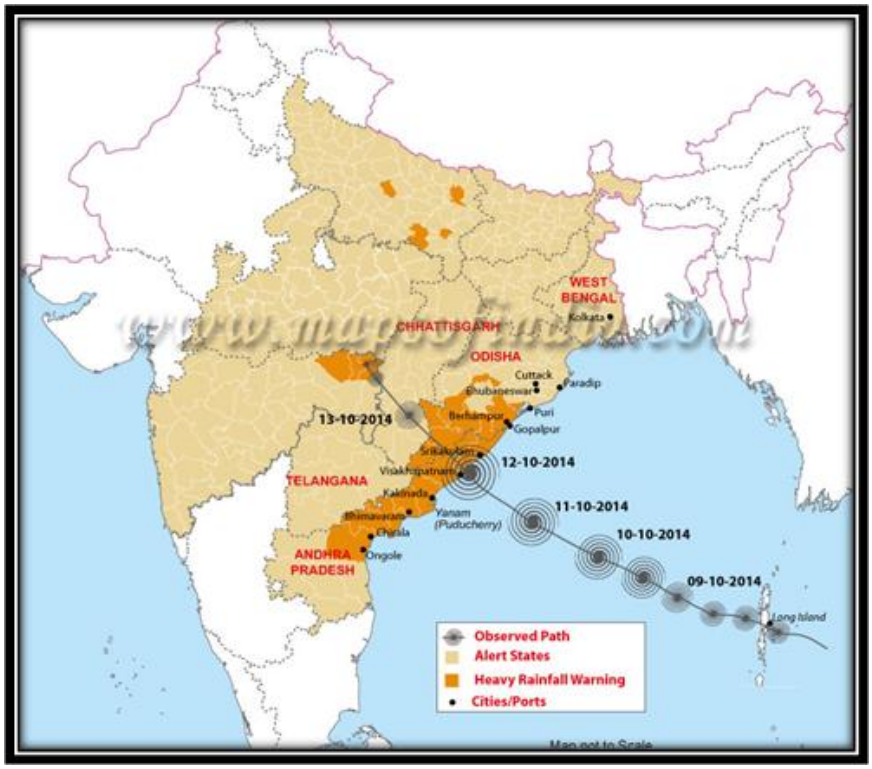

Fig.1: Observed path of cyclone 'HUDHUD' (source: Maps of India)

II. STUDY AREA

The study area chosen for precipitation data visualization of tropical cyclone 'HudHud' from remote sensing satellite based NASA web tools along Bay of Bengal coastal districts of Visakhapatnam, Vizainagaram, Srikakulam and East Godavari (Kakinada) of Andhra Pradesh as shown in Fig. 2.

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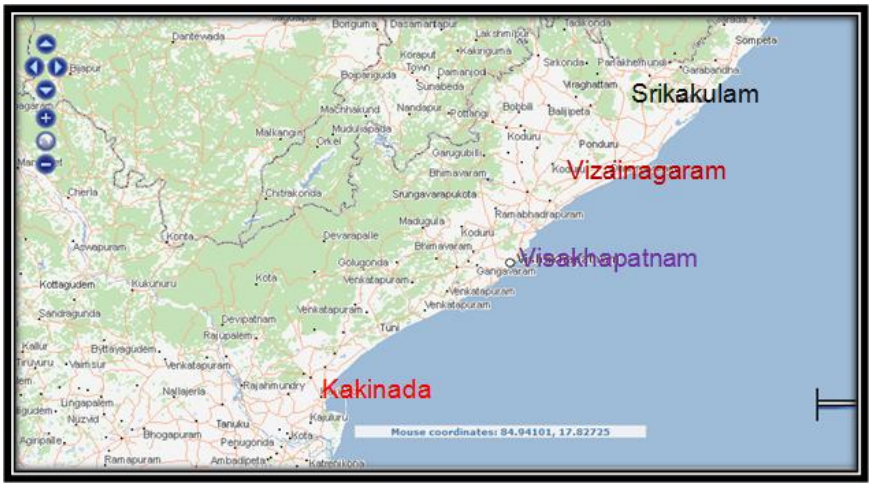

Fig.2: Coastal Districts of Andhra Pradesh along Bay of Bengal

III.MATERIALS

The horrified cyclone Hudhud causes heavy precipitation could be identified using NASA web tools, which are consider as the materials for identification and visualization. The MODIS instrument aboard NASA's Aqua satellite identifies the possibility of cyclone and its movement towards the landfall with cloud pattern formation. The Atmospheric Infrared Sounder (AIRS) instrument aboard Aqua captured infrared data on the storm that showed cloud top temperatures had dropped, indicating stronger uplift and stronger thunderstorms. NASA's Aqua satellite read temperatures of thunderstorm cloud tops that make up Tropical Cyclone. The Tropical Rainfall Measuring Mission-TRMM satellite monitors rainfall in the tropics from its orbit in space. The other important web tool designed by NASA for precipitation monitoring and visualize and download archives is Global Interactive online Visualisation and Analysis Infrastructure (Giovanni). Also NASA designed web tool of Global Flood Monitoring System (GFMS) for precipitation data visualisation for different days of accumulation. The fallowing paragraphs narrate each web tool for precipitation updates and visualisation of HudHud cyclone along coastal belt districts of Bay of Bengal of Andhra Pradesh

IV.NASA WEB TOOLS APPROACH

Moderate Resolution and Imaging Spectroradiometer (MODIS) instrument aboard NASA's Aqua satellite captured an image of Tropical Cyclone Hudhud in the Bay of Bengal On Oct. 9 at 07:45 UTC. Although the image showed that Hudhud looked somewhat elongated from east to west, the cyclone has been consolidating and getting more organized indicating the storm was getting stronger and more organized. According to the Regional Specialized Meteorological Centre for Tropical Cyclones over the North Indian Ocean or RSMC, issued a warning for north Andhra Pradesh coast and south Odisha as Hudhud nears for landfall. The MODIS satellite image of Hudhud cyclone as shown in Fig.3.

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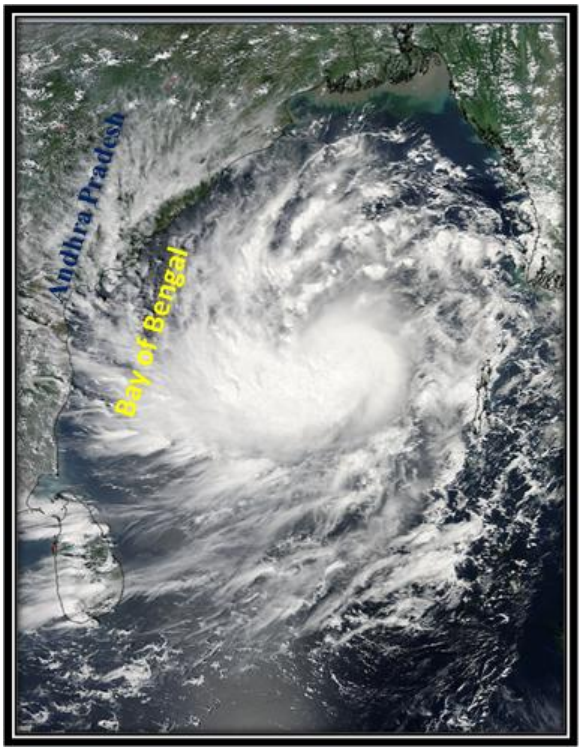

Fig.3: NASA's Aqua satellite image of Tropical Cyclone Hudhud in the Bay of Bengal on 9th October 2014. Image Credit: NASA Goddard MODIS Rapid Response Team

The Atmospheric Infrared Sounder (AIRS) instrument that flies aboard NASA's Aqua satellite read temperatures of thunderstorm cloudtops that make up Tropical Cyclone Hudhud when it passed overhead on Oct. 9 at 19:53 UTC. NASA sees intensifying Tropical Cyclone Hudhud headed for landfall in India on October 10th, 2014. AIRS uses cutting edge infrared technology to create three-dimensional maps of air and surface temperature, water vapour, and cloud properties and provides more accurate information on the vertical profiles of atmospheric temperature and moisture.

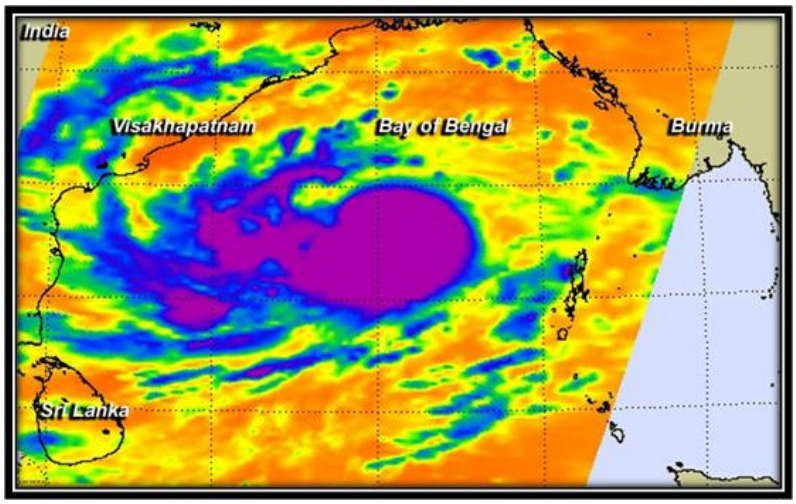

Fig.4: NASA's Aqua satellite infrared image of Tropical Cyclone Hudhud Credit: Image NASA JPL, Ed Olsen

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The temperature data with AIRS instrument showed the coldest cloud top temperatures were in thunderstorms circling a developing eye as in the Fig.4. The purple colour indicates Cloud top temperatures were as cold as -63F/-53C, which have the potential for dropping heavy rainfall.

NASA's Aqua satellite passed over Cyclone Hudhud as it was nearing East-central India's coastline on 11th October 2014. The Atmospheric Infrared Sounder or AIRS instrument aboard Aqua captured infrared data on the storm on Oct. 11 at 07:23 UTC (Fig.5) that showed cloud top temperatures had dropped, indicating stronger uplift and stronger thunderstorms. That's an indication that the storm has strengthened in the last day. On Oct. 11 at 21:00 UTC, cyclone Hudhud's maximum sustained winds increased to 110 knots (75 mph/120 kph), which classifies as a typhoon on the Saffir-Simpson scale. It was centered near 16.8 North and 80.9 East, about 102 nautical miles East of Visakhapatnam, India. Hudhud was moving to the North-Westward at 4 knots. The infrared image in Fig.5 the purple colour indicates cloud top temperatures had dropped, indicating stronger uplift and stronger thunderstorms.

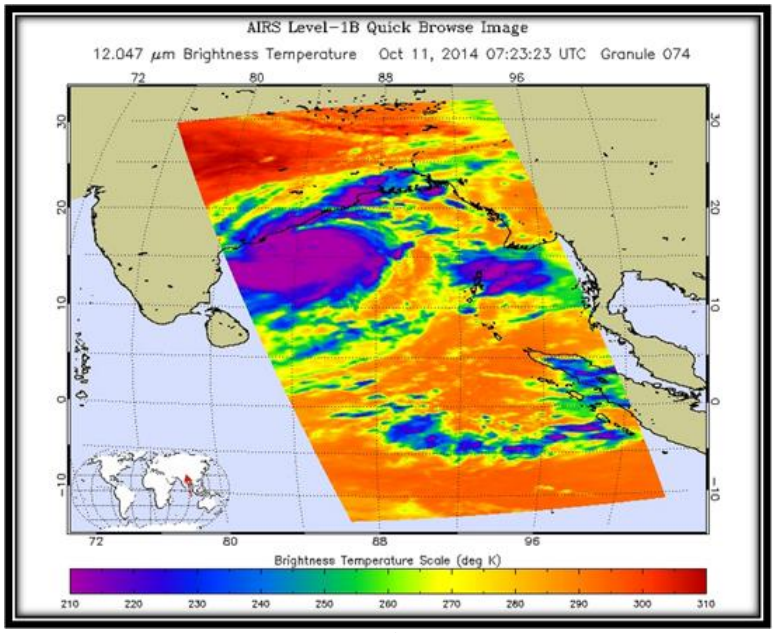

Fig.5: AIRS instrument aboard Aqua captured infrared image (Image Credit: NASA JPL, Ed Olsen)

A joint mission between NASA and the Japanese space agency JAXA, Tropical Rainfall Measuring Mission or TRMM satellite monitors rainfall in the tropics from its orbit in space. Data from TRMM was used to create maps showing rainfall totals as cyclone Hudhud made landfall in East central India. Cyclone Hudhud, which reached the equivalent of a category 4 hurricane on the U.S. Saffir-Simpson scale over the Bay of Bengal, on the central southeast coast of India near the port city of Visakhapatnam on Oct. 12, 2014. The TRMM-based, near-real time Multi-satellite Precipitation data Analysis (TMPA) is used to monitor rainfall over the global Tropics as shown in Fig 6. A TMPA rainfall analysis for the period 7-14 October 2014 over India and the surrounding region shows the rainfall associated with the passage of Hudhud.

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International Journal of Advanced Research in Science, Engineering and Technology
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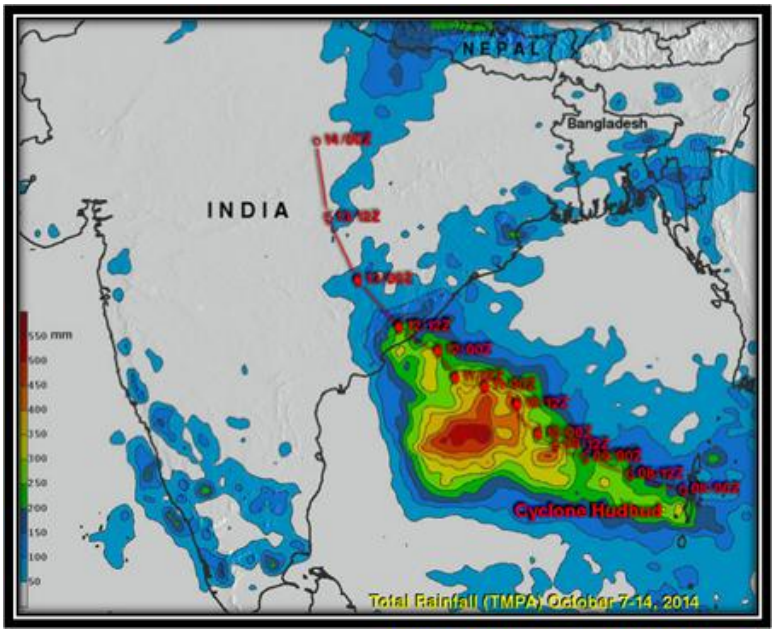

Fig. 6: TRMM rainfall analysis of Cyclone Hudhud from Oct. 7-14
Image Credit: NASA/SSAI, Hal Pierce

This TRMM flyby rainfall analysis of Cyclone Hudhud from Oct. 7-14 showed heavy rainfall in many areas. In the Fig.6 darker red Up to 550 mm over ocean and over land, the highest totals are 200 to 250 mm indicated green colour and blue colour shows a rainfall depth of 50 to 100 mm. The TMPA rainfall totals were highest over the open ocean where upwards of 550 mm may have fallen during cyclone, over land, the highest totals are 200 to 250 mm and were along the coast near where Hudhud made landfall.

Global Interactive Online visualization and Analysis Infrastructure (Giovanni) is an on-line environment for the direct statistical intercomparison of geophysical parameters in which the provenance (data lineage) can easily be accessed. Using the Giovanni user interface, it is possible to easily find and display selected data on a plot. It is also possible to download the plot source files in KMZ format. In this study the time averaged map downloaded to show data values for each grid cell within the user-specified area, averaged (linearly) over the user-specified time range as a map layer [8] as shown in Fig.7

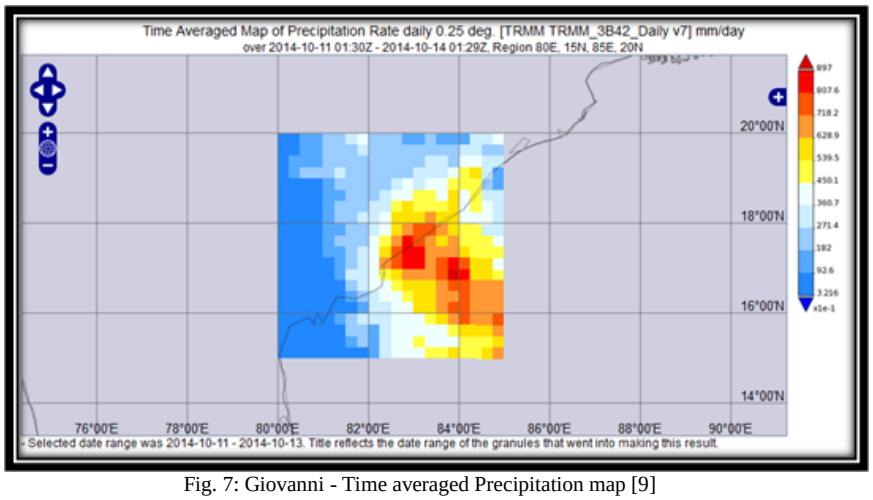

Fig. 7: Giovanni - Time averaged Precipitation map [9]

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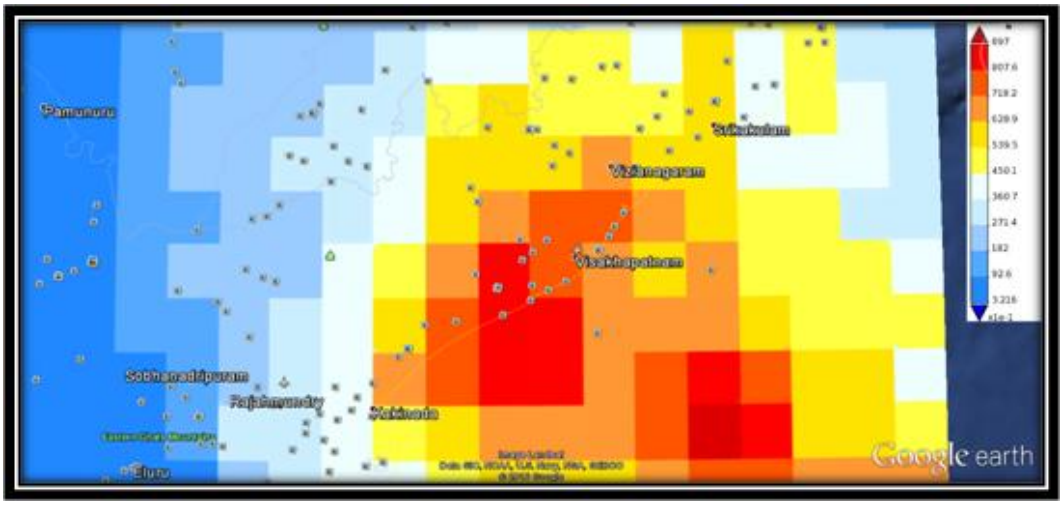

Fig. 8: Giovanni - Time averaged Precipitation map in KMZ format

Giovanni time averaged precipitation map shows that severe cyclone landfall at Visakhapatnam, accordingly the higher rainfall pored between 718.2 – 807.6 mm/day and in the surrounding areas of the district recorded as 628.9 – 807.6 mm/day, at Vizainagaram 628.9-718.2 mm/day and in the nearby areas of the district shows 539.5-628.9 mm/day, at Srikakulam 539.5-628.9 and it surrounding areas in the district shown as 450.1-539.5 mm/day. At Kakinada of East Godavari District 628.9-718.2 mm/day of precipitation occurred on the day of 12th October 2014.

The other vital NASA web tool to visualise precipitation of Hudhud cyclone on 12th Oct 2014 from Global Flood Monitoring System (GFMS). Cyclone Hudhud made landfall near Pudimadaka, some 50 km from Visakhapatnam in Andhra Pradesh at around 11.30 A.M. Visakhapatnam was hit hard. It is reported that the heavy rains this time has broken previous records and Tuesday experienced the maximum rainfall of 61.1 mm in a single day in October ever. GFMS ensures that the rainfall crosses 100 – 150mm at Visakhapatnam shown in fig.9. The rainfall at Vizainagaram, srikakulam and Kakinada shows lower depth of ranging between 50 to 100 mm at 00:00 hrs on 12th October 2014.

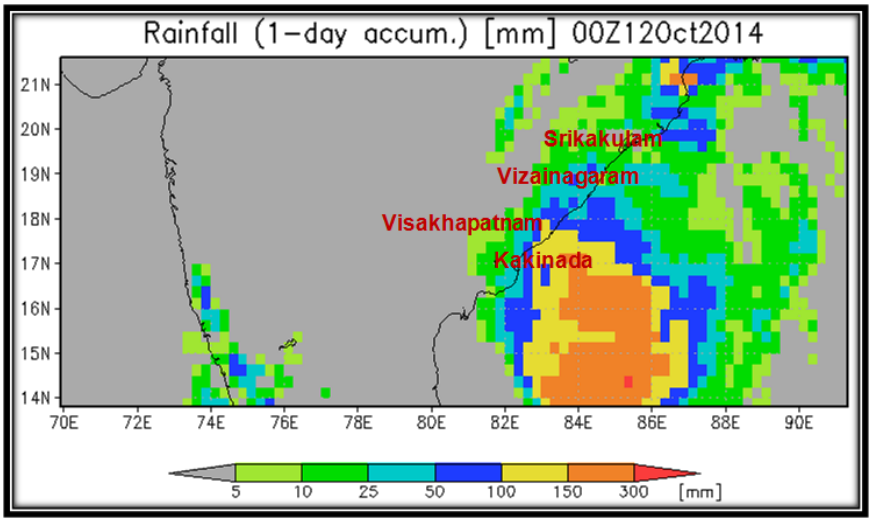

Fig 9: Precipitation from GFMS at 00:00 hrs on 12th Oct 2014

The GFMS is a NASA-funded experimental system using real-time TRMM Multi-satellite Precipitation Analysis (TMPA) precipitation information as input to a quasi-global (50°N-50°S) hydrological runoff and routing model

ISSN: 2350-0328
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running on a 1/8th degree latitude/longitude grid. The severity of cyclone takes place between 12:00Pm and 3:00 Pm on 12th October 2014, as per the Skymet and IMD, India. The news ensure by GFMS prediction of precipitation depths of i day accumulation as shown in Fig 10.

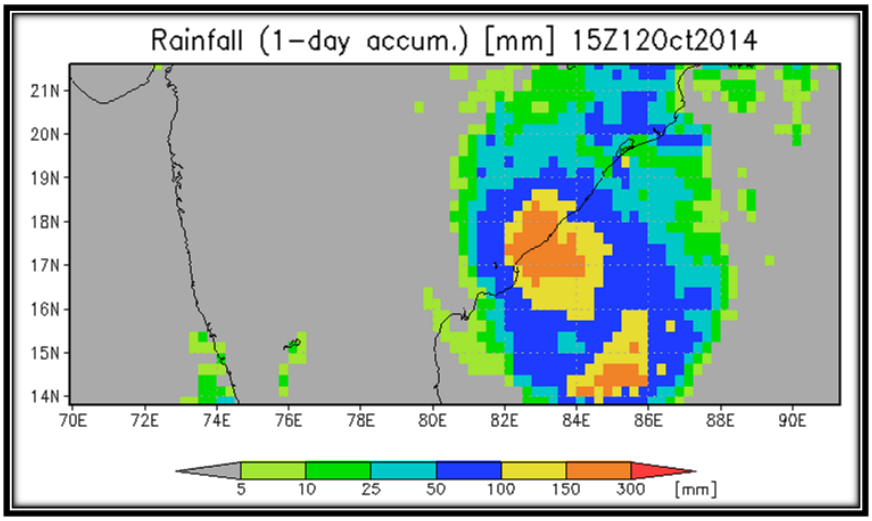

Fig 10: Precipitation from GFMS at 03:00 PM on 12th Oct 2014

Though it is experimental system, the precipitation reaches peak depth showing high of 300 mm at Kakinada, Visakhapatnam, Vizainagaram. A low rainfall range showing at Srikakulam of 100 mm.

V. DISCUSSIONS OF OBSERVATIONS

Incessant rainfall caused by the Severe Cyclone Hudhud has caused massive destruction, death and anguish in 4 coastal districts of Andhra Pradesh Visakhapatnam, Vizainagaram and Srikakulam and East Godavari. NASA's Aqua satellite reveals this destruction through an image of cloud distribution on 9tOct 2014. AIRS instrument that read temperatures of thunderstorm cloudtops that vulnearable Tropical Cyclone Hudhud. The same AIRS instrument captured infrared data on the storm indicating stronger uplift and stronger thunderstorms which leads to torrential rainfall over the areas. The TRMM-based, near-real time Multi-satellite Precipitation Analysis data (TMPA) is used to monitor rainfall over the global Tropics indicates different rainfall depths over. The daily precipitation depth ranges given by Giovanni at coastal districts of AP along Bay of Bengal. This ensures rainfall depth recorded 383 mm at Gantyada in Visakhapatnam, at Srungavarapukota 340 mm of Srikakulam, at Gajapathinagaram 222 mm of Vizainagaram, at Nellimarla 243.4 mm of East Godavari districts respectively. These web tools nowhere show the other pockets under this region did not observe any significant rainfall due to this cyclone.

VI. CONCLUSION

Distant cautionary signal number 2 kept hoisted in all major ports in the State of Andhra Pradesh. The government has alerted all the coastal district administrations for bracing its first cyclonic storm over the Bay of Bengal this year 2014. Control rooms are being opened in district collectorates and mandal offices. Coastal Andhra Pradesh is likely to experience gale and rains beginning on 11th October 2014 morning. HUDHUD cyclone is expected to cross North Andhra Pradesh and South Odisha coast between Visakhapatnam and Gopalpur around 12th October Noon. The prediction weather conditions by IMD and Skymet weather reports of India and media predictions are ensured by NASA Remote Sensing web tools.The precipitation depths given by IMD is quite low when compare to remote sensing web tools of TMPA and Giovanni. The precipitation data visualisation through other NASA web tool of GFMS rainfall depths are nearly matches with Skymet, IMD weather reports. The NASA web tools are potent to predict instantaneous and near real time precipitation data during epidemics. This instantaneous data can be utilised for analysis by the

ISSN: 2350-0328

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engineers and scientists during the time of disasters which enable to take safety measures of people and properties. The other vital feature of NASA web tolls are predicted precipitation can be visualising through digital mode with the help of Remote sensing satellite images.

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