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A Retrospective Comparision Study of Remote Sensing Satellite Derived Tropical Cyclone Caused Flood Prone Areas Along Bay of Bengal Coastal Vicinity Districts of Andhra Pradesh

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Abstract— *Floods are one of the most common and widespread disasters in India, with an estimated 40Mha of land prone to this natural disaster (National Flood Commission, India). Significant loss of property, infrastructure, livestock, public utilities resulting in large economic losses due to floods are recurrent every year in many parts of India. India encountered many cyclonic flood events during Oct-Dec 2013-2014, among which Phailin, Lehar, Madi and HudHud were rated to be very severe cyclonic storm. The path and intensity of these cyclonic events was very well captured by the model and areas were marked with persistent coverage of high runoff risk/flooded area. These thresholds were used to monitor floods in Jammu Kashmir during 4-5 Sep and Odisha during 8-9 Aug, 2014. The present study is to explore the usefulness of Remote sensing satellite derived surface runoff, to relate to the occurrence of flood inundation due to persistent and successive high surface runoff conditions. The study dealt with retrospective comparison of Flood caused due to tropical cyclone HudHud occurred on 12th Oct 2014 along Bay of Bengal coastal belt districts of Andhra Pradesh from NASA web tools and BHUVAN-ISRO web tools. Considering Bhuvan Geoportal for past flood records, not well defined as realistic conditions except at East Godavari district. Global Flood Monitoring System (GFMS) of NASA Web-Tool predicts the realistic flood scenarios during cyclonic storm of Hudhud on 12th October 2014.*

Keywords— *Hudhud, AMSR-E, Webtools, MODIS.*

I. INTRODUCTION

Floods in the Mahanadi and Godavari basins during 2013 caused by cyclone Phailin, Lehar, and Madi, have led to increased interest in research and development of flood forecasting systems. Key information to this includes meteorological observation, rainfall estimates from weather radar and satellites as well as hydrological model for rainfall-runoff and resulting flood estimation. India being a vast country, the problem due to floods is visualized on regional basis. Drainage congestion due to urbanization, inundation and soil/silt erosion are the main problems in India with respect to floods. Flooding is a natural and recurring event for a river or stream. Statistically, streams will equal or exceed the mean annual flood once every 2.33 years [1]. Flooding is considered as the world's most costly type of natural disaster in terms of both human causalities and property damage [2].

The annual disaster record reveals that flood occurrence has increased about 10 folds during the last 45 years, from 20 events in the year 1960, to 190 events in the year 2005 [3]. India is one of the worst flood-affected countries, being second in the world after Bangladesh and accounts for one fifth of global death count due to floods. About 40 million hectares is flood-prone, which is about 12% of the total geographical area (328 million ha) of the country [2]. The 1986 flood on the Godavari River, with a peak discharge of about 99,300 m 3 /s [4], is the largest flood on record in the entire Indian subcontinent till date [5]. The total area affected by floods has also increased during these years. The flooding occurs typically during the monsoon season (July - September), caused by the formation of heavy tropical storms. Studies are continually going on for mapping the flood-prone areas in India. Several agencies, such as the Central Water Commission - CWC (Flood Atlas of India), the Building Materials and Technology Promotion Council-BMTPC (Vulnerability Atlas of India), and the National Atlas and Thematic Mapping Organization–NATMO (Natural Hazard Map of India), have been involved in the flood-hazard mapping. Advances in geospatial technologies (Global Positioning System (GPS), Remote Sensing (RS) and Geographic Information System (GIS) have enabled the acquisition of data and analysis of the river basin for urban flood hazard mapping in a faster and more accurate manner.

This study dealt with identification of flood prone areas based on web-tools from India and USA. The Flood Tools used three basic concepts. First concept is, TRMM provides direct observation of rainfall. The rainfall data are either directly used for inferring to flooding or are used in conjunction with hydrologic models to derive streamflow or runoff. (GFMS, ERDS). Second concept, MODIS provides observations of land-surface. MODIS reflectance from various bands indicate presence of water on land surface. (MODIS NRT, DFO). Third concept, AMSR-E and TRMM microwave data provides information about surface conditions (dry or wet) (DFO, GFDS) [6].

This paper prepared using BHUVAN web tools for past flood record and NASA web tools of GFDS, GFMS and MODIS for flood area identification caused from HUDHUD tropical cyclone occurred on 12-14 October 2014 along coastal belt vicinity of Andhra Pradesh of Bay of Bengal. At the same time, in Andhra Pradesh, the highest number of cyclones target Nellore and Krishna districts followed by east Godavari and Srikakulam. As per IMD's observations, the change in circulation patterns in the north Indian Ocean might

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have played a role in Hudhud making a landfall in Visakhapatnam [7].

II. Study Area

The severe cyclonic effected regions in Andhra Pradesh are East Godavari, Visakhapatnam, Vizainagaram and Srikakulam districts along coastal vicinity of Bay of Bengal as shown in Fig.1. These 4 coastal districts of Andhra Pradesh along Bay of Bengal were shown in study area for identification of flood prone areas through Remote sensing based web tools of Bhuvan-ISRO and NASA. Among these 4 districts, Hudhud cyclone has caused extensive damage due to torrential rains in three coastal districts of Visakhapatnam, Vizainagaram and Srikakulam.

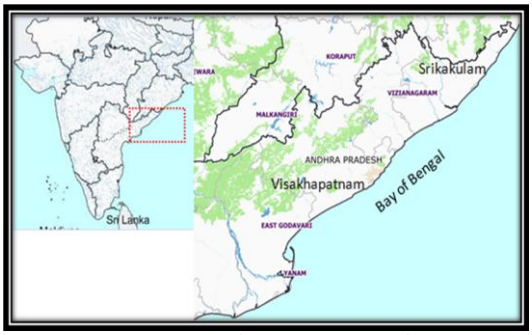

Fig. 1. Study area along Bay of Bengal Districts of Andhra Pradesh.

Most of the damage is seen in Visakhapatnam caused due to incessant rainfall by the Cyclone Hudhud has caused massive destruction in the form of blown away the roof of the city's airport, the ships which had been in the harbour were moved offshore to escape the wrath of the high seas, around 25,000 people were moved from Visakhapatnam district. The damage caused by Cyclone Hudhud not only changed the landscape of the port city of Visakhapatnam, but also made it the first city in the country to be directly hit by a cyclone since 1891 as per the records of the IMD. IMD Hyderabad director K Seetharam said, "Till date, all cyclones made landfall in the plains and semi-urban areas along the Indian coast. For the first time in IMD's recorded history, Cyclone Hudhud ran over a green city like Visakhapatnam, which was never hit by cyclones." [8].

Hudhud not only emerged as first high intensity cyclonic storm in 2014 to make landfall at wind speeds of 206 kmph, but also the third highest intensity cyclonic storm out of the 515 cyclonic storms that developed in either the Bay of Bengal or the Arabian Sea since 1891.

III. Web-Tools for Flood Delineation

Earth Observation (EO) data from multitude platforms are providing wide ranging datasets that are useful for creation of spatially distributed parameters appropriate for hydrological modeling. For the present study, meteorological forcing datasets were created using observational data sets from remote sensing derived data from various satellite sensors. The important web tools utilized for this study are Bhuvan Indian Geo platform of ISRO Disaster service NDEM (National Disaster Emergency Management). The other web tools designed from NASA Godard Space Centre-USA of Global Flood Detection System (GFDS), A component of Global Disaster Alert and Coordination System (GDACS**)** Developed by European Commission - Joint Research Center. GFDS provides global, event-based information which utilizes remote sensing information for flood detection and open for collaboration with water authorities and researchers as a part of GDACS, augment humanitarian and disaster information. GFDS utilizes for monitors floods worldwide using near-real time NASA satellite data (TRMM, Aqua) includes information about current and past disaster events (floods, tropical cyclones, earthquakes). Global Flood Monitoring System (GFMS), Provides global maps, time series, animation of instantaneous rain, accumulated rain over 24, 72, and 168 hour, Stream flow rates and flood detection at 1/8th degree, approximately equal to 12 km flood threshold, past archive available. The inputs information obtained from TRMM and Multi-satellite Precipitation (TMPA), surface temperature and winds from MERRA. The runoff generation from U. Washington Land Surface Model (Variable Infiltration Capacity) and Runoff routing model from U. Maryland Dominant River Tracing Routing (DRTR) model [6].

The other web-tool of MODerate Resolution Imaging Spectroradiometer (MODIS) flying on-board Terra and Aqua – polar orbiting satellites and global measurements, 1 to 2 times per day having 36 spectral bands observing atmosphere, ocean, and land properties and its measurement footprints vary from 250 m to ~1 km. MODIS–NRT based Flood Water (MFW) provides observations of land-surface, based on reflectance from various bands indicate presence of water on land surface.

IV. Flood Prone Areas From Web-Tools

The tenet of this paper is comparison of flood prone areas caused due to tropical clone of HudHud occurred on 12th October 2014 along Bay of Bengal with the satellite derived web tools designed by Indian Space Research organization (ISRO) of Bhuvan and National Aeronautics Space Administration NASA of USA space agency designed GFDS, GFMS and MODIS Near Real Time Flood Water (MFW). The flood prone areas of cyclonic storm of HudHud narrated in the fallowing paragraphs.

A. BHUVAN-ISRO

The National Remote Sensing Centre (NRSC) designed Indian Geo platform portal for visualization and download data of different thematic. One of the portal of Disaster services supply the past flood records of HudHud cyclone [9]. The name for the storm HUDHUD is an Arabic word which means a Hoope Bird in Arabic contributed by Oman. A depression in the Andaman Sea by the India Meteorological Department (IMD) made a landfall over an island, it was classified as a cyclonic storm on 8th October 2014. Cyclone Hudhud was upgraded to a "very severe cyclonic storm" in intensity, large-scale evacuation of people from the coastal areas of Odisha and Andhra Pradesh was underway, four ships of the Indian Navy were on stand-by to rescue missions,

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people were moved from Visakhapatnam ,Srikakulam district, 140 emergency relief shelters had been opened ,Nineteen teams of the National Disaster Response Force (NDRF) were deployed, the army was on stand-by too, trains, flights to Visakhapatnam were cancelled. Cyclone Hudhud made landfall near Pudimadaka, some 50 km from Visakhapatnam in Andhra Pradesh at around 11.30 A.M on October 12, 2014.

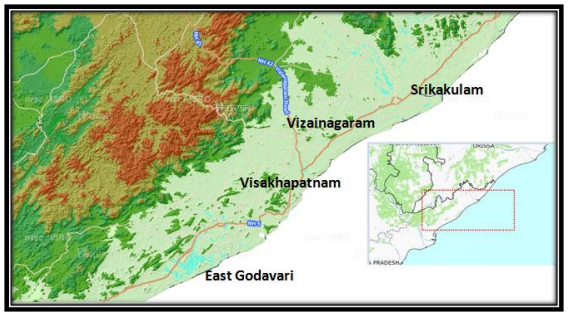

Fig. 2. Flood prone areas along coastal districts-Bhuvan web tool.

This paper focus on the worst hit districts of were Visakhapatnam, Srikakulam, East Godavari and Vizianagaram in Andhra Pradesh and Visakhapatnam was hit hard. Overall, Andhra Pradesh faced the brunt of the storm. The flood prone areas depicted from Bhuvan as shown in Fig.2.

B. NASA-GFDS

The Global Flood Detection System (GFDS) monitors floods worldwide using near-real time satellite data. Surface water extent is observed using passive microwave remote sensing (AMSR-E and TRMM sensors). When surface water increases significantly (anomalies with probability of less than 99.5%), the system flags it as a flood. Time series are calculated in more than 10000 monitoring areas, along with small scale flood maps and animations [10].


Fig. 3. Flood prone areas along coastal districts – GFDS Version2.0.

Using AMSR-E data, De Groeve et al. (2006) developed a method for detecting major floods on a global basis in a systematic, timely and impartial way appropriate for humanitarian response. The circle paths shown in Fig. 3 indicates the flood spreading areas. This web tool provides less flood prone surface area along coastal districts of Visakhapatnam, Vizainagaram and Srikakulam. But at East Godavari District, it shows water spread circles in brown color as indicated in the figure.

C. NASA-GFMS

Cyclone Hudhud makes landfall at Kailashgiri in Visakhapatnam, the Eye of the cyclone Hudhud will pass through Kalinga, Bheemunipatnam and diameter of eye is 50km wide, will be a lull in storm between 11AM-12:30PM on 12th October 2014. The GFMS is a real time quasi-global hydrological calculations at 1/8th degree and 1 km resolution. This web tool is 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 running on a 1/8th degree latitude/longitude grid. Flood detection/intensity estimates are based on 13 years of retrospective model runs with TMPA input, with flood thresholds derived for each grid location using surface water storage statistics (95th percentile plus parameters related to basin hydrologic characteristics [11].

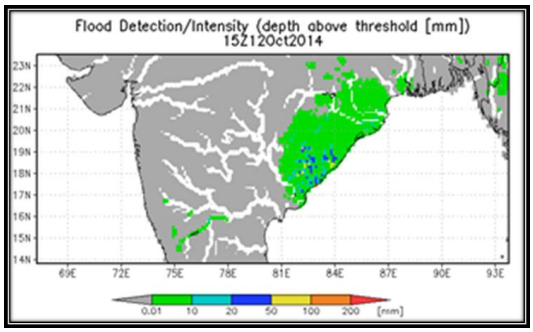

Fig. 4. Flood intensity along coastal districts –GFMS web tool.

As per the NASA-GFMS shows the maximum flood intensity along the coastal districts of East Godavari, Visakhapatnam, Vizainagaram, and Srikakulam as shown in Fig. 4. The flood intensity near Visakhapatnam shows more than 200 mm, at Vizainagaram and East Godavari districts shows 50-100 mm depth. At some places of these districts indicates flood depth of 20-50 mm. The overall these 4 coastal districts flooded with more than 20 mm.

D. NASA-MODIS

Moderate Resolution Imaging Spectroradiometer (MODIS) is a payload scientific instrument built by Santa Barbara Remote Sensing that was launched into Earth orbit by NASA in 1999 on board the Terra satellite and in 2002 on board the Aqua satellite. They are designed to provide measurements in large scale global dynamics including changes in Earth's cloud cover, radiation budget and processing occurring in the oceans on land, and in the lower atmosphere. MODIS Reflectance in Optical Bands 1(620-670 nm), 2(841-876 nm), and 7 (2105-2155 nm). MODIS provides observations of land-surface reflectance from these bands indicates the presence of water on land surface, previously not covered by water. Near-Real Time Global MODIS Flood Mapping Tool has 4 different products namely MODIS Flood Map (MFM) annotated 10x10 degree map/graphic product (currently available in png format), MODIS Surface Water (MSW) and it is based on a ratio of MODIS bands 1, 2, and 7 reflectance values. The third product of MODIS Flood Water

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(MFW) Obtained by subtracting Reference Water from MSW, where as Reference Water is based on MODIS reflectance and Shuttle Radar Topography Mission Water Body Data. The fourth product is MODIS Water Product (MWP). In this study MFM tiles are used for identification of flood on 12th October 2014 of Hudhud cyclone.

A global reference database of water bodies is formed – inundation is mapped with respect to the reference water. NRT MODIS-Global Flood maps were downloaded for the location of Asian region of Andhra Pradesh along Bay of Bengal coastal districts [12]. The Flood maps are available in kmz and.shp formats. The download KMZ files from the MODIS site can be visualized in Google Earth as shown in Fig. 5

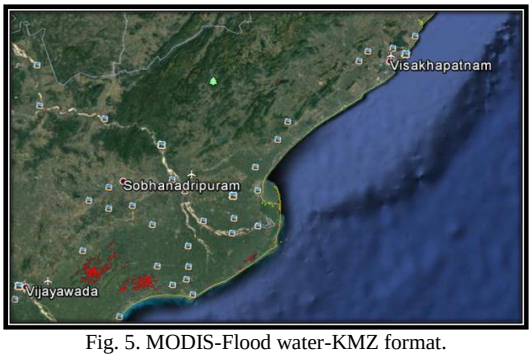

Fig. 5. MODIS-Flood water-KMZ format.

The Flood maps are available in 1 day, 2 day, 3 day and 14 day composite maps. In this study all web tool maps are considered for 3 day composites. As the figure indicates, all 4 districts places not shown any inundated areas, caused due to cloud cover. MODIS has limitation of unpredictability of water surface areas with cloud cover.

Also MODIS Flood Water (MFW) downloaded in shapefile format. The colored Polygons showed in Fig.6 represents inundated lands in the files or surface water areas, respectively. MFW polygons have attributes giving polygon size (in km2), and centroid. The figure reveals that small water spread pockets shown along coast line. From East Godavari to Srikakulam, similar empty space, this represents of no surface water prone zone. The technical reason behind was identified as that MODIS doesn't sensitive to surface water under cloud cover. As per IMD report, on 12th October 2014, cyclone Hudhud made land fall along coastal districts which were covered under severe threat of clouds.

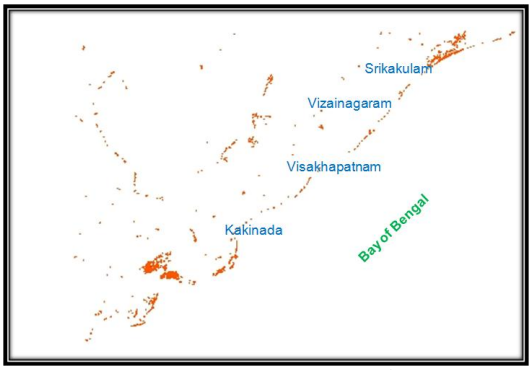

Fig. 6. MODIS Flood Water - .shp format.

There is no indication provided, where there is insufficient clear data in the given product to determine water extent. Thus, these products only indicate where water is likely to be, but the absence of a water polygon cannot be interpreted to mean there was no water present in a given area, it may simply have been sufficiently cloudy over the composite period for the required number of water observations.

V. Discussions of Web-Tools

According to the Regional Specialized Meteorological Centre for Tropical Cyclones over the North Indian Ocean (RSMC) Hudhud is forecast to cross North Andhra Pradesh coast around Visakhapatnam during the afternoon of Oct. 12, 2014. Four different WEB-Tools were utilized for visualization of flood prone areas along coastal districts of Andhra Pradesh. Indian Geo platform portal of National Remote Sensing Centre (NRSC) display the past flood records of Disaster services. The Cyclone Hudhud on worst hit districts of Visakhapatnam, Srikakulam, East Godavari and Vizianagaram in Andhra Pradesh. This web tool shows the maximum flood near East Godavari and Srikakulam district areas. But the hit hard was Visakhapatnam which was not represent the actual flood situation.

The other web-tool of GFDS Ver.2.0 with the Advanced Microwave Scanning Radiometer– Earth Observing System (AMSR-E on NASA's Aqua satellite) provides frequent global coverage for the Earth's surface and, without severe interference from clouds. Though, the sensor provides data at a variety of frequencies, polarizations, look angles, and time-of-days, it doesn't show the real flood prone areas along coastal districts. It might be the reason behind hindrance of actual flood prone area along coastal districts was the Microwave measurements change substantially from dry to wet land the change in microwave measurement signal from dry to wet is used to detect the presence of surface water over previously dry land. GFMS web tool shows the replica of the real water spread over all these 4 coastal districts along Bay of Bengal. Some places flooded with high intensity of depth near Visakhapatnam, Vizainagaram srikakulam and East Godavari districts. Though the MODIS has enough strength like high resolution, globally consistent can provide coastal inundation mapping due to storm surge or tsunamis, it has sufficient limitations of provides surface inundation mapping only outside the water bodies, it does not provide information about water depth or water flow and cannot view the surface in the presence of clouds also mountain and cloud shadows may be erroneously interpreted as water inundated surfaces.

VI. Conclusions

The concept of development of a library hosting a series of Web-Tools representing flood inundation observed from different Remote sensing satellite data, can be used as a quick and cost-effective method for alerting the habitation at risk during flood season. This method can be helpful in anticipating the areas to be affected in situations where satellite images are available, but due to cloud cover cannot be effectively utilized and also when the area of interest is partially covered in satellite data. The retrospective analysis of

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flood prone areas along coastal belt vicinity through web tools are not well defined except at East Godavari district. Considering for comparison of 4 different web tools, GFMS is represents the realistic flood intensity on 12th October 2014 of Hudhud cyclone. Bhuvan Geoportal past flood data was also not compatible with real inundation areas as given by IMD and other web portals. Though simulation of inundation extents through hydrological modelling remains the best means, but keeping into consideration of non-availability of fine resolution DEM and real-time hydrological data, this approach can be of help especially for decision-makers in times of crisis and making disaster management plans for flood season. Most web-tools have interactive, near-real time flood mapping capability with flood potential and/or streamflow/run-off. Regional evaluation by end-users is recommended.

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