Open Source Satellite Images in Flood Monitoring. Do We Need a Liberal Spatial Data Policy During Disasters...?

Image Courtesy: NASA

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The predictions of the meteorological department regarding the onset of natural disasters and the actual incidences of natural calamities were failed to converge in most of the situations in India during the last three decades. The Utharakhand cloud burst occurred in June, 2013 was the most recent example to cite the failure of such predictions. The abrupt changes in the local climate phenomenon together with global climate change triggered the frequency of occurrence of natural disasters in the form of floods, droughts, landslides and uneven rainfall events. Though the recent developments in communication technology and modern mitigation strategies have brought down the severity of natural calamities, the population in disaster prone areas are under threat due to uncertainty. According to CRED (Center for Research on the Epidemiology of Disasters) 2.3 billion people were affected by flood globally during 1995-2015 .

The record of worldwide affected population of 115 million per year, alarm the researchers and decision makers to identify the reliable solutions to overcome and resist the natural calamities of varying intensities. For a quick response during these calamities decision makers need reliable information with greater accuracy and quality for a very large area. Satellite remote sensing provides a synoptic view of the area with repeated updates through images.

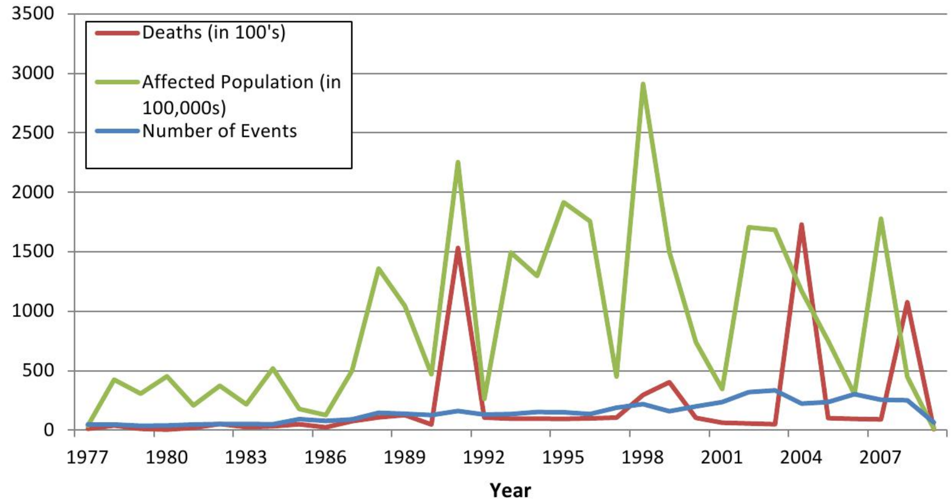
It is the only solution which gives a large amount of information in different scales and perspective with greater accuracy and frequency to the disaster managers and earth science research community. Many satellites have launched by different countries to look at the changing earth and its atmosphere. The volume of data collected by ground stations from these satellites is huge, so that a small government agency cannot handle it easily. According to NASA's Earth Observing System Data and Information System (EOSDIS) metrics of 2014, it managed more than 9 petabytes (PB) of data. It is equivalent to 9000 terabytes. There are many remote sensing agencies currently collecting data in the same level as the NASA does and the data produced are huge in terms of petabytes.

Who really uses it...? Whether this data is underutilized?

Here comes the importance of open data policy. At least during the time of disasters, the barriers of data access have to be taken out, so that the common people with scientific aptitude can process it to help the people in agony. There will be a time in the near future when each panchayath in the country start making their own maps of natural resources and disaster management. This article focus on the use of open source datasets and tools in disaster management and how the participatory approach in data processing can encourage the use of remote sensing.

Land and water resource utilization without any vision and rapid urbanization during the last 3-4 decades made the environment a card castle, where any small change can create a butterfly effect on the environmental balance. Every year droughts and floods are occurring cyclically in the Indian subcontinent. Around one eighth of the total geographical area is flood prone in India. News on loss of life and wealth due to natural calamities are considered as 'usual'. Between July and August in every year, flooding affects more than a million people in North Eastern states of India. For people in Assam, it is, an annually expected phenomenon and the death toll and agony is often less noticed by the rest of the world.

Meteorological information related to flood and rainfall are not available in many parts of the country. If available, the instrumentation at many meteorological stations are not maintained or calibrated properly. This is one of the many reasons that made the satellite-based tools more useful to evaluate the flood and related ground conditions. Since independence, there have been many worst flood events in India. Bihar flood in 1987 killed 1399 people and Maharashtra flood in 2005 killed 1094 people. Gujarat flood in 2005 created a financial loss of 8000 crore rupees for the nation. In 2012 Assam flood displaced around 5 million people from flood inundated areas. The instances of flood disasters in India since independence are still many, and the loss of life and wealth created by these disasters are poorly accounted and the victims are often ignored. Mitigation strategies are often failed, killing hundreds of poor people and making millions homeless. In most of the cases, human being and his technology stay defeated in front of natural disasters, leading to the collapse of his financial well-being. Natural calamities often destroy the habitats and healthy environment around him. The death toll due to sudden disasters followed by epidemic diseases often worsen the situation beyond our control.



Flood events affecting human populations by year

Courtesy: The Human Impact of Floods: a Historical Review of Events 1980-2009 and Systematic Literature Review by Shannon Doocy et. al.

Geo-spatial data and flood management strategies

Scientific and effective disaster management strategies can speed up the resilience. Flood disaster management has mainly three different cycles, which are preparedness stage for flood, flood occurrence stage, and mitigation stage. The scientific and management group has been already reached the consensus of selecting the spatial data sets, as the most effective inputs for achieving the targets for all the three stages.

The major challenges during flood preparedness stage are to identify the most affected geographic regions during the past flood events and planning for evacuation. The second stage, the most critical stage of disaster management, targets to identify the spatial extent of flooding, flood progression, and the recession. The output of this stage is most important for immediate action and rescue operations. The mitigation stage focuses the identification of changes in river courses, flood control works, erosions of river banks, drainage congestion, flood hazard and risk vulnerability assessment. The recent constellation of Earth Observation satellites of different spectral and spatial configurations is sufficient enough to provide reliable inputs for these different stages of management.

Legacy of Earth observation satellites

The occurrence of flood is associated with various reasons. In most of the cases, floods due to heavy rainfall are predominant. At rainy conditions, overcast can limit the use of optical imagery. Thanks to Lansdat program and NASA's Aqua Terra satellites for providing the images for flood monitoring to a greater extent during the last decade.

The synoptic and temporal coverage of satellite images facilitate the flood mapping related studies at inundated areas of different conditions in climate, morphology and land use. Satellite images captured by optical sensors were mainly used for flood related studies before 10 years. Riverine flooding due to glacier melt and coastal flood due to tidal surges can be studied effectively by optical images. The inability of optical sensors to procure clear images during cloudy weather conditions, limits its application potential during flood events accompanied by clouds. The onset of microwave remote sensing satellites paved the way towards all weather condition images. Data acquired from several SAR (Synthetic Aperture Radar) instruments like ERS-2, ENVISAT/ ASAR, RADARSAT1/2, ALOS PALSAR, RISAT, TandemX etc. used in various flood events worldwide. Sentinel 1A and 1B, launched as a part of ESA's Copernicus program is the latest among SAR satellites which have an open data policy.

The space era of Earth Observation satellite began with the launch of Landsat series of satellites in 1972 and today the Landsat mission is the longest acquisition program for satellite images of Earth with its latest in the series, Landsat 8. Landsat mission is the favorite mission for the user community, because of its 30m spatial resolution and 16 days temporal resolution. Free data availability and spectral bands at Visible, Near-infrared Middle infrared and thermal infrared regions make this mission a unique one.

The Indian Remote Sensing Satellites (IRS) series from 1A to today's Resourcesat 2A are another promising series of optical satellite datasets which are useful for flood management studies. A participatory approach in flood mapping is not possible at the current scenario, because the process of ordering data, payment, data processing and its delivery, were the concerned time constraints that delay the retrieval of output for a quick response and action. Since the IRS data availability to the user community is delayed due to policy issues, flood monitoring studies are carried out by government agencies themselves. Liberalizing the data availability to the public during disasters and disseminating them through the internet to the scientific community can boost data processing and disaster management activities.

The requirement of high-resolution image at daily basis is again a hurdle in flood monitoring. MODIS (Moderate Resolution Imaging Spectrometer) images are the only option available today. MODIS on-board Terra and Aqua satellites revisit every nook and corner of the Earth on a daily basis. Since the spatial resolution is 250m, flood maps with moderate resolution can be made using these datasets. This is the only sensor that can provide images in daily basis with reasonably good spatial resolution. Red and Near infrared bands in MODIS has 250m spatial resolution and these bands are used for generating flood maps. NASA's Global Flood Mapping system uses these MOIDIS bands for generating daily flood maps for the entire globe.

Urban flood studies still demand very high-resolution images and getting high-resolution images on a daily basis is a costly exercise. No satellite currently provides high resolution images on a daily basis and the only possible option is to gather data is from a constellation of different satellites that are taken together. Due to this, government agencies mostly depend upon aerial surveys for high resolution images.

Another promising mission is Sentinel 2, which is also an optical remote sensing satellite launched as a part of ESA's Copernicus program. The twin satellites 2A and 2B together has a revisit period of 5 days with a spatial resolution of 10m. The data is free for the user community.

Open data policy in remote sensing has the prospects of connecting communities of different domain together to build a robust solution for quick actions towards disasters. Also the participatory approach can reduce the workload on the government agencies that will help to reduce the gap between the action and reaction. Nowadays, when an earthquake or flood happens, the user community is open to the current data and we expect people to come up with solutions to help the people. The CLOUD to beat the cloud burst is a promising platform for flood disaster management.

Chennai Floods in 2015

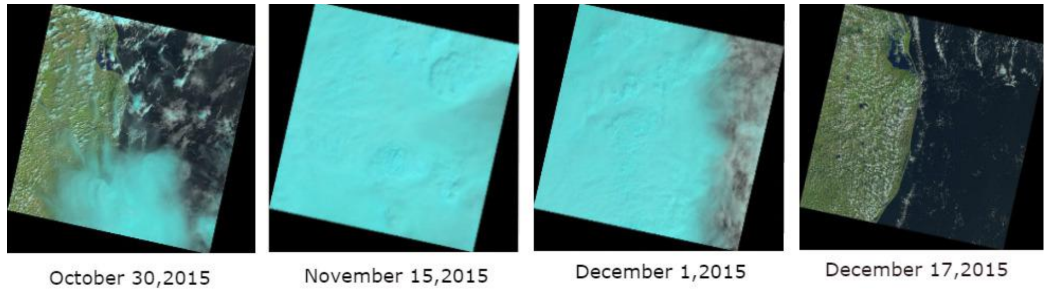
The period of northeast monsoon during October-December 2015 drew a red line in the history of Chennai city by witnessing the flood events of uncontrolled magnitudes and their impacts on human life. Chennai recorded a rainfall of 1218 mm in the month of November as per the Skymet data which was three times more than its normal rainfall and it was the highest received since 1918. The crisis of flood in Chennai opened up the facts related to the management of Cooum river, Adayar river and Buckingham canal which are the major water drains of the city towards the sea. Beyond the magnitude of rainfall, poor management of the drainage system was mainly attributed to the severe crisis of flooding. The illegal encroachment of city's drainage channels through unsustainable development was the sole cause of not keeping the city alive for days after the heavy rainfall. The garbage dumps and solid wastes on storm water drains alarmed the city's population to dig a way out of this situation through proper planning and sustainable management of its resources. The hand-in-hand, of technological advancement and infrastructure development may be a better platform towards an intelligent solution for mitigation of such kind of unprecedented flood events. .

The south Indian flood during 2015 November was due to heavy rainfall and as a result, the overcast conditions for almost 2 months starting from November to December. It was very difficult to get any images of the flood inundated area through optical remote sensing. Figures (1,2) show images from MODIS and ALI (Landsat 8) during this period , which are completely obscured by clouds.

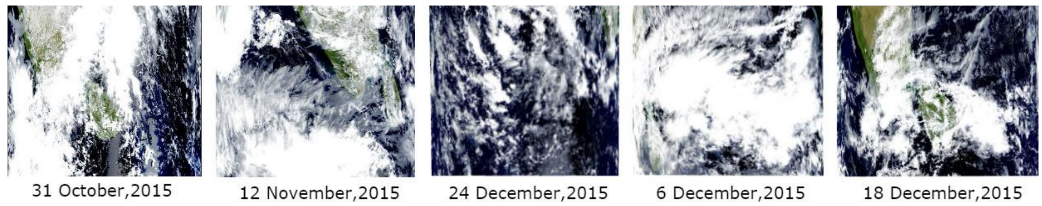
The SAR images to penetrate through the cloud made the technology more appropriate for this type of condition. Another major issue with flooded water bodies is that the water contains high amount of suspended sediments which are carried from channel beds and shores. These reflectances can mis-classify water body as land while using optical remote sensing. SAR images can easily distinguish land and water bodies, even though they carry heavy loads of sediments.

SAR images from sentinel 1A launched by ESA in 2013 gave a clear picture of the flood occurred in and around Chennai region. The Ground Range Detected images collected on 31st October, 12th November,24th November, 6th December and 18th December 2015 gave a clear picture of flooding in this region. SAR backscatter coefficient (sigma nought) is used for distinguishing flooded and non flooded areas.

Image threshold is one of the most common technique for flooded and non-flooded areas. It is generally performed by acquiring two imageries taken before and after the flood. The histogram of VV sigma nought images of flooded area can give a clear difference between the pixels of flooded and non-flooded areas. The advantage of selecting VV polarization is that it has the potential to identify partially submerged features also. The idea behind using SAR images is that the back-scatter from the water surface is very low compared to land and vegetation. As a result flooded areas appear as darker in sigma nought images. Extracting the pixels with low back-scatter values by applying an



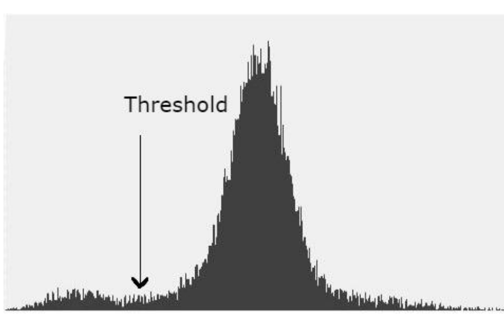
Figure(1). Landsat 8 images obscured by clouds during different dates during south Indian floods in 2015



Figure(2). MODIS images obscured by clouds during different dates during south Indian floods in 2015

optimum threshold value can generate a flooded area map with greater accuracy. Selection of optimum threshold value can be done by analyzing the histogram of the sigma nought image.

Histogram of 6th December is shown in the Figure (3) with optimal threshold value. Peaks in the histogram shows pixels containing flooded and non flooded areas.The back-scatter coefficient value midway between these peaks is taken as threshold value. Optimization of threshold values to be done in certain situations where the back-scatter values from different polarization channels are analyzed and a threshold value is determined.



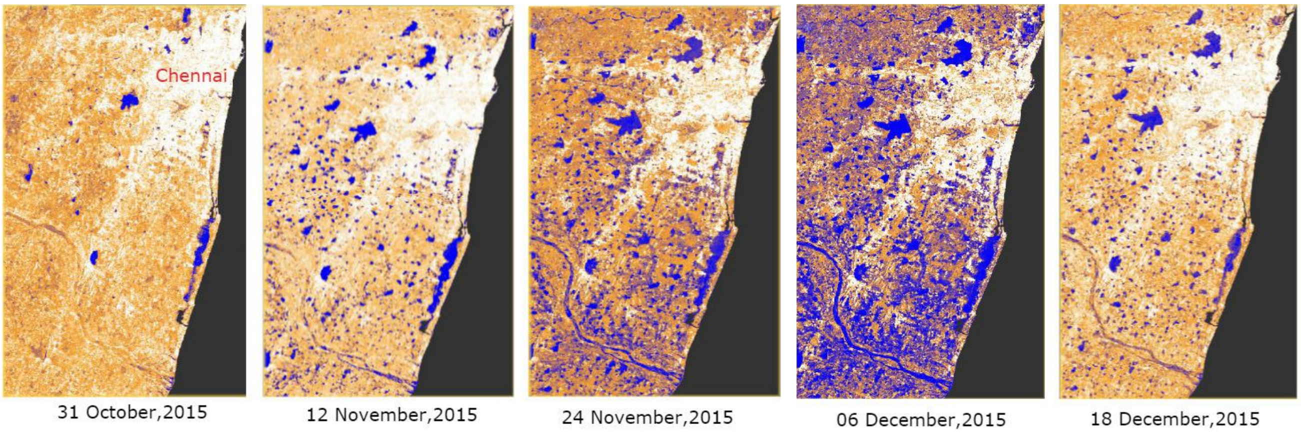
Figure(3). Histogram of sigma nought Sentinel 1A image dated 06 December 2015

Figure (4) shows the sigma nought images of 5 different dates in and around Chennai region. It is clearly observed that during 24th November and 6th December flood inundated a very large area in the region. It was reported that the maximum rainfall happened during 22-24 November and 1-2 December 2015. On 24th December at Nungampakkam and Meenumpakkam areas reported rainfall of 50mm in an hour and within 8.30 PM many areas was engulfed by knee level flood water. According to NASA's GPM data, during November 29th to December 2nd, over 400mm rainfall occurred in the southern part of Chennai. Figure (5) shows the thresholded map of the Chennai and surrounding areas in which white pixels show the water bodies and submerged areas.

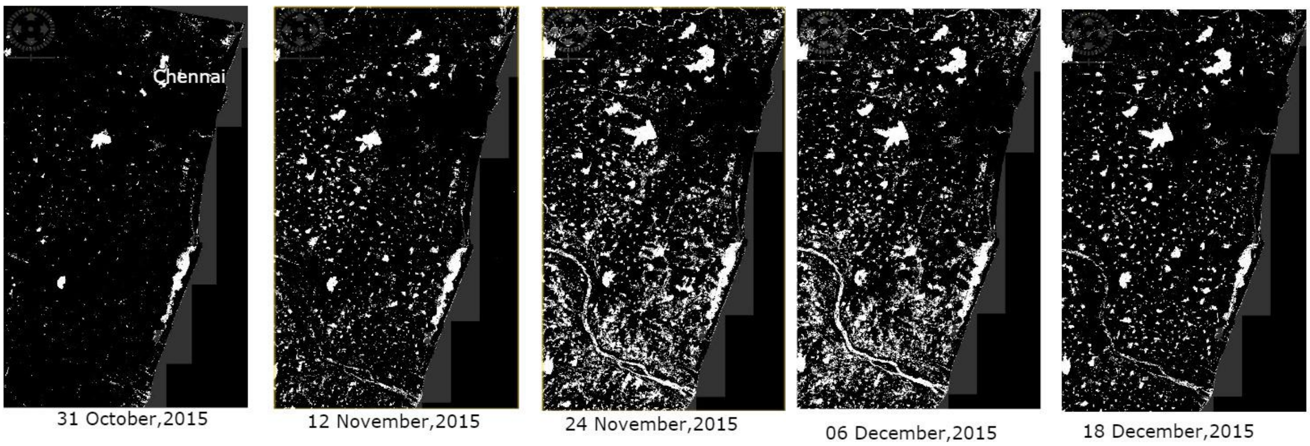
Figure (6) shows interesting developments on the Palar river and the great salt lake back waters. The river was almost dry with stagnant pools of water in October 2015, flooded to a dangerous extend submerging small land masses in its estuary on 24th November. The great salt lake was also encroached nearby areas by increased flood levels.

Tail End

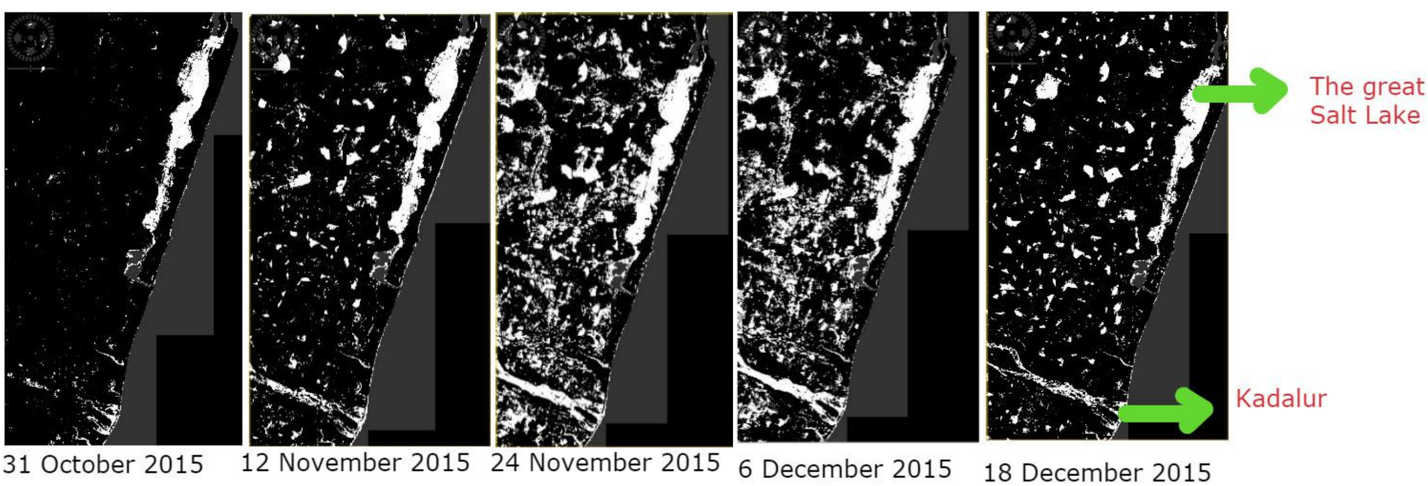
In India, getting data from government agencies is the most difficult task. Especially geospatial data is mostly denied due to security reasons.



Figure(4). Sigma Nought images from Sentinel 1A SAR Images showing Chennai and surrounding areas during floods in 2015.



Figure(5). Thresholded images from Sentinel 1A SAR Images showing Chennai and surrounding areas during floods in 2015. White pixels are water bodies..



Figure(6). Thresholded images from Sentinel 1A SAR Images showing Palar River and great salt lake

Scientific community and the common man always understand the spirit of such restrictions. Still a huge amount of data is collected at the cost of common man's money in spatial and non spatial category and laid to rest in the files of government agencies. Let the data be in the cloud, which are not sensitive to any security issues. Era has gone when people look at satellite images as a rare thing that they have never seen before. Now people are capable of mapping the land surface with their own drones with loaded cameras.

Acknowledgement

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