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In this Issue

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Editorial

Indian Society of Geomatics (ISG), established in 1993, is a premier society of professionals and institutions involved in promoting and popularising Geomatics in India. It has about 1271 life members. ISG regularly brings out a biennially newsletter (ISSN: 0972-642X) for circulation to its members. Many special issues of ISG Newsletter have been published in recent years on various themes such as Agriculture, Urban Planning, Coastal and Marine Environment, Space-based Cartography, GIS: Education and Training in India, Water Resources, Location-based Services, Geomatics in India: Retrospect and Prospects, Impact of Climate Change, Spatial Data Infrastructure, etc.

This issue of newsletter marks the sixth one in a series of newsletters released to coincide with national / regional conferences of the Society. As a practice the issue covers important topics related to disaster management- the theme of the regional conference being held in Bhagalpur during Feb 23-24, 2012.

Floods, landslides, earthquakes, forest fires, oil spills, marine natural disasters are some of the topics which are featured in this issue along with technological and communication related issues like satcom and airborne radar. The dozen odd articles drive home the important role space technology plays in mitigation, prevention, recovery, relief and damage assessment in all phases of disaster.

We started with a long wish list of 20 odd topics including some state level studies and review articles but could get up to the twelve as in your hand. However this collection is still a wonderful bouque of knowledge with variety and depth of excellent standards. The opening article by Anup Kumar Das sums up disasters in general and covers the variety of roles microwave remote sensing data can play. The problem of urban flooding is brought out by Anjan Vyas and Gaurav Jain through their state of art research on runoff and storm water drainage studies. The complications of InSAR techniques and earthquake precursor studies are nicely presented by Ratheesh Ramakrishnan, Sreejit and A S Rajawat. Sikkim ladslides are subject matter of Rajshekhar's contribution. Beena Kumari brings out an out of sight disaster of algal blooms in the oceans. M M Kimothi and C P Singh take stock of the forest fires in the context of Uttarakhand. Deval Mehta summarises the technological developments in satellite communications which are playing a key role in disaster mitigation. P M Udani proposes the use of mobile GIS as an aid for communications using GSM phones. A critical infrastructure of airborne surveys using Radar is brought out D B Dave.

We would like to thank all the authors for sending the contributions at a very short notice. We would like to thank our guest editors DR A S Rajawat and Shri K L N Sastry for all the help in collection and compilation. Dr. Puneet Swaroop deserves our thanks for processing the communications. Shri C P Singh compiled all the inputs and designed the cover page for the issue. Members of the editorial team are acknowledged for editorial comments and lot of enthusiasm shown in the team meetings.

Wishing a happy reading and soliciting your cooperation for upcoming volumes of future issues of ISG NL.

R P Dubey
Editor

Role of SAR in Natural Disaster Management

Anup Kumar Das **Space Applications Centre (ISRO), Ahmedabad**

INTRODUCTION

Natural disasters are extreme events within the earth's system that result in death or injury to humans and damage or loss of valuable goods, such as buildings, communication systems, agricultural land, forest, natural environment etc. The economic losses due to natural disasters have shown an increase with a factor of eight over the past four decades, caused by the increased vulnerability of the global society, but also due to an increase in the number of weather-related disasters.

The natural disasters can be broadly categorized as: (1) Hydro-meteorological (tropical cyclone, tornado and hurricane, floods, drought, hailstorm, cloudburst, landslide, heat & cold wave, snow avalanche and sea erosion); (2) Geological (earthquake, tsunami, volcanic eruption, landslide, land subsidence, dam burst and mine fire); (3) Biological (deforestation, epidemics, pollution, pest attacks, desertification, etc); and (4) Accidental (forest fires, oil spills, mine flooding, chemical & industrial disasters and other technological accidents).

The Fig.1 shows the world-wide distribution of natural disasters by origin by decades starting from the year 1900. Scientists believe the increase in hydro-meteorological disasters is due to a combination of natural and made-made factors. Global warming is increasing the temperatures of the Earth's oceans and atmosphere, leading to more intense storms of all types, including cyclones. The climatic variability triggered by anthropogenic activities and industrialization has resulted into extreme temperature events. People are also tempting nature with rapid and unplanned urbanization in flood-prone regions, increasing the likelihood that their towns and villages will be affected by flash floods and coastal floods. Growth in urbanization has also given rise to clearance of more vegetation and covering of soil surface with concrete. This has resulted in higher and more intense surface runoff causing landslides and much bigger floods.

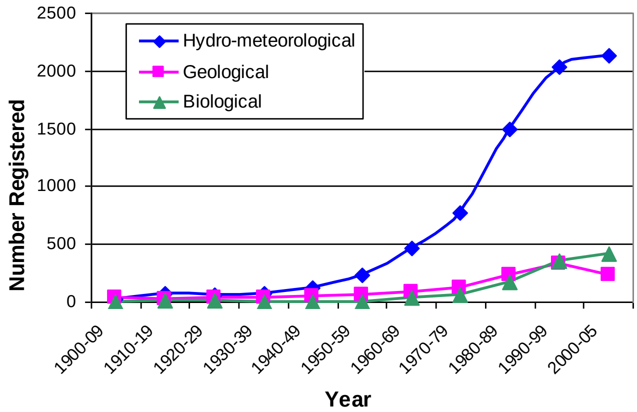


Fig. 1. Distribution of natural disasters: by origin (1900-2005, by decades)

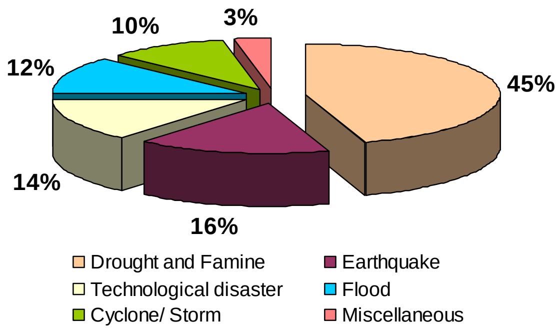


Fig. 2. World Scenario: Reported deaths from all disasters (1992 – 2001)

The *Fig. 2* shows the deadliest disasters of the decade (1992 – 2001). Drought and famine have proved to be the deadliest disasters globally, followed by earthquakes, technological disasters, floods, cyclones, extreme temperatures and others. Global economic loss related to disaster events average around US $880 billion per year. (Source: CBSE textbook on 'Natural hazards and disaster management', 2006).

India has been traditionally vulnerable to natural disasters on account of its geo-climatic conditions. Floods, droughts, cyclones, earthquakes and landslides have been recurrent phenomena. More than half of the landmass is prone to earthquakes of various intensities; over 40 million hectares of land is prone to floods; area adjoining to about 5700 km length of coastline is prone to cyclones and 68% of the geographical area is susceptible to drought. Also, the east and part of west coast and the islands of India (Andaman & Nicobar and Lakshadeep) are vulnerable to Tsunami. Apart from that, the deciduous / dry-deciduous forest in different parts of the country experience forest fires. The Himalayan region and the Western Ghats are prone to landslides and certain tracts in the Himalayas experience avalanche.

Management of Natural Disasters:

Natural disasters cannot be stopped, however suitable measures can be taken to minimize the effects on life and property. Disaster Management includes sum total of all activities, programmes and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses. Disaster management is a cyclical process; the end of one phase is the beginning of another (see *Fig.3* below), although one phase of the cycle does not necessarily have to be completed in order for the next to take place. Often several phases are taken place concurrently. The three key stages of activities that are taken up within disaster risk management are:

1. Before a disaster (pre-disaster): Activities taken to reduce human and property losses caused by a potential hazard, for example, carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level etc. Such risk reduction measures taken under this stage are termed as mitigation and preparedness activities.

2. During a disaster (disaster occurrence): Initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called emergency response activities.

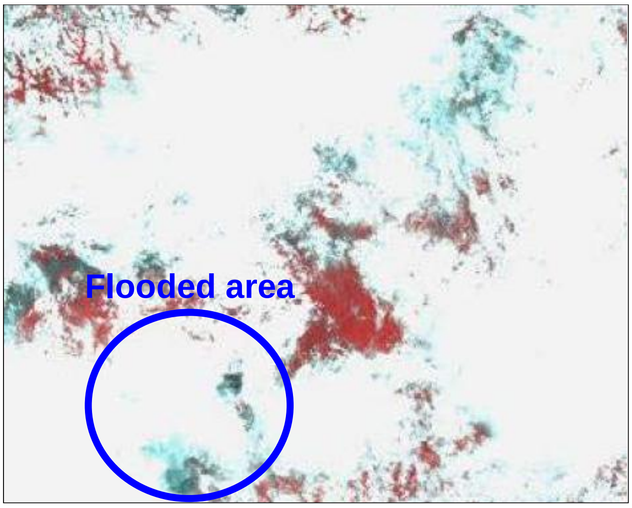
3. After a disaster (post-disaster): Initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as response and recovery activities.

Fig. 3. Disaster management cycle

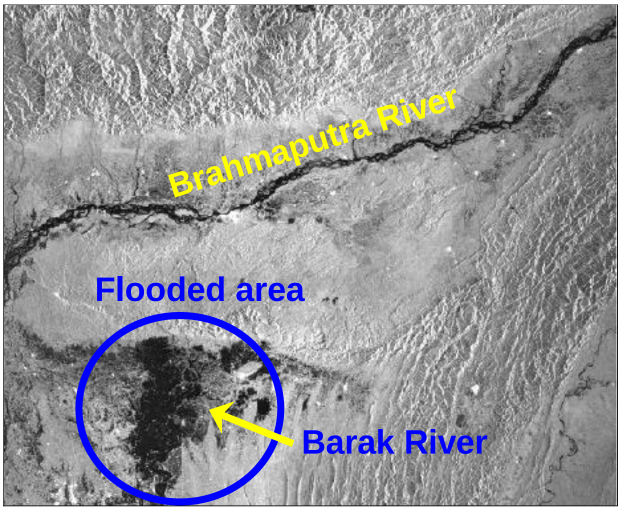
Remote sensing has been evolved as a powerful technique for management of natural disasters. In fact, one of the most important applications of satellite technology can be found in the case of natural disasters, where satellite images can be used to provide advance warning for specific hazardous events, to monitor the process for a quick evaluation of the damage and therefore support the decision-making process in the rescue operations.

Role of SAR:

Although optical remote sensing have been traditionally used for management of natural resources due to their synoptic coverage, high resolution, better visual perception and ease of image handling and processing. But at certain environmental conditions, like cloudy sky, rainfall, fog, smoke & smog conditions and poor sun-illumination conditions like that in high latitude areas, optical remote sensing miserably fails (Fig. 4). Therefore, microwave remote sensing such as Synthetic Aperture Radar (SAR) have a great potential as a source of relevant and near real time information for the early warning, mitigation, and management of natural disasters. That is because of its observation capability regardless climate conditions and sun illumination. Natural disasters like flood, tropical cyclone, volcanic eruptions, forest fire etc. are better studied using SAR data.



Optical (IRS WiFS) data of 10 July 2002



SAR (Radarsat-1) data of 10 July 2002

Fig. 4. Limitations of optical satellite data for monitoring and assessment of natural disasters like flood (Courtesy: G. Srinivasa Rao, NRSC, Hyderabad)

Apart from that SAR data due to its sensitivity to soil moisture, ability for surface and plant canopy penetration and ability to measure distance of a target (through phase angle) and thereby estimate displacement of a target from radar line of site (LOS), has enormous potential for detection, mapping and monitoring changes in the environment and help in the management of natural disasters. The only disadvantage of SAR is the complexity involved in SAR data processing and information extraction. SAR, due to its side looking geometry is affected by land surface topographic effects. This needs to be corrected using a good Digital Elevation Model (DEM) when data over hilly region is analysed. Also, the viewing geometry of SAR is a critical parameter for determining SAR intensity and a slight change in the geometry would result into change in backscatter intensity, that severely affect multi-temporal coherence in SAR data. With the advancement in sensor technology, high resolution DEM generation techniques, data processing techniques and parameter retrieval models, SAR have been emerged as powerful tool for earth observations and natural disaster management. The important parameters and SAR data products used for natural disaster management are: SAR backscatter intensity, multi-temporal coherence, interferometric SAR (InSAR) and DEM. Here the advantages and use of SAR for some of the natural disasters are discussed.

Flood:

The use of optical sensors for flood mapping is seriously limited by the extensive cloud cover that is mostly present during a flood event. SAR data from ERS and RADARSAT have been proven very useful for mapping flood inundation areas, due to their repetitive coverage and larger swath. In India, ERS -SAR has been used successfully in flood monitoring since 1993 and Radarsat since 1998 (Chakraborti, 1999). SAR backscatter intensity and InSAR coherence can be successfully used together for mapping of regions affected by flooding. Flooded areas appear darker on SAR intensity images and, therefore, comparing two images before and during flooding it is possible to map flooded areas with a high degree of accuracy. By combining SAR with other geospatial data such as DEMs, it is also possible to estimate the depth of water in flooded regions. By comparing multiple-temporal images acquired during a flooding event, flood progression mapping can be done, which is crucial for damage assessment and relief operations. The *Fig.5* shows the use of SAR data for flood inundation and progression mapping over Bihar in 2010. By using air-borne SAR systems like ISRO's DM-SAR, the multi-temporal acquisition of SAR data has been dramatically improved by increasing repeativity.

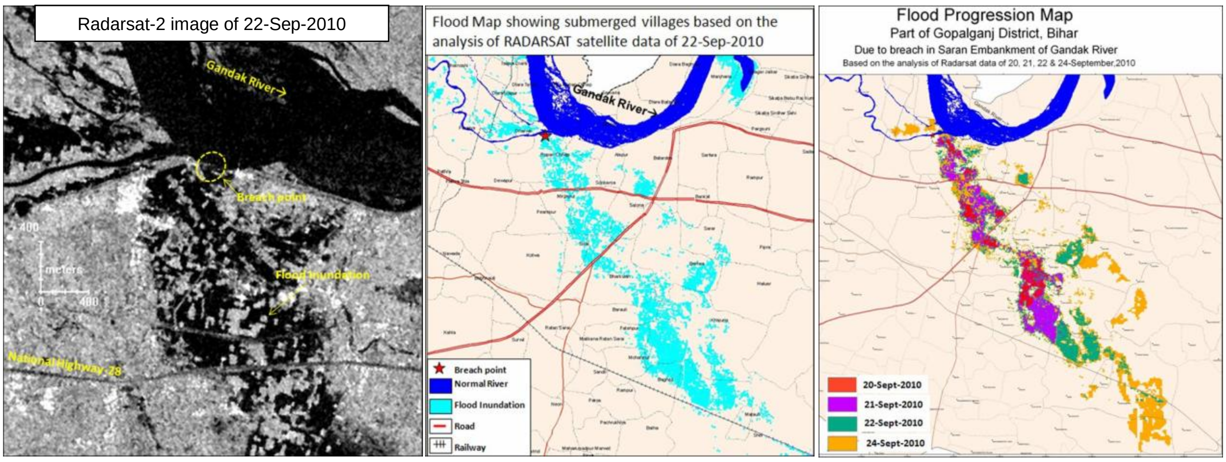


Fig. 5. Flood inundation and progression mapping using SAR (Radarsat-2 HH polarization) data in Bihar, 2010. (Courtesy: P. Manjushree, NRSC, Hyderabad)

One of the unique features of SAR is its ability to detect areas of flooding under closed-canopy vegetation. Areas of flooded vegetation show with enhanced backscatter, due to the corner-reflector effect formed from the vegetation and the smooth water surface. The effect is wavelength and vegetation dependent, with short-wavelength (X- and C-band) sensitive to flooding under grasses (MacDonald *et al*., 1980), mid-wavelength (S-band) sensitive to flooding under reed and brush vegetation (Lewis *et al*, 1998), and long-wavelength (L- and P-band) sensitive to flooding under trees (Imhoff *et al*., 1987).

Cyclones:

Cyclones are most terrifying and destructive weather phenomena on Earth. The tropical cyclones are responsible for huge loss of life and property in India, every year. Like floods, cyclones are also associated with rainfall and clouds and optical remote sensing data fails to assess the damage during a cyclone. On the other hand, microwave instruments have the great advantage that they penetrate into, even through, most clouds and at certain wavelengths interact with the precipitation, which can, therefore, be measured below the cirrus cloud shield. SAR, not only helps in damage assessment during and after cyclone, it also helps in retrieving wind velocity and rainfall potential during a cyclone to assess its severity (Reppucci et al., 2010). This helps in adopting proper management strategies.

Space-borne scatterometer and radiometer and rain radars are also examples of microwave sensors like SAR used efficiently in mapping and monitoring cyclones. With the advancement of microwave sensor technology, monitoring of cyclones have been improved manifold in recent years. The high spatial resolution of precipitation data from the Tropical Rainfall Measuring Mission's (TRMM) rain radar, combined with scatterometer or SAR data, give a significant improvement in the details that can be seen from space, at the surface, and in the precipitating areas of tropical cyclones. Fig. 6 shows an example of the tropical cyclone wind field retrieval from SAR data.

Drought / Famine:

In a country like India where majority of the agriculture is rain fed, a slight variation in rainfall pattern and a delay in Monsoon results into drought. A significant part of the country experiences drought and drought-like situation, almost every year. SAR, due to its sensitivity to soil moisture, has unique capability in monitoring and assessment of drought. Multi-temporal SAR intensity data is used to monitor agriculture soil moisture and crop sowing status every year. Whenever there is a deficit in soil moisture, the crop production hampers and drought situation is declared. Optical remote sensing data is also effectively used to monitor drought situation based on crop sowing and growth status. But SAR data can be used to predict drought situation much earlier to adopt suitable management strategies and rehabilitation.

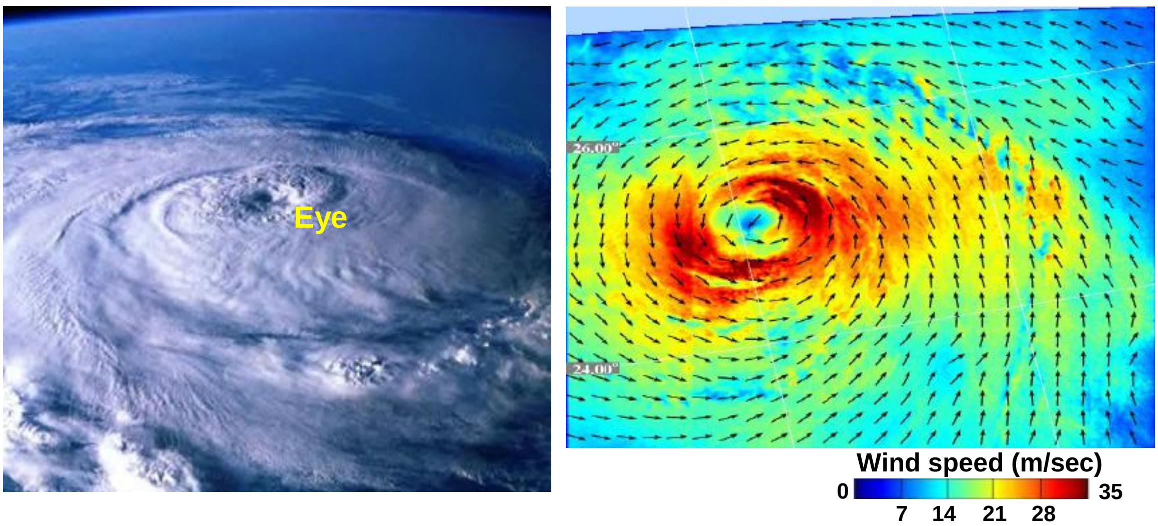


Fig. 6. (Left) Optical image showing a tropical cyclone; (right) Wind speed and direction retrieved for a tropical cyclone using Radarsat data.

Landslide:

Landslides are a common disturbance in mountainous areas. Due to specific geological and climatic conditions, landslides are a major hazard affecting the hilly regions of India. Landslide events are complex geological / geo-morphological processes caused by a large number of factors and therefore it is very difficult to classify the existing and predict the future occurrences.

Traditionally, landslides are monitored using multi-date SAR or optical image through intensity correlation methods, which are based on an existing image archive, provide a way to investigate, possibly since their onset, ground displacement events. But these techniques are not useful to quantify the movement of landslides and land displacement rate. Moreover, the topographic effects increase the ambiguity of landslide detection and mapping. For that topographic correction of data using a good DEM is required, which again is a limitation. The Differential SAR interferometry (DInSAR) has been emerged as a powerful tool to assess surface movements and has proven its mettle in landslide related ground displacement assessment. A relatively new technique, based on permanent scatterer (a target that doesn't undergo any change over a period of time) DInSAR has been proven to be capable of quantifying ground displacements associated with slow moving landslides, very accurately (Colesanti *et al.*, 2006). Fig. 7 shows an example of landslide related ground displacement estimation using PS DInSAR technique over Alps. Unfortunately, such a high accuracy is only possible in regions not covered by dense vegetation that are coherent for extended periods of time.

Land Subsidence:

Land subsidence is an environmental hazard that requires attention to understand the process and mitigate the hazard. More than 200 occurrences of land subsidence have been documented throughout the world during the past few years. The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compaction, sinkholes, and thawing permafrost. Land subsidence may not be noticeable because it can occur over large areas rather than in a small spot.

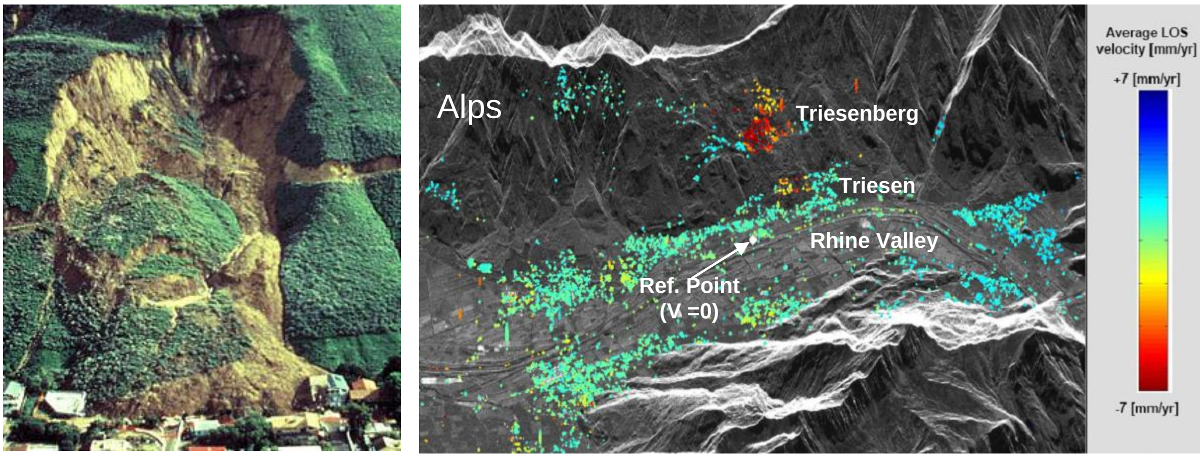


Fig. 7. Permanent scatterer (PS) DInSAR technique based estimation of ground displacement rate along radar LOS over Triesenberg–Triesen landslide located in the Italian Alps, 2002. Note: location of the reference point (depicted in white dot) assumed motionless (velocity V =0).

Repeat-pass interferometric SAR technique is useful tool for monitoring land subsidence. Urban land subsidence and that due to mining can be studied using differential interferometric SAR (DInSAR) techniques. Like landslides, permanent scatterer base DInSAR technique has been shown to be a valuable tool for estimating land subsidence with unprecedented accuracy. Fig. 8 shows an example of applications of SAR data for estimation of land subsidence rate over Kolkata city, India.

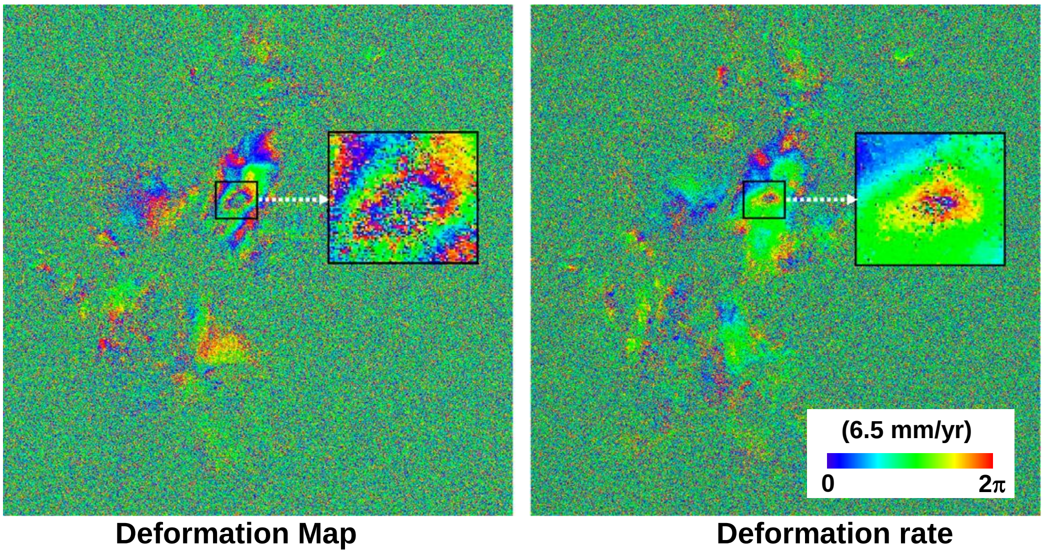


Fig. 8. Deformation maps showing average rate of land subsidence in Kolkata city obtained from differential interferogram of ERS-1 data. The rate of land subsidence was found to be 6.55 mm/year (Source: R.S. Chatterjee et al, 2006).

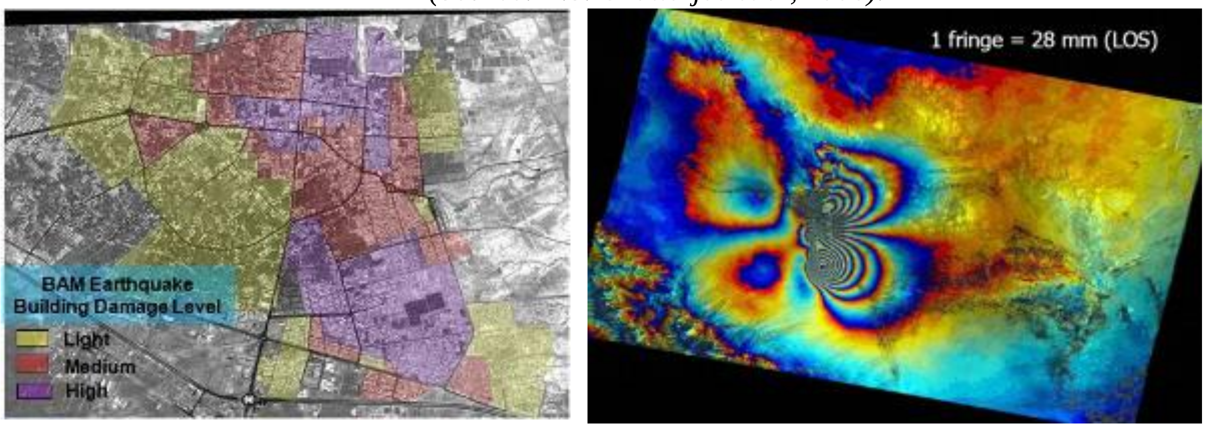


Fig. 9. (Left) Seismic damage assessment map based on pre-seismic and co-seismic intensity correlation and coherence analysis and (Right) Differential InSAR derived ground displacement (along radar line of sight, LOS) map after 2003 Bam earthquake, Iran.

Earthquakes:

There are no generally accepted operational methods for predicting earthquakes. Although there is some mentioning of observable precursors for earthquakes in literature, such as variations in the electric field or thermal anomalies, they are heavily disputed. However, high resolution SAR data has been successfully demonstrated for assessment of post earthquake damages and land deformations due to earthquake. Multi-temporal observations from SAR can be used to detect changes in urban infrastructure either by using intensity or phase of the returned signal from the pre and post seismic images. The intensity correlation and the complex temporal coherence are two important parameters for recognizing changes on the surface caused by an earthquake. Interferometric

SAR (InSAR) is a powerful tool to map earthquake deformation fields (Massonnet *et al*., 1994, 1996). It allows for a better understanding of fault mechanism and strain. Differential SAR interferometry is possibly one of the best techniques used for mapping ground deformation produced by earthquakes. Differential interferometry (DInSAR) calculates the phase difference between SAR images acquired before and after an event or some other period when deformation has occurred (Massonnet and Feigl, 1998; Rosen *et al*., 2000). In the most favourable conditions it is possible to achieve accuracy better than one quarter of SAR wavelength, about 0.5–1 cm for X-band, 1–2 cm for C-band, and 2–3 cm for L-band. This accuracy is sufficient for mapping ground deformation of a moderate earthquake (M5 and up) depending on the depth of the epicenter. Fig. 9 shows an example of advantage of SAR data for mapping earthquake related damage and ground displacement during Bam earthquake in Iran in 2003.

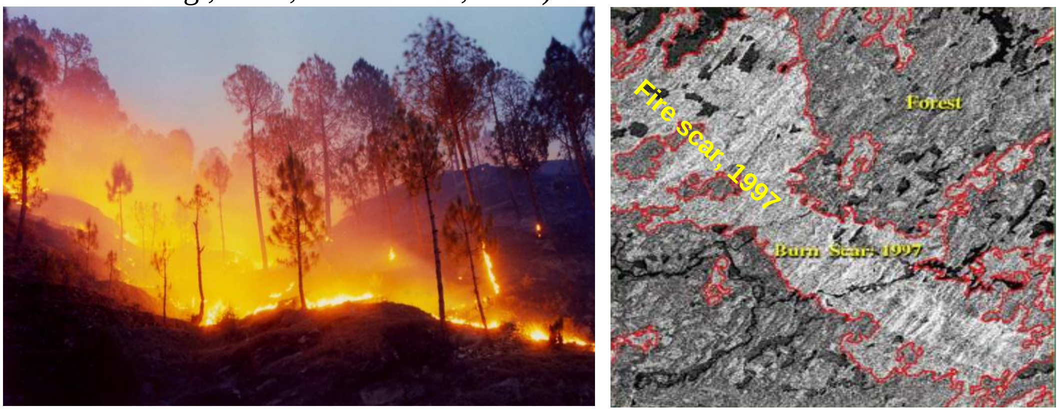


Fig. 10. Forest fire (left) and fire scar as seen on Radarsat-1 data over boreal forest in Quebec, Canada in 1997 (right).

Forest Fire:

Synthetic aperture radar has been successfully used for identification of burnt areas over the boreal forest of Alaska, Canada (Bourgeau-Chavez and Kasischke, 2002), and Siberia (Ranson *et al*., 2003) as well as over the tropical rain forest of Indonesia and semi-arid Mediterranean forest. In these studies it was shown that the intensity of SAR backscatter signal was noticeably different between predominantly undisturbed and fire-disturbed forest. This was due to an increase in soil moisture, increased surface roughness exposed to the incoming microwave radiation, and damage to the vegetation canopy by fire It was also shown that acquisitions with low incidence angle are the most successful in identification of burnt areas in hilly regions. In Couturier *et al*. (2001) the relationship between SAR backscatter intensity and fire-related Daily Drought Index (DDI) was investigated over rain forest of Indonesia. A strong correlation between these two characteristics was observed, which suggested that SAR data can be successfully used not only for identification of burnt areas but also as a proxy for the susceptibility of forest to burn.

Volcanic Eruptions:

SAR has successfully been used for mapping volcanic deformations as well as for monitoring of pyroclastic flows and lahars (Terunuma *et al*., 2005). It is particularly useful in eruptions where there is a lot of smoke obscuring the target and preventing the effective use of optical data. Three products derived from SAR data are usually used: SAR backscatter intensity, InSAR coherence, and DInSAR interferometry. Various

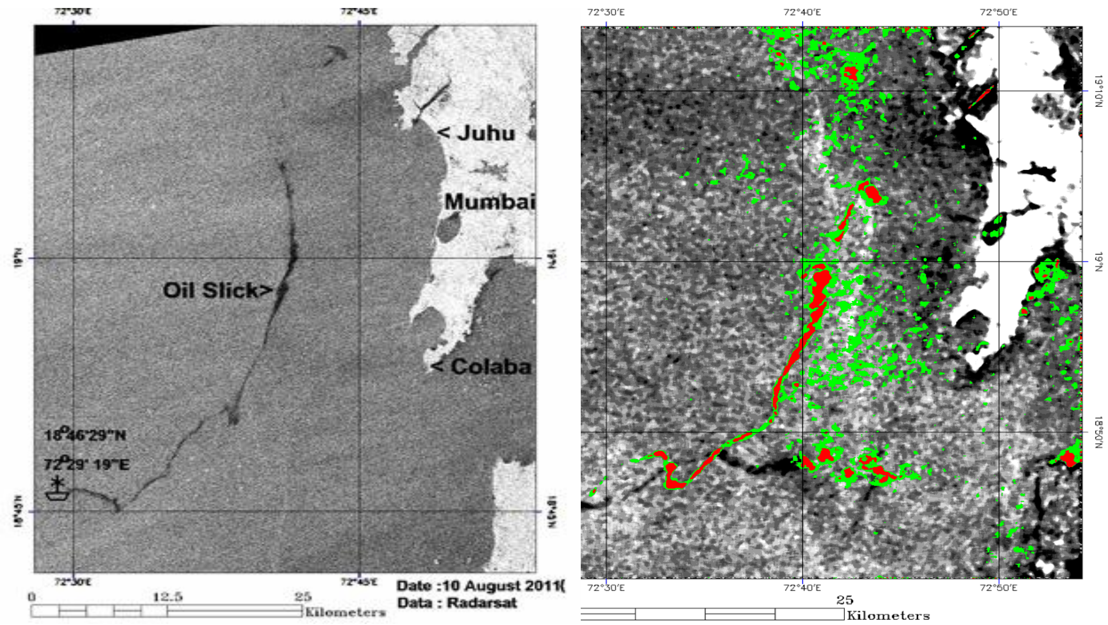


Fig. 11. Spread of oil slick in the coastal waters of Mumbai as monitored using Envisat ASAR data on 8th August (left image) and Radarsat data on 9th August (right image) 2011 (Courtesy: S.K. Sasmal, NRSC, Hyderabad)

ground conditions (eg, roughness, soil moisture and slope) affect intensity of reflection. Therefore, calculating a difference or a ratio of intensity images from before and after the event should produce an image where changes caused by pyroclastic flows or lahars are easily observable. Coherence calculated for the pair of images before and after an event is used to be significantly lower in regions where pyroclastic flows or lahars had occurred. However, estimation of coherence variation is only possible in regions with a high initial degree of coherence, ie, those not covered by dense vegetation or snow, and not being eroded too quickly. SAR interferometry can be used to derive DEMs before and after an eruption. By subtracting these models it is possible to observe large-scale deformations caused by lahars or pyroclastic flows. Alternatively, differential interferometry can estimate deformation with sub-centimeter accuracy caused by thermal and pressure sources underlying the surface. Topographic measurements and especially the change in topography are very important for the prediction of volcanic eruptions. By monitoring volcanoes over a long period it is possible to reconstruct temporal patterns of deformation using permanent scatterers techniques (Ferreti *et al*., 2001; Hooper *et al*., 2004).

Oil Spill:

Oil spills in coastal and oceanic water are one of the disasters that are required to be monitored as they cause severe threat to the marine and coastal ecosystems. Oil spills resulting from accidents involving ships or tankers or that released from oil refineries, industrial plants or oil platforms remain floating on the sea surface for few days to weeks before disintegrating and evaporating to the atmosphere. Oil slicks due to their higher viscosity make the water surface smooth and hence look dark in the SAR data. Multi-temporal SAR data, preferably in VV-polarization have shown great potential in identification, mapping and monitoring of oil spills. Periodic monitoring of the movement of oil slick helps in adopting suitable management strategies to mitigate the hazard. Fig. 11 below shows the spread of oil slick in the coastal waters of Mumbai resulting from a cargo accident during August 2011.

Concluding Remarks:

The use of remote sensing for mapping and monitoring natural hazards has diversified in recent years owing to an increase in data availability and technological advances in their interpretation. Synthetic aperture radar has been playing a responsible role in natural disaster management. Multiple space-borne SARs have been working in tandem to increase the observation frequency whenever a natural hazard strikes. The Japanese ALOS PALSAR, or TerraSAR-X from DLR and Cosmo-SkyMed from ASI, and the C-band Radarsat-2 are dramatically enforcing the role of SAR systems in disaster monitoring. These sensors provide high performance in terms of spatial resolution and revisiting time (some of them are satellite constellations) thus matching most of the end user requirements.

SAR data and InSAR techniques, for example, are of considerable value for mapping flooding extent, cyclones, landslide, land subsidence and earth deformations due to volcanic or tectonic activity, but are unable to detect thermal anomalies owing to forest fire or concentrations of volcanic gaseous emissions. Optical data offers several advantages over SAR, but is inherently affected by cloud cover, smoke or haze at the time of satellite overpass. Thus optical and SAR data can be used synergistically to provide solution to some of the natural disaster managements. The flexibility provided by a multi-sensor, multiplatform approach is likely to give the most comprehensive coverage of a disaster event.

References:

Bourgeau-Chavez, L. and Kasischke, E. (2002). Mapping fire scars in global boreal forest using imaging radar data. *International Journal of Remote Sensing*, **23,** 4211–34.

Chakraborti, A.K. (1999). Satellite remote sensing for near-real-time flood and drought impact assessment- Indian experience. Workshop on Natural Disasters and their Mitigation - A Remote Sensing & GIS perspective, 11-15 October 1999, Dehradun, India.

Chatterjee R. S. *et.al*, (2006). Subsidence of Kolkata (Calcutta) City, India during the 1990s as observed from space by Differential Synthetic Aperture Radar Interferometry (D-InSAR) technique, *Remote Sensing of Environment*, **102**, 176–185

Colesanti, C. and Wasowski, J. (2006). Investigating landslides with space-borne synthetic aperture radar (SAR) interferometry, *Engineering Geology*, **88**, 173-199.

Couturier, S., Taylor, D., Siegert, F., Hoffmann, A. and Bao, M. (2001). ERS SAR backscatter. A potential real-time indicator of the proneness of modified rainforest to fire. *Remote Sensing of Environment*, **76**, 410–17.

Ferreti, A., Prati, C. and Rocca, F. **(**2001). Permanent scatterers in SAR interferometry. *IEEE Transactions on Geoscience and Remote Sensing* **39**, 8–20.

Imhoff, M.L., Vermillion, C., Story, M.H., Choudhury, A.M., Gafoor, A. and Polcyn, F. (1987). Monsoon fl ood boundary delineation and damage assessment using space borne imaging radar and Landsat data. *Photogrammetric Engineering and Remote Sensing* **53**, 405–13.

Lewis, A.J., Henderson, F.M. and Holcomb, D.W. (1998). Radar fundamentals: the geoscience perspective. In Henderson, F.M. and Lewis, A.J., editors, *Principles and applications of imaging radar*, New York: Wiley, 131–81.

MacDonald, H.C., Waite, W.P. and Demarcke, J.S. (1980). Use of Seasat satellite radar imagery for the detection of standing water beneath forest vegetation. *Proceedings of the American Society of Photogrammetry Annual Technical Meeting* **RS-3(B)**, 1–13.

Massonnet, D. and Feigl, K. (1998). Radar interferometry and its application to changes in the Earth surface. *Reviews of Geophysics* **36**, 441–500.

Massonnet, D., Feigl, K.L.and Rossi, M. (1996) Co-seismic deformation field in the M=6.7 Northridge, California earthquake of January 17, 1994 recorded by two radar satellites using interferometry. *Geophysical Research Letters*, **22**, 1541-1544.

Massonnet, D., K. L. Feigl, M. Rossi, and F. Adragna, (1994). Radar interferometric mapping of deformation in the year after the Landers earthquake, *Nature*, **369**, 227-230.

Ranson, K., Kovacs, K., Sun, G. and Kharuk, V. (2003). Disturbance recognition in the boreal forest using radar and Landsat-7. *Canadian Journal of Remote Sensing*, **29**, 271–85.

Reppucci, A. Lehner, S. Schulz-Stellenfleth, J. Brusch, S. (2010). Tropical cyclone intensity estimated from wide-swath SAR images, *IEEE Trans. on Geosci. and remote sensing*, vol. **48 (4)**, pp. 1639-1649.

Rosen, P., Hensley, P., Joughin, I., Li, F., Madsen, S., Rodriguez, E. and Goldstein, R. (2000). Synthetic aperture radar interferometry. *Proceedings of the IEEE*, **88**, 333–82.

Terunuma, T., Nishida, K., Amada, T., Mizuyama, T., Sato, I. and Urai, M. (2005). Detection of traces of pyroclastic flows and lahars with satellite synthetic aperture radars. *International Journal of Remote Sensing* **26**, 1927–42.

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Urban Flood – Experiencing the use of Geographical Information System

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INTRODUCTION

An increase in urbanization has raised the issue of efficient delivery of urban infrastructure services by the local body. Lack of infrastructure led us to another dimension of the problem of disaster and its management in urban area. In the recent decades, the officials of urban local bodies have focused attention to the improvement of the infrastructure. The literature mention that one of the most frequent hazards, flood occur most frequently across the very part of ward and the reported damages from flood has been increasing too. All The natural hazards, flood is the most destructive because it occurs most frequently. Cities are with high built density; this flood causes unexpected and heavy damages. By the turn of this century it is estimated that at least thirteen cities around the world that are prone to natural hazard. These cities are medium to large cities in regard to the population that range of 10 to 25 million. The alarm is out of these, nine cities are in Asia. The annual loss due to disaster during the last decade was $ 80 billion. The change in land use associated with urban development affect flooding in many ways. Decrease and removal of agriculture, vegetation, soil, land resurface and construction of drainage networks increase the chances of runoff. All these lead us to a need for proper planning and infrastructure in urban areas.

India is one of the worst flood-affected countries. It accounts for one fifth of global death count due to floods. About 40 million hectares or nearly 1/8th of India's geographical area is flood-prone. This paper aims to identify the urban flood risk and planning for mitigation with specific reference to heavy rainfall. An application of GIS (Geographical Information System) is done to indentify the potential areas of the flood (water logged for longer duration). The models are used to calculate the runoff, velocity and discharge considering the rain fall and time of concentration. The result of this study provides a guide line to the urban government in order to know the requirement of storm water drainage to be upgraded, enhanced or design the network. Spatial multi-criteria decision-making technique has been used which provides a systematic approach for assessing and integrating the impact of various factors.

STUDY AREA AND DATA:

Ahmedabad City, the largest city in the State of Gujarat and sixth largest metropolis of nation has been studied for flooding.

The secondary data has been collected in the form of maps and related information from Ahmedabad Municipal Corporation. The base map has been prepared using these maps digitized. After geo-referencing, these maps have superimposed on to the high resolution satellite imagery for mapping the thematic layers. The themes are: road, railway, water body, open plots, gardens, built up area have been demarcated and digitized using satellite imagery. The map of storm water drainage pipeline network has been procured from the respective department of AMC.

Table 1: Satellite Data Used:

Type of Satellite Data	Acquisition Dates	Data Processing	Scale of Mapping
LISS IV P6	18 January 2007	P 203 – R 013	1: 15000
LISS IV P6	12 March 2007	P 201 – R 097	1: 15000

The rainfall data has been procured for last 60 years on daily, monthly and annual average basis from IMD. Those are analyzed and calculated ± 2 σ in order to work out the variations in the rainfall pattern up to five ranges.

The major landmarks in the study area have been collected while undertaking the GPS survey. A detailed survey was carried out for collecting information at land parcel level. Thus the study required to have secondary data collection as well as primary field survey.

Land Use:

As per the Master plan 1997, more than one third (36%) of the total area is under residential use and 15 % of the area is under the industries. Large tracts of land (23.44%) are lying vacant, mostly in the newly acquired area of the AMC. Only 9.5 percent of the total area is under transportation network as against the norm of 15-18 percent as specified by Urban Development Plans Formulation and Implementation (UDPFI) guidelines.

Storm Water System Scenario:

AMC has 2500 km of the road length. It has laid down around 350 km of storm-water drainage line in the city and another 250 km of it will be added to the present network. The storm-water drainage network is scattered in various areas of the city. Storm water drains in the Ahmedabad city cover only 23% of the roads in the city. There are three types of drains laid in the city - RCC pipes, Box type drains and Arch drains. Many parts of the western and eastern zones experience water-logging problems during the rainy season. However, the Walled City area does not have any problems of flooding/water logging.

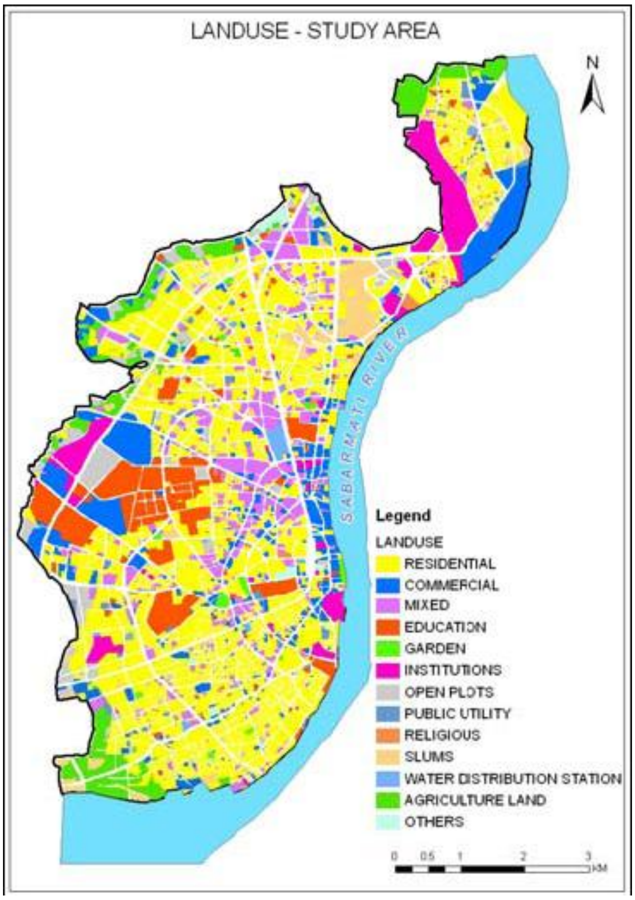
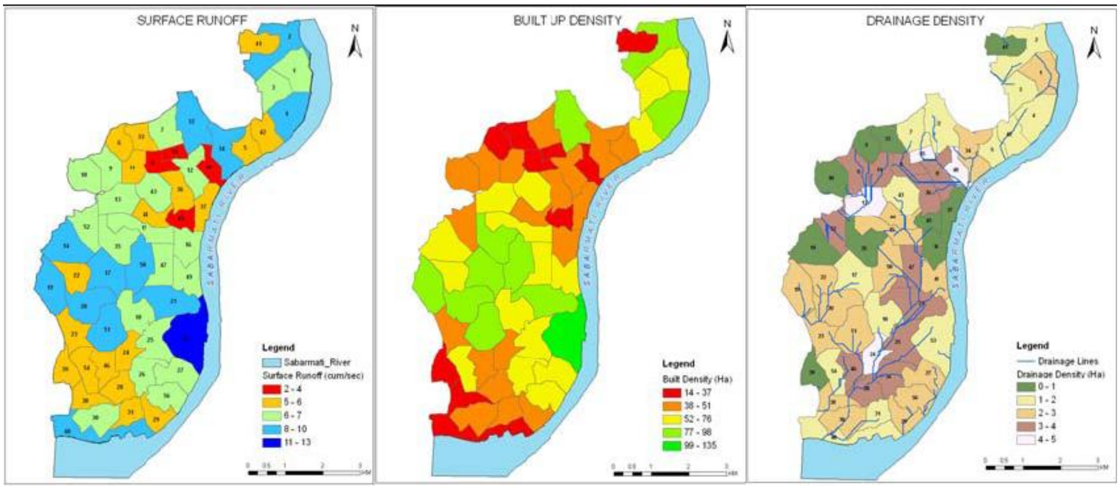


Figure 1: Land use

Water Logging and Flooding Problems:

Negligence of natural drainage during physical development of the city, has led to problems of water logging and flooding during the monsoons. There are 36 outlets of storm water drainage is opening in to the river Sabarmati. Of which 9 outlets are blocked due to some technical reason. Similar blockage and silting has also been reported in the general drains. Rapid urbanization has brought large scale building activities for residential, commercial and other purposes. There are no maps available showing the details of natural drainages. Hence, when planning for construction activities this important aspect is ignored. Most of the storm water drainage has been filled up with silt and solid waste. It caused obstruction to the smooth flow of water to the river, creating severe water-logging in the city during monsoon, causing loss of property, materials and goods. The lower income community and the slums are the worst affected.



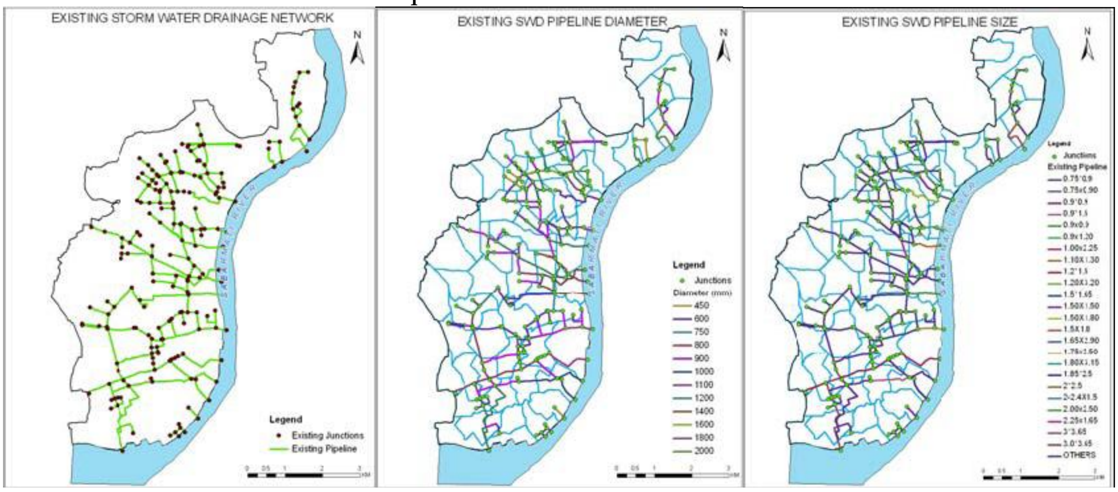
Application of GIS:

Several thematic layers representing roads, railways, property plots, important land marks, land use, slope, contour, storm water drainage network, location of manholes, etc have been prepared. The analytical maps have been generated in GIS environment such as population density. The projection used is WGS 1984 UTM Zone 43N Projection. This urban study requires at the cadastral level mapping of each parcel. Those are at 1:2500 with submeter to centimeter planimetric and geometric accuracy. It is now possible to map using high resolution satellite data. The mapping in this project was done in conjunction with on-site checking with the use of GPS.

Method of mapping Surface Runoff:

Runoff is defined as the portion of the precipitation that makes its way towards rivers or oceans as surface or subsurface flow. The movement over ground of rain water is run off. It occurs when the rainfall is very heavy and when the rocks and soil can absorb no more. After the occurrence of infiltration and other losses from the precipitation (rainfall), the excess rainfall flows out through the small natural channels on the land surface to the main drainage channels. Such types of flow are called surface flows. A part of the infiltrated rainwater moves parallel to the land surface as subsurface flow and reappears on the surface at certain other points. Such flows are called interflows. Another part of the infiltrated water percolates downwards to ground water, moves laterally to emerge in Depression Rivers and joins the surface flow. This type of flow is called the subsurface flow or ground water flow.

This study demands to calculate the runoff. It is known that there are many formulas through which the runoff can be estimated. In present study, run off is calculated using peak runoff and rainfall intensity. The Time of Concentration consists of an overland flow time to the point, where the runoff is concentrated or enters a defined drainage feature plus the time of flow in a closed conduit or open channel to the design point. Use of the Rational Formula requires the Time of Concentration (Tc) for each design point within the drainage basin. The duration of rainfall is then set equal to the Time of Concentration and is used to estimate the average rainfall intensity (I). For each drainage area, the distance is determined from the inlet to the most remote point in the tributary area. From a topographic map, the average slope is determined for the same distance.



Surface Runoff for different Catchment Areas:

The surface runoff has been calculated at each catchment wise. The catchments area has its land use, the road network and the storm water drainage network. A micro level study has been attempted here.

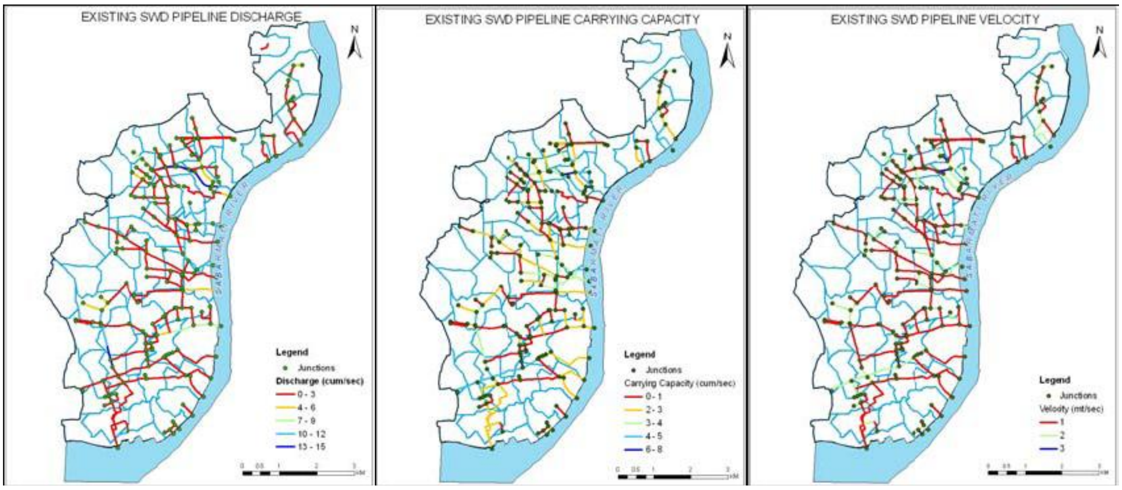
The Surface runoff in the above map is classified in five categories. Surface runoff is computed in cum/sec. Red color shows the minimum surface runoff while dark blue color shows the maximum surface runoff. Minimum surface runoff is 2 cum/sec and maximum surface runoff is 13 cum/sec. All watersheds have maximum built up area as compared to open land and paved land. Mostly all areas have same runoff coefficient (0.8), only catchment no 48 has maximum unpaved land so the runoff coefficient of that watershed is (0.6). Slope is another factor responsible for flood, which is also taken into consideration. The slope function calculates the maximum rate of change between each cell and its neighbors, for example, the steepest downhill descent for the cell (the maximum change in elevation over distance between the cells with its eight neighbors). Slope map is generated from digital elevation model (DEM). There are four categories of slope identified and used for final analysis. The slopes represented in percentage. The area under yellow color is showing the least slope area (0-1%), light brown color is showing moderate slope area and dark brown color shows the highest slope area (4.1-5%). The slope is represented in percent. The yellow colour represents the lowest slope. The larger part of the study area is under least slope, a little area is under moderate and very small area is under higher slope percent. These are couple of mounds (called Tekra) exists shows higher slope percent.

Built density can be defined as concentration (amount) of buildings in a given geographic area. High resolution satellite imagery is very much useful for identification of the building foot prints. Moreover the floor space index of the city with different land use help in identifying the building density. LISS IV and Cartosat data have been used for mapping the foot prints and final plot maps of the town planning schemes falling under study area for calculating building density. It is presumed that the buildings are constructed have covered the open space hence the area for seepage of the rain water gets reduced. Secondly due to the manmade activity the blockage of storm water drainages are observed, the pre-monsoon cleaning of the drains become compulsory. Keeping this argument in consideration more weight is given to this category. Therefore it shows the positive relationship, higher is the built density higher is the flood vulnerability. That is more people will be affected and chances of property loss are more, where population density is high. The built-up density is divided in to five classes, red color indicates the lowest density area, dark green color represents the highest density area and yellow color indicates moderate density area. Drainage density is a measure of stream spacing. Drainage density reflects basin's geology climate. Basins underlined by resistant, permeable materials have low drainage density; basins underlined by weak, impermeable materials have high drainage density. The highest drainage density is 5 and lowest is 0.19 per ha area of Catchments.

From the above table conclusion is made that the drainage density for the study area varies from 0.19 to 5 per ha of the catchments. Some of the areas remain out of this type of drainage facility. Areas having maximum drainage density are very less (only 3 to 4 catchments).

Storm Water Drainage Network:

Planning, design, operation and maintenance of urban storm water drainage systems is a challenge for urban authorities because of unplanned development activities. The effectiveness of storm water management systems can be directly linked to the floods in the city. The Manning's formula for has been used for calculation of velocity of the storm water pipelines. The pipeline diameter ranges from 450mm to 2000mm. Different colored lines illustrate the pipelines of different size. Size of pipelines varies from (0.75*0.90) meter to (3*3.65) meter. Pipeline of unknown size is categorized as others. Calculate the runoff coefficient for the drainage area tributary to the inlet at the upstream end of the Storm drains under consideration.



The map below shows the pipeline discharge for the study area. The discharge is categorized here in five classes. The minimum discharge is 0.03 cum/sec and maximum discharge is 15 cum/sec.

Existing SWD Pipeline Discharge:

The carrying capacity of existing storm water drainage pipelines from upstream to down stream. Variation in carrying capacity of pipelines is shown with different colors. Carrying capacity is divided mainly in five classes. Lowest carrying capacity is 0.01cum/sec while highest carrying capacity is 8 cum/sec. First class shows the carrying capacity of 0 to 1 cum/sec while fifth class shows the highest carrying capacity ranges from 6 to 8 cum/sec. Velocity is classified in mainly three classes. In first class (red color lines) velocity is 1 m/sec which the lowest velocity class. Class 2 (green color lines) has 2 m/sec pipeline velocity. Class three (blue lines) shows the highest pipeline velocity ranges 3 m/sec.

Then, multi-criteria decision analysis (MCDA) is a used to arrive at final result. Here the decision maker's preferences with respect to the evaluation criteria are incorporated into the decision model. The preferences are expressed in terms of the weights of relative importance assigned to evaluation criteria under consideration. A weight can be defined as a value assigned to an evaluation criterion that indicates its importance relative to other criteria under consideration. The inverse ranking has been applied to these factors. 1 is the least important and 5 is the most important factor. This method is a highly used in planning. In the ranking method, the respondent is asked to rank the criteria or objective in order of importance. In this study, GIS professionals, planners, students, geologists, Civil Engineers and common man were consulted to give their preference and order of importance. Saaty's Standard scale was used in ranking. Higher score value is assigned to lower slope percentage which represents very high vulnerability of flooding.

In this case it is less than 1.0 percent. In the areas where higher slope exists, the rain water gets drained and therefore less vulnerable for flood. Hence the score value is 1. The slope in percent is 4.0 -5.0 and is less vulnerable for flood disaster. The reclassified slope map shows the different areas with high vulnerability and low vulnerability. The table below shows the different runoff values in cum/sec and the category they fall into. The runoff values between of 3 – 8 cum/sec is low vulnerable while as the very high vulnerability is when run off values vary from 9 – 13 cum/sec. The reclassified Drainage Density map is prepared with the use of SWD pipelines, in which the software takes automatically the range showing high vulnerability and low vulnerability values. This represented in different color code.

Based on the ranking method adopted and Delphi technique used weightages are given to four criteria. Surface runoff, slope, drainage density and building density are the four criteria which are given below:

Table: 3: Ranking Values

Criteria	Rank	Weightage
Surface runoff	1	0.4 (40%)
Drainage density	2	0.3 (30%)
Slope	3	0.2 (20%)
Building density	4	0.1 (10%)

Weights were calculated as 0.4, 0.3, 0.2, 0.1 respectively for surface runoff, drainage density, slope, building density. The result is a map showing vulnerable zones.

The map reveals that more than 50 percent area falls under high and very high vulnerable zone. This is because the runoff is very high and low carrying capacity of storm water drainage pipelines. 15 percent of the total study area is under low risk of flooding and water logging. Some of the catchments do not have storm water drainage pipeline so they have high risk of water logging during heavy rainfall. The minimum carrying capacity of pipeline for the catchment is 0.13 cum/sec and maximum carrying capacity of the pipeline for the catchment is 10 cum/sec. In this map dark green color shows the area having very low vulnerability, light green color shows low vulnerability, yellow color shows moderate vulnerability, orange color shows high vulnerability and red color shows very high vulnerability. Here, most of the areas are under high to moderate vulnerability.

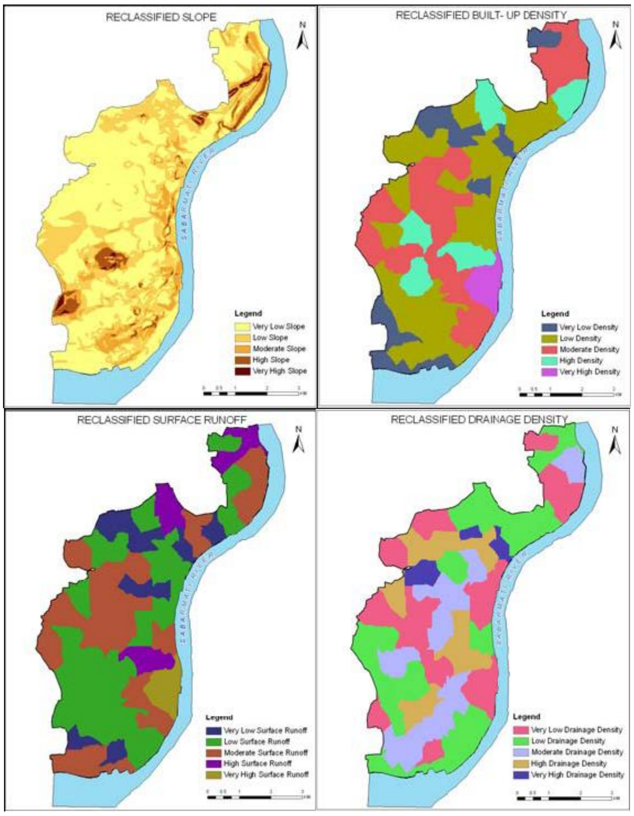


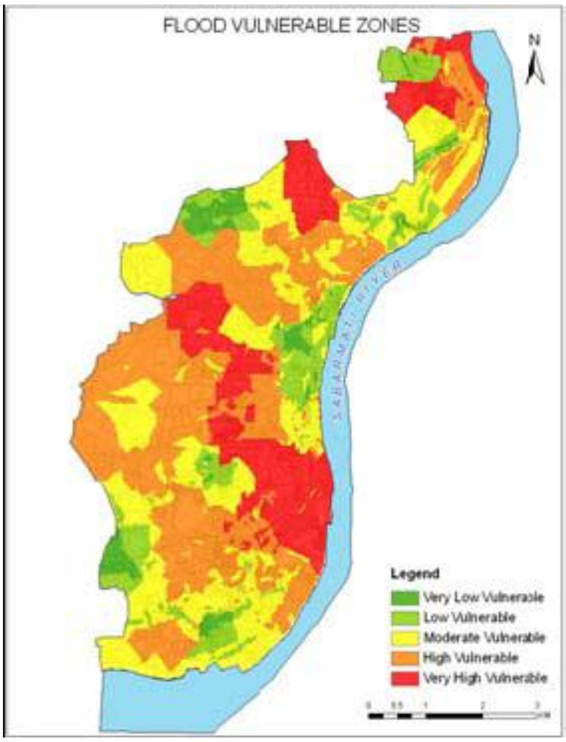
Table 4: Flood Vulnerable Zone

Vulnerability	Total Area (Ha)	Total Area (%)
Very Low Vulnerable Zone	149	4%
Low Vulnerable Zone	422	11%
Moderate Vulnerable Zone	1112	29%
High Vulnerable Zone	1453	38%
Very High Vulnerable Zone	706	18%

CONCLUSION:

Occurrence of floods is high. The damage due to flood is high. The cities are the most vulnerable after agriculture as the damage is very high. It affects to the routine life of large number of people. The property, the business, the production, the infrastructure, all gets affected. The loss affects the gross domestic production of the respective State. The after effect of flood such as redevelopment, resettlements, repair and maintenance, spread of diseases, etc is a responsibility of the local body that has meager resources.

The analysis has been carried out while preparing thematic maps of land use, pipleline network and infrastructure. The multi-criteria decision support tool has been employed to arrive at the identification of vulnerable areas. GIS Spatial Technique is used for analysis and understanding of the flood and water log problem. Flood affected areas of different magnitude has been identified and mapped using.



The result is useful for the local planning authority, engineers, rescue management system for planning for flood vulnerable areas, identification of the gap in the available infrastructure for prioritization of implementation of new infrastructure and plan for appropriate rescue system. Ultimately it will be useful for the decision making process.

Acknowledgement:

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References:

1. Ahmedabad Municipal Corporation, City Development Plan Ahmedabad 2006-2012.

2. American Society of Civil Engineers, 1960. Design Manual for Storm Drainage. New York.

3. AUDA Development Plan (2011): Jointly published by AUDA Space Application Centre, Ahmedabad.

4. CEPT University (2002) Establishment of disaster management unit detailed project report Ahmedabad municipal corporation, Ahmedabad

5. Das (2000): Geo-informatics for sustainable development for agricultural Area, New Delhi.

6. Georgia Storm Water Management Manual, Volume-:1, Storm Water Policy Guidebook, First Edition- August 2001

7. Malczewski, J. (1999b).Spatial Multi-criteria decision analysis. In: J. C. Thill (ed.), Multi-criteria decision making analysis: a geographic information sciences approach. Brookfield, VT; Ashgate Publishing, pp.11-48

8. Saaty, T.L., (1980). The Analytic Hierarchy Process. McGraw-Hill, New York, 20-25.

9. Yelcin Guler, Akyurek Zuhal (2005): Multiple Criteria Analysis for Flood Vulnerable Area, International Journal of Geographical Information System.

Internet References:

Http://en.wikipedia.org/wiki/gujarat

Http://www.Ahmedabad.org

Http://www.thebestindia.com/city/ahmedabad.asp

Http://dcm2.esri.state.nc.us/planning/userguide-lsa2005.pdf

Http://www.emsgujarat.org/background.htm

Http://expresshealthcaremgt.com/20040715/coverstory.shtml

Http://edn.esri.com/index.cfm?fa=downloads

Http://www.esri.com/software/mapobjectlt/index.html

Http://www.ahmedabadcity.org

Http://en.wikipedia.org/wiki/Ahmedabad-Wikipedia.htm

Http://en.wikipedia.org/wiki/2005_Mumbai_floods

Flood Risk Assessment in Part of Surat city using Continuous Rainfall-Runoff Simulation Model

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INTRODUCTION

Urban flooding, which is a specific type of flooding caused primarily due to the lack of drainage in an urban area, is one of the most frequently occurring disaster hitting Indian cities. In recent times, several Indian cities such as Surat, Mumbai, Chennai, Kolkata, Bangalore, etc. have witnessed unprecedented incidences of flooding. In year 2005, flooding was reported in 10 Indian Cities, with Mumbai being the worst affected city of all. The number of cities affected by flooding rose to 22 in year 2006, and 35 in the year 2007. Rapid urbanisation of country-side resulting in large-scale increase in impervious surfaces and hence the surface runoff, coupled with failure of storm water drainage infrastructure has increased the risk of flooding and surface inundation in several Indian cities. With changes in surface landscapes in ever evolving urban activity system, the runoff and flow regimes are continuously being altered making urban areas more vulnerable to incidences of flooding. The capacity of storm water drainage infrastructure is often constrained by fiscal and technical limitations and hence calls for innovative management of urban storm water. The increasingly erratic rainfall in most of the urban areas, which may be attributed to climate change, demands scientific analysis of urban drainage system.

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to design of drainage facilities. The methods applied to undertake hydrological analysis in urban areas may vary from simple formulas (e.g. Rational Method, Berkely-Ziegler equation etc) to complex continuous simulation numerical models such as Hydrocomp Simulation Model and EPA SWMM. The hydrologic models can broadly be categorized in terms of how they deal with time, randomness, and the level of spatial detail. Accordingly, they are distinguished as the Event models and Continuous simulation models. Event models simulate a single event such as the hydrograph of a single storm. Event Models such as the Rational Method and Unit Hydrograph Method use rainfall as an input and return flood peaks and hydrographs as output. Most event models were developed specifically to design the urban drainage systems and other small projects. These models provide estimates of flood peaks which are used for sizing of drainage network components.

The continuous simulation models such as SWMM are capable of generating outflow hydrographs over long periods of time. These models attempt to represent the entire hydrologic system on the computer so as to simulate the natural system. A continuous model includes algorithms which maintain a continuous water balance for the catchment so that the conditions antecedent to the each storm event are known. These models simulate the runoff process including interception, infiltration, evaporation, overland flow, channel flow, etc. The application of these models for municipal use has been limited primarily due to large amount data requirements. This gap in retrieving data for continuous simulation models can be bridged using remote sensing and Geographic Information System (GIS). This paper demonstrates the application US-EPA SWMM in modelling the response of drainage network in a part of Surat city to three specific (assumed) rainfall events with peak rate of rainfall corresponding to 2 year, 5 year, and 50 year frequency storms.

STUDY AREA

The study covers a part of Surat city spread over 25 sq. km area (Figure 1). The city of Surat is located along the western coast of India. The city with a population of 24,33,835 (Census of India, 2001) is second largest city of Gujarat. The decadal growth rate of Surat city was observed to be 62.30% during 1991 to 2001. The city is situated nearly 13 miles away from the mouth of River Tapi. Tapi is a tidal River up to 35 miles from its mouth. The study area is subject to flooding due to release of water from Ukai dam in the upstream of the City, tides occurring in the Tapi River, and the heavy rainfall that frequents South Gujarat region. The flood in year 2006 caused great damage to the city and over 200 lives were reportedly lost.

Figure 1 Study Area Location

Storm Water Management Model (SWMM)

SWMM is a comprehensive computer model for analysis of quantity and quality problems associated with urban runoff. Both continuous and single-event simulation can be performed on catchments having sanitary sewers, storm sewers, or combined sewers and natural drainage, for prediction of flows, stages, and pollutant concentrations. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub-catchment as well as the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprising multiple time steps.

The model conceptualizes a drainage system as a series of water and material flows between several major environmental compartments, viz. Atmospheric Compartment, Land Surface Compartment, Ground Water Compartment and the Transport Compartment (Rossman, 2005). In simple terms, the precipitation in form of rainfall or snow, from the Atmospheric compartment enters the Land Surface Compartment comprising of one or more sub-catchment areas. A portion of the rainfall entering the sub-catchments infiltrates to the Ground Water Compartment, whereas the remaining forms the surface runoff. A part of this surface runoff finds its way to Transport Compartment comprising of drainage network and flows to the receiving water body through an outfall.

METHODOLOGY

The study used Cartosat-1 data merged with IRS-P6 LISS IV data for land cover mapping of the study area at 1:10,000 scale. The map of

Final Plot boundaries obtained from each of the 23 Town Planning Schemes covering the study area were geo-referenced with the Satellite image and seam-less mosaic of final plot boundaries was created for entire study area. The plot boundaries were subsequently digitized in GIS environment and a final plot boundary feature class was thus prepared. The study area has 3303 plots, excluding the area covered by roads. Each plot was treated as a sub-catchment area and an outlet was assigned based upon its topology and topography. An outlet of a sub-catchment defines the exit point of runoff from a particular sub-catchment. It can be another sub-catchment area, or a junction of the drainage network from where the runoff transported to the outfall.

The bare-earth Digital Elevation Model (DEM) of the study area was created from Cartosat-1 stereo-pair, and slope was thus derived. Average slope was computed for each plot from the slope map. Similarly, percentage of impervious surface, impervious subarea, and pervious subarea were derived from the land cover feature class for each plot (*Figure 3*).

The CAD drawings of drainage network were processed and conduits, junctions, and outfalls from the drainage network were separated into feature classes. The study area has 346 conduits, 346 junction nodes, and 15 outfalls as shown in *Figure 2*. The invert levels of each of the outfalls in study area were obtained from Surat Municipal Corporation. The invert levels of all other nodes (junctions) in the drainage network were derived by assuming slope in each conduit required for generating self-cleansing velocity of 1 m/s. The feature classes of sub-catchment areas (polygon), conduits (line), junctions (points), and outfall (point) were converted into SWMM input file (.INP). The input file was opened in SWMM software, as shown in Figure 4 and rainfall and evaporation data were attached to the project file.

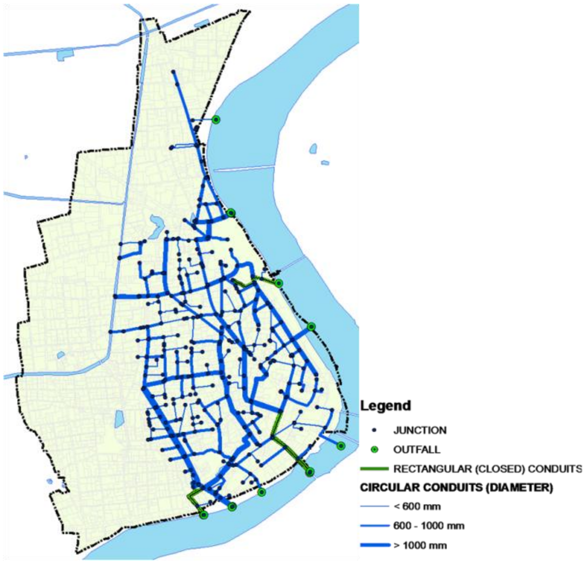

Figure 2 Drainage Network

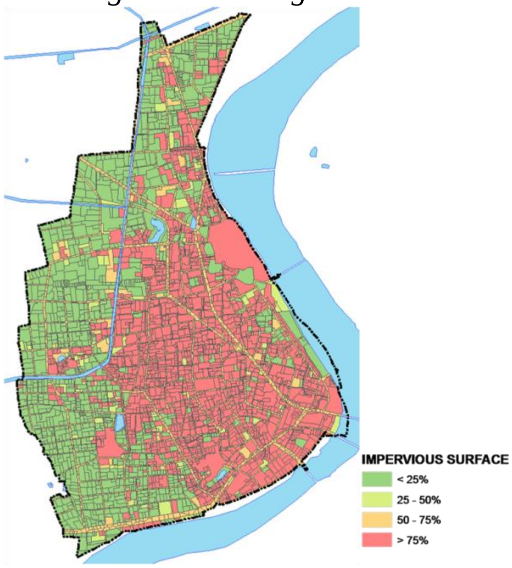

Figure 3 Percent Impervious Surface

The flow routing within a conduit link in SWMM was done using Dynamic Wave Routing. Dynamic wave routing solves the complete one-dimensional Saint Venant flow equations and therefore produces the most theoretically accurate results (Rossman, 2005).

RESULTS AND DISCUSSION

The simulations of rainfall-runoff response were carried out with one-hour rainfall of 2 year, 5 year, and 50 year frequency over the study area. The hourly maximum rainfall in Surat with 2 year, 5 year and 50 year frequency as obtained from standard charts (Garg, 1999) are 4.5, 7, and 10 cm/hour respectively. The time intensity curve with rainfall peak at corresponding hourly maximum rate was assumed. The mean daily evaporation was assumed as 5 mm per day for the month of August from the charts published by Indian Meteorological Department.

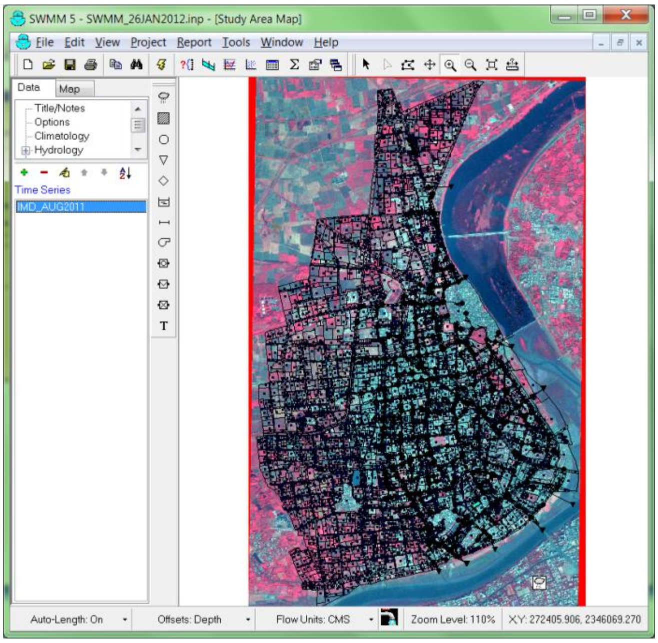

Figure 4 INP file Opened in US EPA SWMM

Table 1 show the runoff generated from the study area under each of the three scenarios. The corresponding wet weather inflow entering the drainage network under each of the three conditions is 34.65 ha-m, 55.43 ha-m, and 80.54 ha-m for 2 year, 5 year, and 50 year scenarios respectively.

The surface flooding at nodes is obtained from simulation results. The surface flooding indicates the quantity of inflows (in cubic meters per second) lost from the system when the water depth exceeds the defined maximum node depth.

This amount of flow may cause surface ponding and hence flooding. Figure 5 shows the duration of flooding at each node along with maximum flow in each link observed during the simulation period.

Table 1 Runoff Quantity Continuity

	2 Year	5 Year	50 Year
Precipitation (mm)	45	70	100
Precipitation (ha-m)	111.99	174.2	248.86
Infiltration (ha-m)	3.78	3.81	3.83
Evaporation (ha-m)	18.24	18.42	18.54
Surface Runoff (ha-m)	93.41	156.11	232.44
Continuity Error (%)	-3.07	-2.38	-2.39

It is evident that the drainage network will require more time to drain-out the urban areas as the rainfall intensity increases. The total number of nodes susceptible to flooding for more than one hour has increased from 6 in 2 year frequency rainfall, to 42 in 50 year rainfall. Thus the plots draining out to these nodes are more vulnerable to meet urban flooding disaster.

Table 2 Flood Duration at Nodes

	Number of Nodes		
Hours Flooded	**2 Year**	**5 Year**	**50 Year**
< 15 minutes	73	103	109
15 – 30 minutes	8	13	16
30 – 45 minutes	13	17	20
45 – 60 minutes	17	17	33
> 60 minutes	6	26	42
Total	**117**	**176**	**220**

CONCLUSION

The study demonstrated the application of continuous simulation of rainfall-runoff processes in an urban areas using US-EPA Storm Water Management Model. The model however requires several inputs which can be obtained from remote sensing and Geographical Information System. The simulation was carried out for three scenarios with one hour rainfall corresponding to 2 year, 5 year, and 50 year frequency.

The drainage networks are typically designed for rainfall intensity corresponding to 2 year recurrence interval, which in case of Surat is 45 mm/hour (Garg, 1998). Thus, in events when the rainfall exceeds the systems design capacity, inundation becomes inevitable. The continuous simulation of rainfall-runoff response using hydrological and hydraulic models such as SWMM enables scientific management of runoff generating in an urban area, providing timely inputs to policy makers in planning evacuation, and minimizing the damages that may otherwise be incurred by overflowing drainage network.

REFERENCES

Garg, Santosh Kumar, 1998, Environmental Engineering (Vol. II) – Sewage Disposal and Air Pollution Engineering, 11th Edition, Khanna Publishers, Delhi.

Garg, Santosh Kumar, 1999, Irrigation Engineering and Hydraulic Structures, 13th Edition, Khanna Publishers, Delhi.

Rossman, Lewis A., (2005), Storm Water Management Model, User's Manual, Version 5.0, United States Environmental Protection Agency, Cincinnati OH.

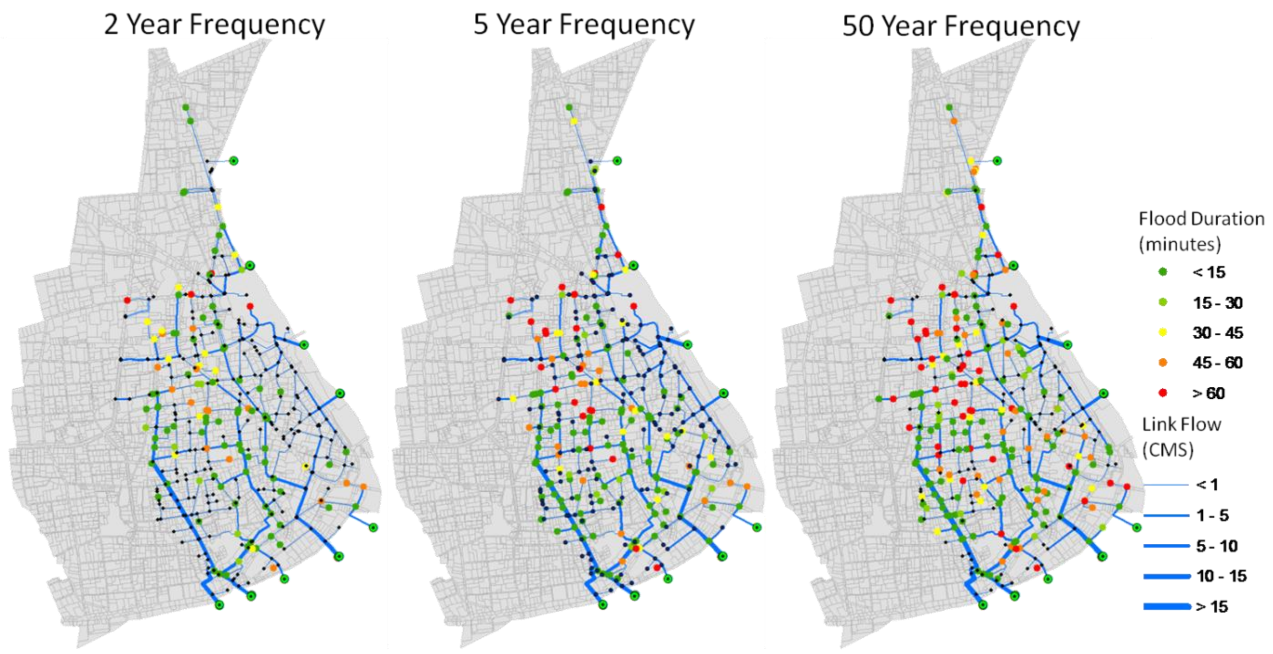

Figure 5 Duration of Flooding and Maximum Link Flows

Space inputs to earthquake precursors and surface deformation studies

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INTRODUCTION

After each earthquake the scientific community usually faces a fundamental question from both media and people; is it possible to predict when and where would the next large earthquake occur? Here the reference is short-term prediction and unfortunately, short-term prediction that led to practical actions has seldom been achieved and pessimistic views are widespread in seismological community. Earthquake prediction is broadly classified into three categories: long-term, intermediate-term, and short-term predictions. They differ in their methods, accuracy, and purpose. Both long-term and intermediate-term predictions are in essence estimates of the statistical probability of earthquakes to occur. Long-term prediction deals with the probability of earthquake occurrence on time-scales of 10 to 100 years, based on geologic studies of faults and historic records of seismicity (Uyeda et al, 2009). Intermediate-term (1 to 10 years) and short-term (<1 year) prediction uses more of recent instrumental data of seismology and geodesy.

An earthquake is a sudden mechanical failure in the earth's crust in response to stresses accumulating for millions of years. Due to highly heterogeneous nature of earth, it is very difficult to develop a unique mathematical model for the earthquake process and hence prediction of the earthquake becomes the most complicated affair. However, it is reasonable to expect that its preparatory process has various facets which may be observed before the final catastrophe: namely geochemical, hydrological and electromagnetic changes (Uyeda et al, 2009). Satellites could be more effectively utilized for searching and monitoring of verity of earthquake precursors than land-based instruments which has very limited coverage. The objective of this article is to introduce satellite based thermal and electromagnetic earthquake precursors. Further, a brief description of surface deformation monitoring caused by earthquakes using InSAR (Synthetic Aperture Radar Interferometry) technique is given.

Thermal precursors:

The modern operational space-borne sensors in the infra-red (IR) spectrum allows monitoring of the Earth's thermal field with a spatial resolution of 0.5 - 5 km and with a temperature resolution of 0.12 - 0.5 C. Sensors may closely monitor seismic prone regions and provide information about the changes in surface temperature associated with an impending earthquake with better temporal resolution. Thermal observations from satellites indicate the significant change of the Earth's surface temperature and near-surface atmosphere layers. Statistically significant correlation between thermal anomalies and seismic activity was proofed (Tronin, 2004).

The problem of thermal anomalies nature belongs to fundamental problem of litho-atmospheric coupling. The causes of the thermal anomalies lie in the lithosphere and are related to the earthquake preparation. The geological structures (faults, cracks, fractures etc.) act as preferred conduits because the convective flow of fluids and gas in the upper levels of the lithosphere, and thereby the transport of heat, is orders of magnitude higher than the diffusive flow. The thermal anomalies are typically observed above large faults and their intersections. On January 20, 2001, there is a strong land surface temperature (LST) increase (with a maximum of +4°C) for the area close to the epicenter of the January 26, 2001, Gujarat earthquake that dissipates within a few days after the event (Saraf et al., 2005).

Electromagnetic Precursors:

It has been recently reported that electromagnetic phenomena take place in a wide frequency range prior to an earthquake, and these precursory seismo-electromagnetic effects are expected to be useful for the mitigation of earthquake hazards (Hayakawa et al, 2007). Earthquake related EM signals may be conveniently classified into the following two major groups, each covering wide frequency ranges: i) EM signals believed to be emitted from within the focal zones and ii) Anomalous transmission of EM waves over epicentral regions. The first is the direct observation of electromagnetic emissions (natural emissions) from the lithosphere and the second is to detect indirectly the seismic effect taken place in a form of propagation anomaly of the pre-existing transmitter signals (radio sounding).

There were few satellites for measuring electromagnetic signal related to earthquakes like Intercosmos 24 (1989-90), QuakeSat (2003-2005), Demeter (2004-2010). The Intercosmos 24 satellite detected ELF-VLF electromagnetic emissions associated with earthquakes. During 180 orbits from November 16, 1989, to December 31, 1989, twenty-eight rather strong earthquakes (Ms between 5.2 and 6.1) took place with emissions in the two frequency bands with spectrum maxima at ULF-ELF (f less than 1000 Hz) and at VLF (f = 10–15 kHz), typically observed as bursts, in the region nearly above the earthquake epicenter before 12-24 hrs before the earthquakes. Maheshwari et al (2002) reported the fluctuations of ion density measured with the help of Retarding Potential Analyser (RPA) payload aboard Indian SROSS - C_2 satellite in altitude of 500 km. Satellite based EM precursors are one of the promising area in earthquake prediction research which has to be developed further.

Surface deformation related to earthquake processes:

Major earthquakes are strongly associated with observable surface deformation of the order of meters. The surface deformations associated with an earthquake are categorized under co-seismic, post-seismic and inter-seismic deformations. Co-seismic deformations are associated with the episodic event that last for few minutes. The majority of slip occurs in this stage. Elastic and inertial effects dominate in co-seismic deformation. For Gujarat earthquake of 2001, the co-seismic deformation is estimated to be about 6 m running over a fault length of 80km. The post-seismic deformations are associated with the non-inertial (aseismic slip or creep) deformation together with inelastic stress relaxation within the upper part of asthenosphere. This stage of deformation, which falls off exponentially with time, follows immediately after the earthquake. For great earthquakes, such as, 2001 Bhuj Earthquake, it can last for many years. The inter-seismic deformation accounts for most of the period between consecutive earthquake events during which the plates load and stress build-up. Thus surface deformation studies are very important aspects to understand the physics of earthquake processes.

A continuous long period observation of deformation along active faults could be achieved through two sophisticated space-borne techniques, the SAR Interferometry (InSAR) and Global Positioning System (GPS). The GPS can provide highly accurate horizontal displacement with an error of few millimetres and vertical displacements with lesser accuracies. The InSAR measures displacement along the Line of Sight of the Satellite with an accuracy in terms of a fraction of radar wavelength. GPS, being a point-based measurement technique, can provide a continuous time series of measurement, but lacks spatial coverage. SAR Intereferometry, on the other hand, has a poorer temporal resolution; but it provides a complete spatial coverage. Hence accurate surface deformation measurements are possible with synergetic use of GPS and InSAR.

The GPS technology is well-known and widely utilised for a variety of applications whereas InSAR technique is relatively new particularly in seismology. InSAR is a method to combine the phases of two different radar images gathered simultaneously or at different times with slightly different looking angles from the satellites. This technique calculates the interference pattern caused by the difference in phase between these images. The resulting interferogram is a contour map of the change in distance between the ground and the radar instrument. The measured phase difference shows an ambiguity cycles of 2π that corresponds to a 2-way travel path difference of the radar wavelength (λ) along with phase terms proportional to the target motion caused by deformation during that time interval. Thus, if the phases due to topography are removed from the interferogram the residual fringes correspond to the ground surface motion along the sensor-target Line of Sight (LOS) direction. This technique is generally known as Differential InSAR (DInSAR) and has been used to measure surface deformations caused by a variety of sources like earthquakes, landslides, mining etc. The principle of measuring surface deformation using InSAR technique is described in Fig. 1.

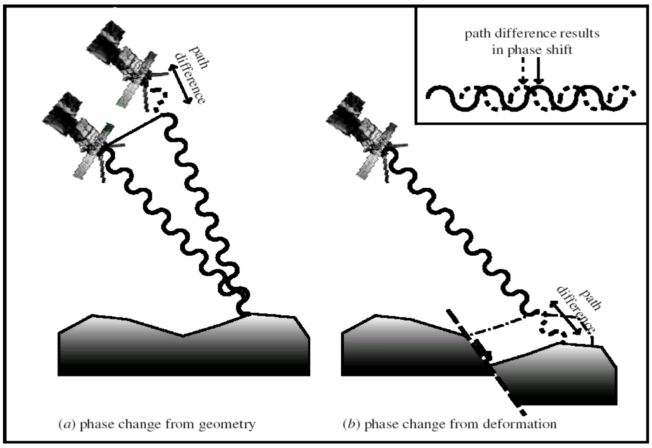

Figure 1: Cartoon showing the mapping of surface deformation using InSAR technique

The InSAR applications for studying earthquakes was first demonstrated by Massonnet et al. in a classic paper which graced the front cover of Nature (Massonnet et al. 1993). Their interferogram generated from ERS-1 SAR data sets could successfully capture the surface movements produced by the 1992 Landers earthquake. Further, it was proved that InSAR could be used as an alternative tool to obtain location, magnitude and type of an earthquake which otherwise could be only possible with seismological observations. Since then, several studies have been attempted demonstrating the application of InSAR for earthquake deformation studies.

Lack of data availability and loss of coherence produced by various decorrelation effects provides constraints in using InSAR techniques in certain areas. Nevertheless, recently developed techniques like Persistent Scatterers (PS) technique has given promising results for monitoring long term surface deformation as it is independent of overall phase decorrelation.

In India, InSAR studies for seismic deformation mapping have achieved limited success. Though Killari earthquake of 30 September 1993 was mapped using InSAR technique (Satyabala et al., 2003), the Bhuj earthquake of 26 January 2001 of magnitude 7.8 could not be effectively mapped due to loss of coherence. This earthquake was one of the largest intraplate events ever reported causing wide spread destruction. According to Gujarat government records, more than 20,000 people died, 166,000 injured and more than 370, 000 houses were collapsed leaving 600,000 people homeless.

Kachchh region falls in Zone-V (most prone to earthquakes) of the Seismic Zonation map of India. Recent studies reveal intense seismic activity around the epicentral area of 2001 Bhuj earthquake. Space Applications Centre (SAC), Ahmedabad and Institute of Seismological Research, Gandhinagar have recently initiated studies to map the on-going deformation using seismological geodetic and SAR datasets as part of the R&D Support to the Disaster Management Support Program (DMSP) of Department of Space. The analysis of SAR data for the period 2007-2009 resulted in mapping the surface deformation of about 0-50 mm along the line of sight of the satellite over a part of Kachchh region (Figure 2). These results were validated using DGPS based field surveys, which showed comparable deformation rates.

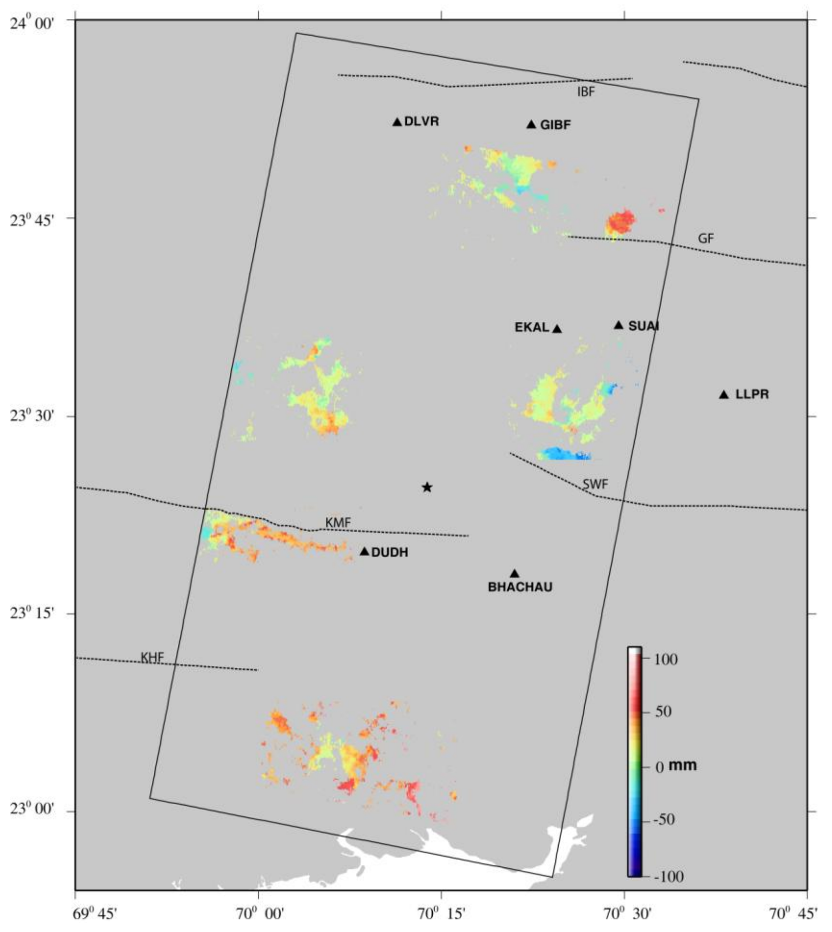

Figure 2: LOS range-change generated from ENVISAT-ASAR interferogram. Positive values represent displacement towards the satellite (max. around 50mm during 1.5 yr corresponds to about 40mm/yr). Interferogram fringes were identifiable in hilly-uplifted areas only but not in large low-lying areas. The star indicates the 2001 Bhuj earthquake.

The study reveals that InSAR technique can be an effective tool for understanding the crustal deformation in Kachchh. More SAR data analysis at regular time intervals may further improve the results. The currently operating

SAR sensors like ENVISAT- ASAR, ALOS-PALSAR have very limited data availability over India. Launch of ISRO's planned RISAT Mission may improve the data availability.

References:

Hayakawa M, Hattori, K and Ohta, K. Monitoring of ULF (ultra-low-frequency) Geomagnetic Variations Associated with Earthquakes . Sensors, 2007, 1108-1122

Maheswari, N., Sharma, D.K., Khurana, M.S. and Rai, Jagadish, Ionospheric Ion density variation in the low and mid latitude ionosphere : possible connection with earthquake. IJRSP, vol. 39, pp. 353-358, 2010.

Massonnet, D., Rossi, M., Carmona, C., Adragna, F., Peltzer, G., Feigl, K. and Rabaute, T., The displacement field of the Landers earthquake mapped by radar interferometry. Nature, 1993, 364, 138–142.

Molchanov, O.A., Hayakawa, M., Afonin, V.V., Akentieva, O.A. and Mareev, E.A. Possible influence of seismicity by gravity waves on ionospheric equatorial anomaly from data of IK - 24 satellite 1. Search for idea of seismo-ionospheric coupling, Seismo Electromagnetics : Lithosphere – Atmosphere – Ionosphere coupling, Eds. M. Hayakawa and O.A. Molchanov, pp. 275-285. 2002.

Saraf, A.K. and Choudhury, S., NOAA-AVHRR detects thermal anomaly associated with the 26 January 2001 Bhuj earthquake, Gujarat, India. 2007, Int. Jour. Rem. Sens.,26:6, 1065-1073

Satyabala, S. P., Coseismic ground deformation due to an intraplate earthquake using synthetic aperture radar interferometry: The Mw6.1 Killari, India, earthquake of 29 September 1993. J. Geophy. Res., 2006, 111, B02302, doi:10.1029/2004JB003434.

Schmidt, D. A., and Burgmann, R., InSAR constraints on the source parameters of the 2001 Bhuj earthquake. Geophy. Res. Lett., 2006, 33, L02315, doi:10.1029/2005GL025109.

Tronin A.A., Biagi P.F., Molchanov O.A., et al., Temperature variations related to earthquakes from simultaneous observation at the ground stations and by satellites in Kamchatka area. Physics and Chemistry of the Earth.,2004, 29, 501-506.

Uyeda, S, Nagao, T., Kamogawa, M. Short-term earthquake prediction: Current status of seismo-electromagnetics. 2009, Tectonophysics, 470, 205–213.

Detection of oil spill and prediction of its dispersion using synergistic application of SAR images and numerical simulations – A case study of Mumbai oil spill 2010

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INTRODUCTION

Oil, spilled in the ocean are surely a cause of concern among both the scientific and management communities. If the spills are of accident or normal/illicit ship operations, the issues sprout up relating with the environmental degradation and pollutions. The natural oil seepages on the other hand are received with a higher amount of expectations on the ground of oil exploration activities. Even though the accidental seepages contribute only 7% of the total marine oil pollution on a global basis (Pavlakis et al., 2001), they spill out an enormous amount of oil in relatively lesser time. Marine oil spills have a devastating effect on the marine habitat due to the factors such as petroleum toxicity and oxygen depletion in the affected area. Both the prey and predator equally share the consequences; microbes, fish, birds, crustaceans, molluscs, reptiles, mammals, in the region would be either wiped out or left to starve in lack of food, where it may take decades for the ecosystem to recover. The oxygen depletion as a result of oil spill can smother the coral reefs in the vicinity of the affected area. As the spills get advected by the prevailing ocean currents, extent of the disaster also spreads. On reaching the coast, tar balls get accumulated in the coastal belt destroying the delicate ecosystem like mangroves and affecting the inhabitants fringing the coastline. During accidental seepages, authorities or management communities are left with little time to act over these disastrous consequences of oil spills.

While in case of accidental oil spill, the initial concern is on where the oil spills have occurred and how much is its spread. Satellite remote sensing data finds its efficient applicability in detecting the oil seepage area. The oil spill detection, monitoring and decision making using remote sensing data are nowadays a cardinal research activity. The viability of remote sensing data for oil spill detection has been reviewed by Jha et al (2008) and Brekke and Solberg (2005). Oil spills in the marine environment can be detected using space borne Synthetic Aperture Radar (SAR) data (Frate et al., 2000 and Topouzelis et al., 2007), Multispectral data (Hu et al., 2003, and Srivastava and Singh, 2009), Hyperspectral data (Salem and Kafatos, 2001) and also from the apparent thermal inertia (Cai et al., 2010) from the sea surface temperature. After detecting the oil spill region the anxiety arises to know where the spills get advected. Researches in numerical modelling of oil spill have contributed very much in predicting or understanding the oil spill behaviour and movement in the marine environment. Wanga et al (2005) and Vethamony et al (2007) have described the feasibility of numerical simulation in describing the trajectory of oil spills in the marine environment.

Detection of Marine Oil Spill:

In monitoring oil spills, space-borne Synthetic Aperture Radar (SAR) data is found to be more efficient than the other techniques used in remote sensing. The brightness in a SAR image for ocean surface is due to the wind-generated short gravity-capillary waves. The wave lengths of these short gravity-capillary waves are at comparable to the microwave and satisfies the Bragg resonance model given as

$$\lambda_w = \frac{n\lambda_r}{2\sin\theta}, n = 1,2,3 ....$$

where λ_w is the wave length of Bragg-selected ocean surface waves, λ_r is the radar wavelength and θ is the incidence angle.

On the ocean surface, presence of these waves makes the ocean surface rough as perceived by the radar wavelength and hence even for a relatively calm ocean; the sea surface have considerable contribution of backscatter at the radar sensor.

When the slick covers the surface, the wind has less effect and amplitude of the wave decreases. Also the surface stress gradient due to the visco-elastic property of the oil film acts against the up and down wave motion which results in dampening of the short gravity-capillary waves. As the slick dampens the short gravity-capillary waves, the dynamic roughness of the ocean also get reduced. As a consequence radar backscattering level gets reduced in the slick affected region and in the radar image the slick region appears as a dark patch with weak backscattering in comparison with the surroundings.

The gravity-capillary waves are also dampened under the presence of natural biogenic surfactants or natural films; reducing the backscatter and giving an impression as oil spill in the radar images. The reduction of backscatter in the radar images also occur due to low surface winds, rain cells and at shear zones. In the context of SAR image interpretation, they are collectively known as lookalike of oil spill.

Dark formation in the SAR images; hence can be either due to oil spill or its lookalikes. Detection of the dark spots in the radar image is considered as the fundamental step in oil spill detection systems and constitutes the first step in oil spill detection approach. Dark spot detection is followed by feature extraction, which helps to classify the segmented dark regions to oil spill or look alike. Features can be grouped into three, which is generally described as shape: representing the geometry and orientation of the slick, contrast or homogeneity: referring to the physical behavior of the spill and the third one is the surroundings or contextual features of the segmented region. Classifications techniques are developed to discriminate the dark region into oil spill and/or lookalike based on the features extracted from the suspected oil spill detected as dark spots on the radar images. Neural network, fuzzy logic and statistical classifiers are the common techniques used to classify the detected dark spot into oil spill or lookalike.

Simulation of spill trajectories:

In accidental seepages, spill modelling is important to predict the trajectories and oil fate for devising suitable combating mechanisms and to understand the extent of the disaster. Advection of oil in the prevailing ocean currents and its dispersion due to the wind are accounted in the monitoring of oil spill. Along with the advection and dispersion, weathering processes, gravitational, viscous and surface tension decides the spread of oil spill and its fate.

Weathering of oil spills in marine environment is mainly depended on the emulsification rate, evaporation rate and mechanical dispersion.

Emulsification of oil in the marine system is a complex phenomenon which is rather poorly understood. Emulsification involves the dispersion of water droplets into the oil medium. As the percentage of water increases, the viscosity, effective volume and the density of the resulting emulsion increases and become difficult for cleanup activities. Furthermore, evaporation of components from the emulsion will also be diminished.

Air temperature and cloudiness are two important environmental factors affecting the rate of evaporation of oil spills. Light fractions of the oil evaporate and dissipate quickly depending on meteorological and oceanographic conditions. The rate of evaporation of the lighter components is influenced by the percentage of lighter components in the crude oil itself, the oil temperature, the oil thickness and area, and the physical forces of wind and wave energy. As crude oil spreads out on the sea surface a large surface area is exposed and the initial rapid loss of the volatile components occurs. The process then slows down with the increasing proportion of the higher boiling components remaining in the residue. The effect of evaporation is thus to increase the density of the remaining oil and to increase its viscosity, leading to a complex process of emulsification and solidification, which reduces the surface area of the slick and hence the rate of evaporation.

In the mechanical processes of dispersion, water turbulence tears off globules of oil and entrains them forming an oil-in-water emulsion. In harsh weather, the dominant mechanism is wave breaking, while in calm weather, the stretching and compression of the slick lead to droplet separation.

For majority of the crude oils, weathering leads to residue lighter than the sea water. But these floating residues can come into contact with heavy mineral particles like sands and silts in the coastal region. At these circumstances the solid particle is incorporated into the bulk of oil or may become coated with a layer of oil, resulting in the mixture to become negative buoyant and gradually sinks.

Case Study:

A case study is presented here demonstrating the applicability of SAR data in detecting the oil spill and numerical models in simulating the oil spill dispersion. The study was done for Mumbai oil spill, where an accident on 7th August 2010 caused around 800 tons of oil to spill into the sea near the Mumbai coast. The oil spill had an alarming ecological impact along the Mumbai coast, where the fish and other marine creatures were found to be coated with the oil. The oil slick was reported to enter the sensitive mangrove belt and the shores along the green mangroves were observed to be coated with black oil.

Data and methodology:

The region affected by the accidental oil spill over the Mumbai coast were detected using browsed images of C-band RADARSAT SAR for 15th and 16th of August 2010. ALOS PALSAR image of 24th August was procured and analysed to study the fate of the oil spill in the marine environment.

MIKE-21 SA (Oil spill analysis) module was used to simulate the trajectory of the accidental oil spill. The currents in the near shore region were simulated using MIKE-21 HD (Hydrodynamic) module. Digital hydrographic chart from CMAP was used to create the bathymetry for the region. The domain used for the oil spill simulation is shown in Figure 1. Tidal elevations, predicted using FES-99 at the western boundary was given as the open boundary condition. In the model, wind conditions prevailing in the region was given from the GFS model output winds.

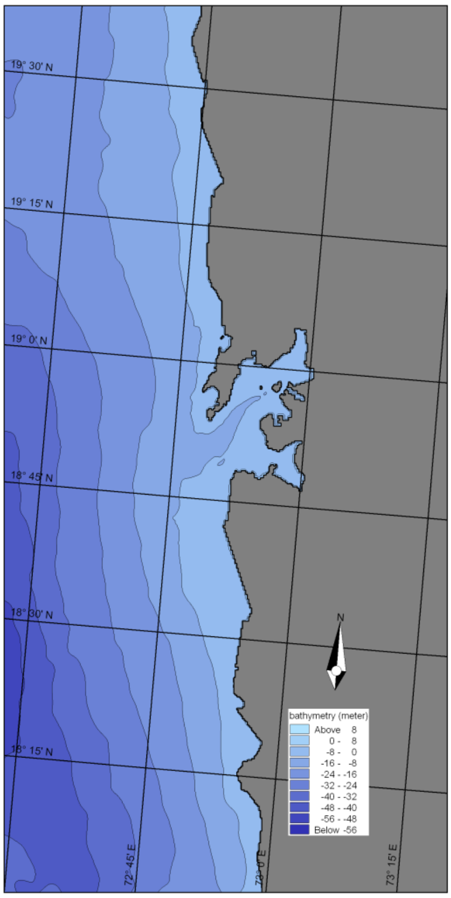

Figure 1: Model domain and bathymetry around Mumbai

Results:

Oil spill simulation studies were carried out from 7th August 2010, for a period of one month. The simulated oil spill trajectories were compared with SAR detected oil spills for 15th, 16th and 24th August 2010. Figure 2 shows the SAR images and corresponding simulated oil spill dispersion patterns. During 15th and 16th of August 2010, the oil spills detected from the SAR images were observed within the creeks of Mumbai.

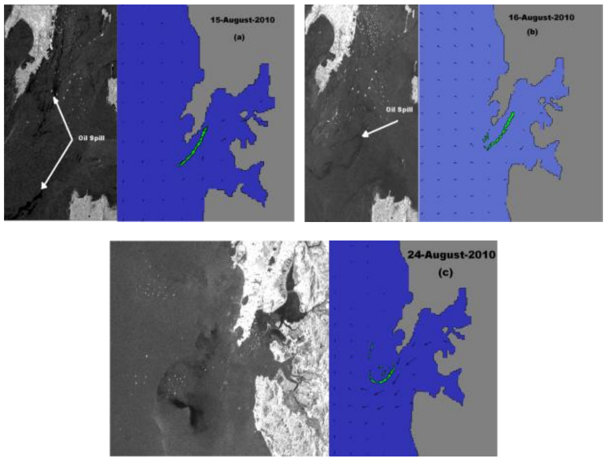

Figure 2: Oil spill detected in region around Mumbai from SAR images and corresponding simulated spill trajectories. a) RADASAT SAR; 15 August 2010. b) RADARSAT SAR; 16 August 2010. c) ALOS PALSAR; 24 August 2010

The model also has recreated the spill scenario, where the spills were observed to be dispersed within the Mumbai creeks. On 24th of August, both ALOS PALSAR and simulated results shows the oil spill to get dispersed away from the Mumbai creek mouth. From the comparison studies it was observed that the numerical simulation is able to recreate the oil spill scenarios of the accidental oil seepage near Mumbai Coast. This study underlines the importance of remote sensing data and numerical simulation techniques in oil spill mitigation activities.

References:

Pavlakis, P., Tarchi, D., Sieber, A.J., Ferrao, G and Vincent. G 1996. On the monitoring of illicit vessel discharges, A reconnaissance study in the Mediterranean Sea. European Commission, Report EUR 19906 EN. pp 21.

Jha, M.N., Levy, J and Gao, Y. 2008. Advances in remote sensing for oil spill disaster management: sate-of-the-art sensors technology for oil spill surveillance. Sensors. 8: 236-255.

Brekke, C and Solberg, A. 2005. Oil spill detection by satellite remote sensing. Remote Sensing of Environment. 95(1): 1 –13.

Frate, F.D., Petrocchi, A., Lichtenegger, J and Calabresi, G. 2000. Neural networks for oil spill detection using ERS-SAR data. IEEE Trans. Geoscience and Remote Sensing. 38(5): 2282–2287.

Topouzelis, K., Karathanassi, V., Pavlakis, P and Rokos, D. 2007. Detection and discrimination between oil spills and look-alike phenomena through neural networks. ISPRS J. Photogrammetry Remote Sensing. 62: 264-270.

Hu, C., Frank, E.M., Taylor, C., Myhre, D., Murch, B., Ana, L.O and Godoy, G. 2003. MODIS detects oil spills in lake Maracaibo, Venezuela. EOS. 84(33): 313-319.

Srivastava, H and Singh T.P. 2010. Assessment and development of algorithm to detection of oil spills using MODIS data. Journal of Indian Society of Remote Sensing. 38: 161-167.

Salem, F and Kafatos, M. 2001. Hyperspectral image analysis for oil spill mitigation. In proc: 22nd Asian Conference on Remote Sensing. 5-9 November Singapore.

Cai, G., Huang, X, Du, M and Liu, Y. 2010. Detection of natural oil seeps signature from SST and ATI in South Yellow Sea combining ASTER and MODIS data. International Journal of Remote Sensing. 31(17-18): 4869-4885.

Wanga, S.D., Shena, Y.M and Zhengb, Y.H. 2005. Two-dimensional numerical simulation for transport and fate of oil spills in seas. Ocean Engineering. 32: 1556-1571.

Vethamony, P., Sudheesh, K., Babu, M.T., Jayakumar, S., Manimurali, R., Saran, A.K., Sharma, L.H., Rajan, B and Srivastava, M. 2007. Trajectory of an oil spill off Goa, eastern Arabian Sea: Field observations and simulations. Environmental Pollution. 148: 438-444.

Inventory of landslides with respect to the Sikkim earthquake of September, 2011 : A case study from north and east Sikkim regions

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INTRODUCTION

The term landslide means any rapid down–slope movement of mass of regolith and / or bedrock under the influence of gravity. Slope failure occurs when the equilibrium of average shearing stress of slope forming mass exceeds its average shearing resistance. The word landslide particularly represents only a type of movement that is slide. However it is generally used as a term to cover all the types of land movements including falls, creep, spreads, flows and other complex movements. High relief and steep slope provide ideal conditions for high frequency and high magnitude slope failures, massive rock falls and catastrophic debris flows. The landslide activity is primarily influenced by structural, lithological, geomorphological, climatic, environmental, hydrological, seismological conditions. Vast areas of Himalayas including Sikkim, Kumaun, Garhwal and Himachal Pradesh are being robbed of their protective vegetation cover.

Landslides occur during earthquakes as a result of two separate but interconnected processes: seismic shaking and pore water pressure generation. For the main part seismically generated landslides usually do not differ in their morphology and internal processes from those generated under non-seismic conditions. However, they tend to be more widespread and sudden. Rock falls, disrupted rock slides, and disrupted slides of earth and debris are the most abundant types of earthquake-induced landslides, whereas earth flows, debris flows, and avalanches of rock, earth, or debris typically transport material the farthest.

GIS techniques are used increasingly for regional analysis and prediction. Several digital data sets are typically used for such analysis. These can include an inventory of landslides; seismic records; large-scale geological mapping; extensive geotechnical data on rock properties; high-resolution digital elevation data, and suitable high-resolution remote sensing data.

STUDY AREA

In the Eastern Himalayan State of Sikkim (27^0-28^0N and 88^0-89^0E) massive landslides kill several people with catastrophic damages. This Himalayan state of India is generally characterized by steep slopes, lofty hills, and complex geological and tectonic settings. The elevation in the region ranges from 244 to 8534 m, encompassing the third highest mountain (Mount Kanchenjunga) in the world. Landslide occurrences are quite common in the Sikkim Himalaya, and the magnitude of damages caused every year in various parts of the state is quite large. Hundreds and sometimes thousands of people are killed each year from landslides in Sikkim. In 1968 alone, more than 33,000 people were killed by landslides (Choubey, 1992). Landslides in Sikkim occur along one or more discrete surfaces and involve earth and/or rock debris or bedrock, but sometimes both the rock and its cover move.

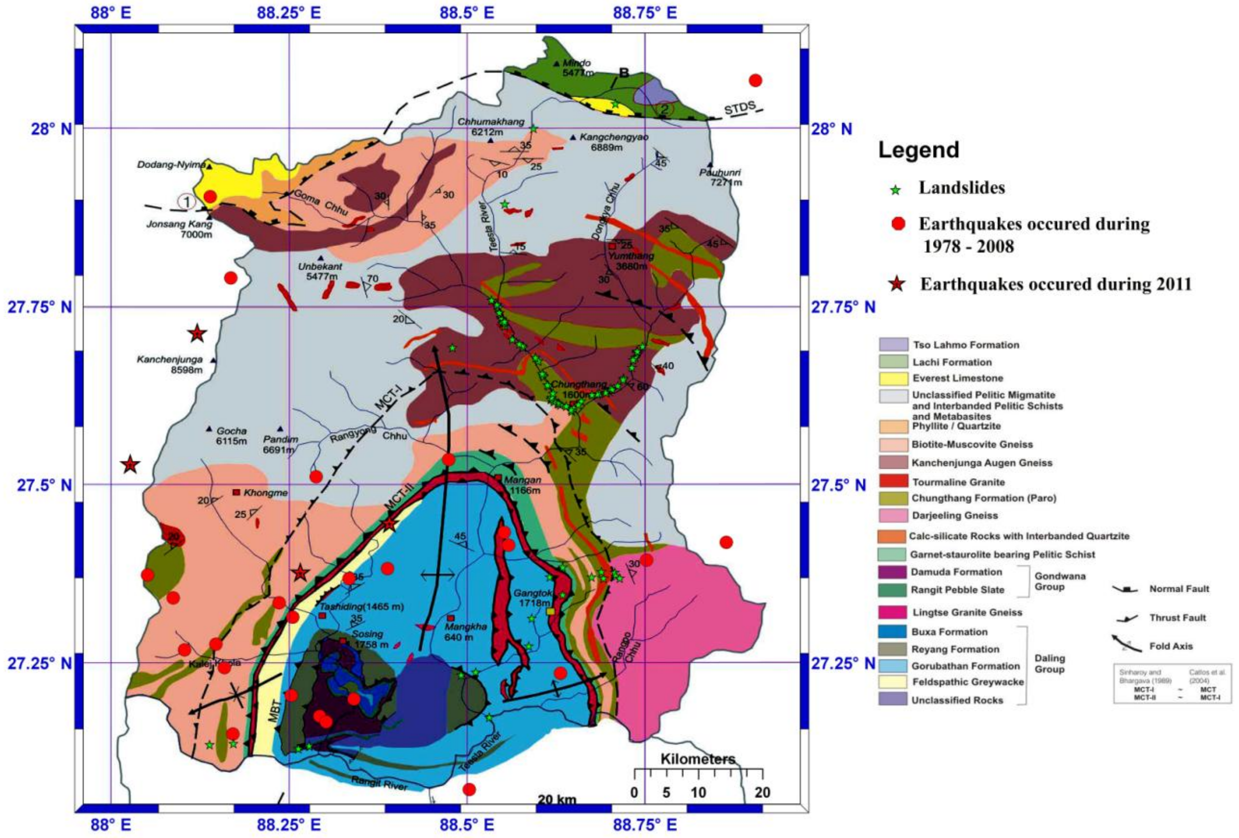

Fig.1 Geological map of the Sikkim, showing the landslides mapped in north and east Sikkim regions (yellow rectangle) and earthquakes (red colour circles for 2011 and red colour stars for the earthquakes occurred during 1978-2008) are shown.

Geology of Sikkim:

Geologically, Precambrian rocks cover a major portion of the Sikkim Himalaya and are represented by the following four major rock formations, listed from youngest to oldest (Bhasin et al., 2002): Everest Pelitic Formation, Sikkim Group, Chungthang Formation, Kanchenjunga Gneiss Group.

DISCUSSION AND SUMMARY

An earthquake of magnitude 6.8 occurred on 18th September at 18:11 hrs IST in Sikkim-Nepal Border region at a focal depth of 10 km and was also reported widely felt in Sikkim, Assam, Meghalaya, northern parts of West Bengal, Bihar, parts of other eastern and northern regions of India. Sikkim region is known for seismically active and traversed by major thrust zones like Main Central Thrust and Chungthang thrust zones. This earthquake has disrupted the communication network and road connectivity, especially between north and south Sikkim regions. This earthquake has triggered so many landslides in parts of Sikkim i.e reactivation of existing landslides and some new landslides.

In the above context, in this study survey was conducted for landslide mapping in third week of November covering three major sectors i.e Lachen and adjoining regions to Chungthang; Chungthang – Lachung; Gangtok – Nathula pass along the roads using handheld GPS, taking the field Photographs.

a)

b)

c)

Fig.2 Figure showing the field photographs of devastation caused by earthquake, hotel building destroyed due to rockslide at Lachung; road sections destroyed by landslides along the Chungthang-Lachung (b) section and Gantok – Nathula pass section.

Besides that information related to seismicity (i.e historical earthquakes) and recent available geological maps of the regions are also compiled to correlate the spatial distribution of the landsides with respect to major thrust zones of the region. Past historical earthquakes (1975 – 2008) and last year (2011) earthquakes are superimposed over the geological map of the Sikkim was shown in Fig.1. Locations of landslides mapped during this survey as mentioned above are also superimposed over geological map along with earthquake locations (Fig.1). This map shows that most of the landslides occurred along the major thrust zones of this region. Some of the field photographs of the landslides mapped during the field survey (from Chungthang, Lachung regions of north Sikkim and Gangtok – Nathula section of East Sikkim region) are shown in Fig.2. Mapping of these landslides over the earlier satellite images to know status of re-activation of earlier landslides is in progress.

REFERENCES

Bhasin,R., Grimstad, E., Larsen,O.J., Dhawan,A.K., Singh,R., S.K. Verma ,S.K., Venkatachalam,K., 2002. Landslide hazards and mitigation measures at Gangtok, Sikkim Himalaya. *Engineering Geology* 64 (2002) 351–368.

Choubey, V.D., 1992. Landslide hazards and their mitigation in the Himalayan Region. Proceedings of the Sixth International Symposium on Landslide, 10– 14 February, Christchurch, New Zealand, 1849– 1868

Forest fire and Landslide Hazard Mitigation using Geospatial Tools

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INTRODUCTION

DHimalayas are rugged terrain owing to sharp elevational gradients with extreme climatic conditions. The fragility of the region stems mainly from the geological history and evolution of the terrain. As the Tethyan Sea intervening in between Indian and Asian plates closed due to the plate motion, mammoth blocks of rock masses moved southward for tens of kilometres. This movement of the earth blocks initiated many a weaknesses in the rocks of the region. From the Indus Suture Zone (along which the two plates are welded) southward Tethyan Thrust (TT), Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Himalayan Frontal Fault (HFF) form the major tectonic discontinuities along which major movement has taken place. Besides these, there are numerous thrusts and faults intervening in between. These have made the terrain highly folded, faulted, fractured sheared and fragile (Rautela and Thakur 1999).

Uttarakhand State forms part of Central Himalaya comprising Garhwal and Kumaun region is seismically and ecologically very sensitive domain. This State is most fragile and diverse region and vital to the ecological security of the Indian landmass, through providing forest cover, feeding perennial rivers which are the source of drinking water, irrigation, and hydropower, conserving biodiversity, providing a rich base for high value agriculture and spectacular landscapes for sustainable tourism. Modernization, in the name of better connectivity and development, tampered the terrain worstly, affecting rich floral and faunal wealth. Therefore, increas in over pressurized barren slopes, networking of haphazardly constructed road, proliferating urban network has threatened environment and thus the people of the region.

Forest fires, Landslides, flash floods, earthquakes, avalanche and cloud bursts are the major disasters affecting the Uttarakhand state that destroy habitat and affect economy of the area. This is due to amalgamation of geomorphology with frequent annual precipitation and topographical factors (steep slopes). Every year these hazards cause loss of property and life in the state. Excavating roads, inherent fragile geological setting, ancient landslide deposits, presence of active screed slopes and use of explosives facilitated widening of fissures in fractured rocks. All these factors combined together constitutes the above mentioned hazards.

In view of the vastness of the area and inaccessible nature of the mountainous terrain, space technology in the form of remote sensing and GIS is the most effective tool for the comprehensive and repetitive study of the natural resources in a cost effective manner. To make use and exploration of space technology for disaster management related problems, Uttarakhand Space Application Centre (USAC) is working on cost effective manner while initiating various programs. Simultaneously State government has also established Disaster management, Disaster Mitigation and Management Centre (DMMC) on hazard management.

FOREST FIRES

Forest fires are considered as one of the major drivers of climate change having deleterious impacts on earth and environment, as studies reveal their significance in producing large amounts of trace gases and aerosol particles, which play a pivotal role in troposphere chemistry and climate (Badrinath *et.al.*, 2009). The causes of the forest fires can be classified into three main categories (i) natural causes, (ii) intentionally/deliberately caused by man and (iii) unintentionally/accidentally caused by man. Around 90% of the forest fires in India are anthropogenic in nature (Jaiswal *et.al.*, 2001). Fires strongly affect the distribution and abundance of plant species, habitats of animals and hence landscape properties.

Uttarakhand state is highly susceptible to forest fire. In severe fire of 1995, total of 2115 km^2 which is 21.5 per cent of the total geographical area of four districts had been subjected to various degrees of fire damage (Kimothi and Jadhav 1998). Forests in the state comprises of tropical forests in the plains to the alpine forests at higher altitude. Chir Pine (*Pinus roxburghii*) forests are most susceptible to fires due to highly flammable nature of the resin tapped needles that accumulate on the forest floor in hot and dry summer period. Sal forests and plantations of Teak and Eucalyptus are also susceptible due to the accumulation of dry leaves on the forest floor. Higher regions of the forest are used for grazing, especially during the summer, and regularly set fires to promote new plant growth for cattle destroy the understory. Every year (April-June) lot of areas are affected by forest fire due to various reasons, which causes great economic loss and even greater environmental impact on the ecosystem. Due to varied topography (undulating slopes) and climate it is very difficult for the agencies to control fire.

LANDSLIDES

Various types of downhill earth movements ranging from rapidly moving catastrophic rock avalanches and debris flows in mountainous regions to slowly moving earth slides are called landslides. Factors that trigger landslide movement include heavy rainfall, erosion, poor construction practices, freezing and thawing, earthquake shaking, and volcanic eruptions. The potential for a site to slide is influenced by slope steepness, properties of soil and rock, and hydrologic factors. Landslides are typically associated with periods of heavy rainfall or rapid snowmelt and tend to worsen the effects of flooding. Areas burned by forest and brush fires are particularly susceptible to landslides.

Post-fire landslide hazards include fast-moving, highly destructive debris flows that can occur in the years immediately after wildfires in response to high intensity rainfall events, and those flows that are generated over longer time periods accompanied by root decay and loss of soil strength. Rainfall that is normally absorbed into hill slope soils can run off almost instantly after vegetation has been removed by wildfire. This causes much greater and more rapid runoff than is normal from creeks and drainage areas. Highly erodible soils in a burn scar allow flood waters to entrain large amounts of ash, mud, boulders, and unburned vegetation. Within the burned area and downstream, the force of rushing water, soil, and rock can destroy culverts, bridges, roadways, and buildings, potentially causing injury or death.

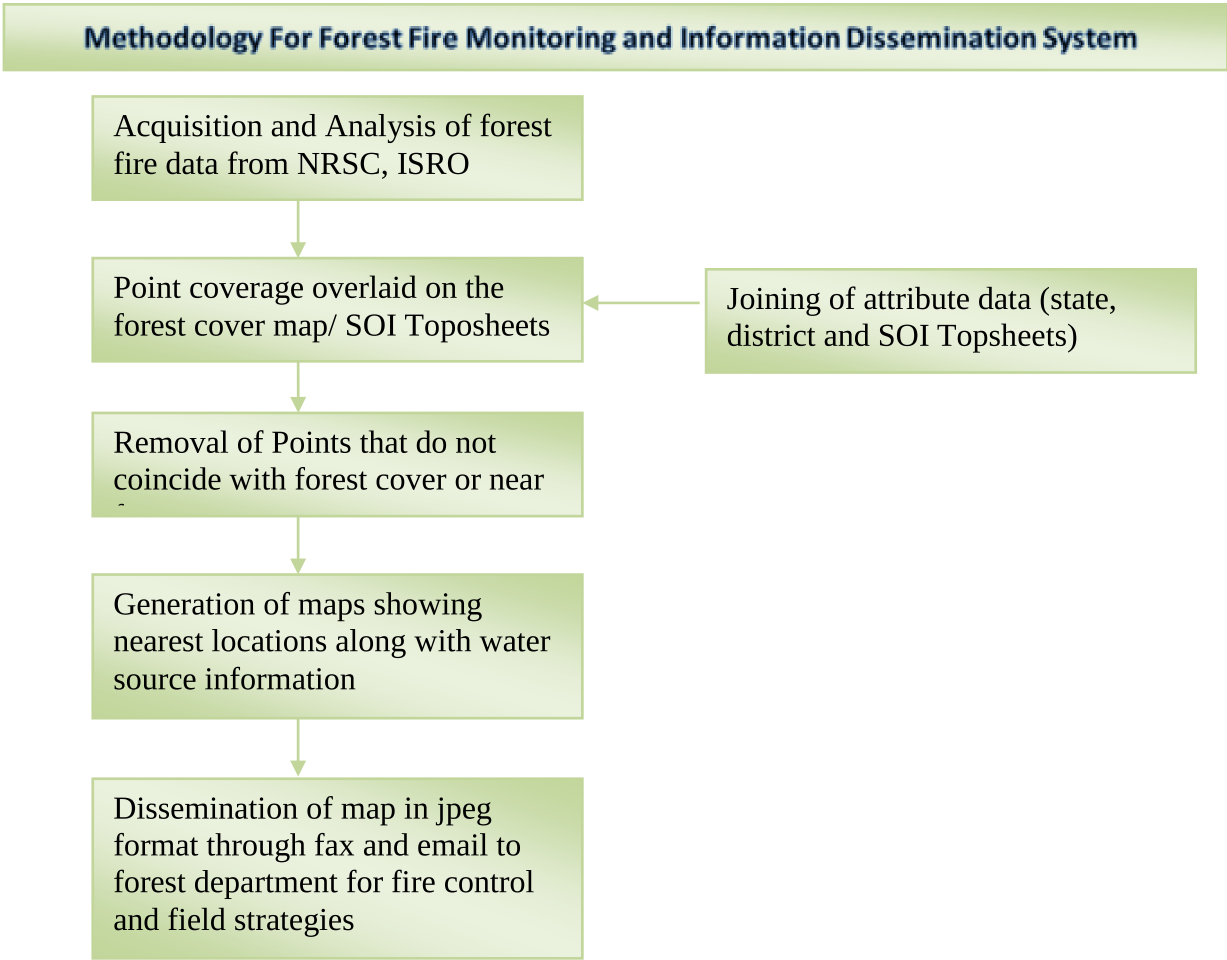

Fig. 1: Methodology Flowchart

Wildfires could potentially result in the destabilization of pre-existing deep-seated landslides over long time periods (Cannon *et.al.*, 2007).

Vegetation influences the likelihood of sliding through the soil-stabilizing effects of root systems and the effects of vegetation structure and composition on hydrology. Landslide removes soil and vegetation from steep slopes and damage forests on gentler slopes where landslide deposits come to rest. Landslides in forest landscapes can also damage aquatic resources and threaten public safety (Dale *et.al.*, 2001).

ROLE OF GEOSPATIAL TECHNOLOGY IN DISASTER MANAGEMENT

Disaster management can be successful only when detailed knowledge is obtained about the expected frequency, character, and magnitude of hazard events in an area. Although, natural disasters have shown in the last few decades a drastic increase in magnitude and frequency, it can be observed that there has been a dramatic improvement in technical capabilities to mitigate them. Remote Sensing and Geographical Information System (GIS) can be a very useful tool to complement conventional methods involved in disaster management.

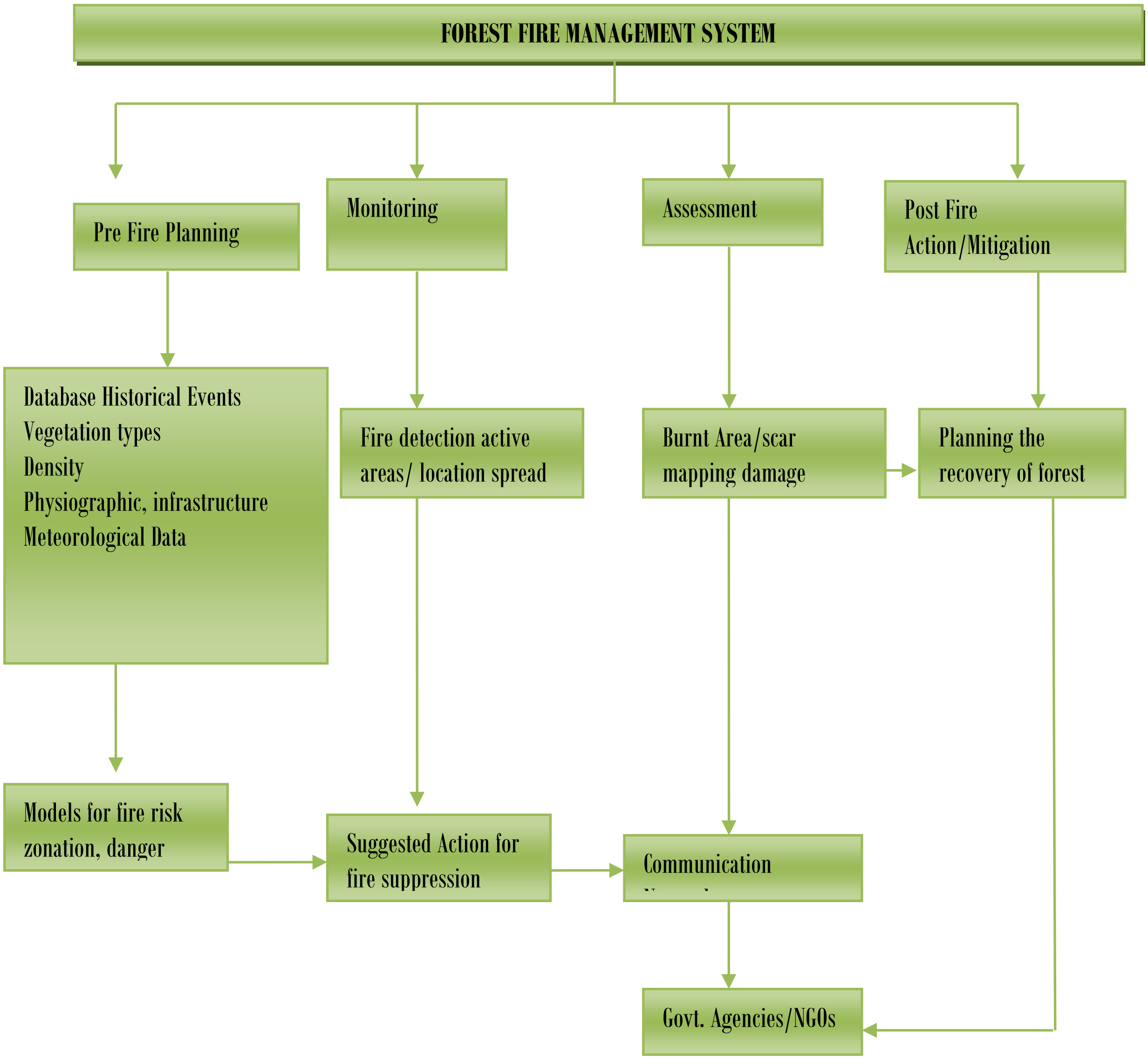

Fig. 2: Flowchart of Forest Fire Management System

The use of remote sensing data, such as satellite imageries and aerial photos, allows us to map the variabilities of terrain properties, such as vegetation, water, geology, both in space and time. Satellite images give a synoptic overview and provide very useful environmental information, for a wide range of scales, from entire continents to detail of a few meters.

GEOSPATIAL TECHNOLOGY AND FOREST FIRE

Conventional methods may be found suitable for smaller regions but for monitoring large areas coupled with the inaccessibility of the region, advanced monitoring methods are suitable for combating fire. Remote sensing and GIS has opened up opportunities for qualitative analyses of forests and other ecosystems at all geographic and spatial scales. It has also been effectively used in monitoring and detection of forest fires. Satellite remote sensing with its synoptic and temporal coverage can augment ground operations in terms of fire detection, damage assessment and planning mitigation in a time and cost efficient manner.

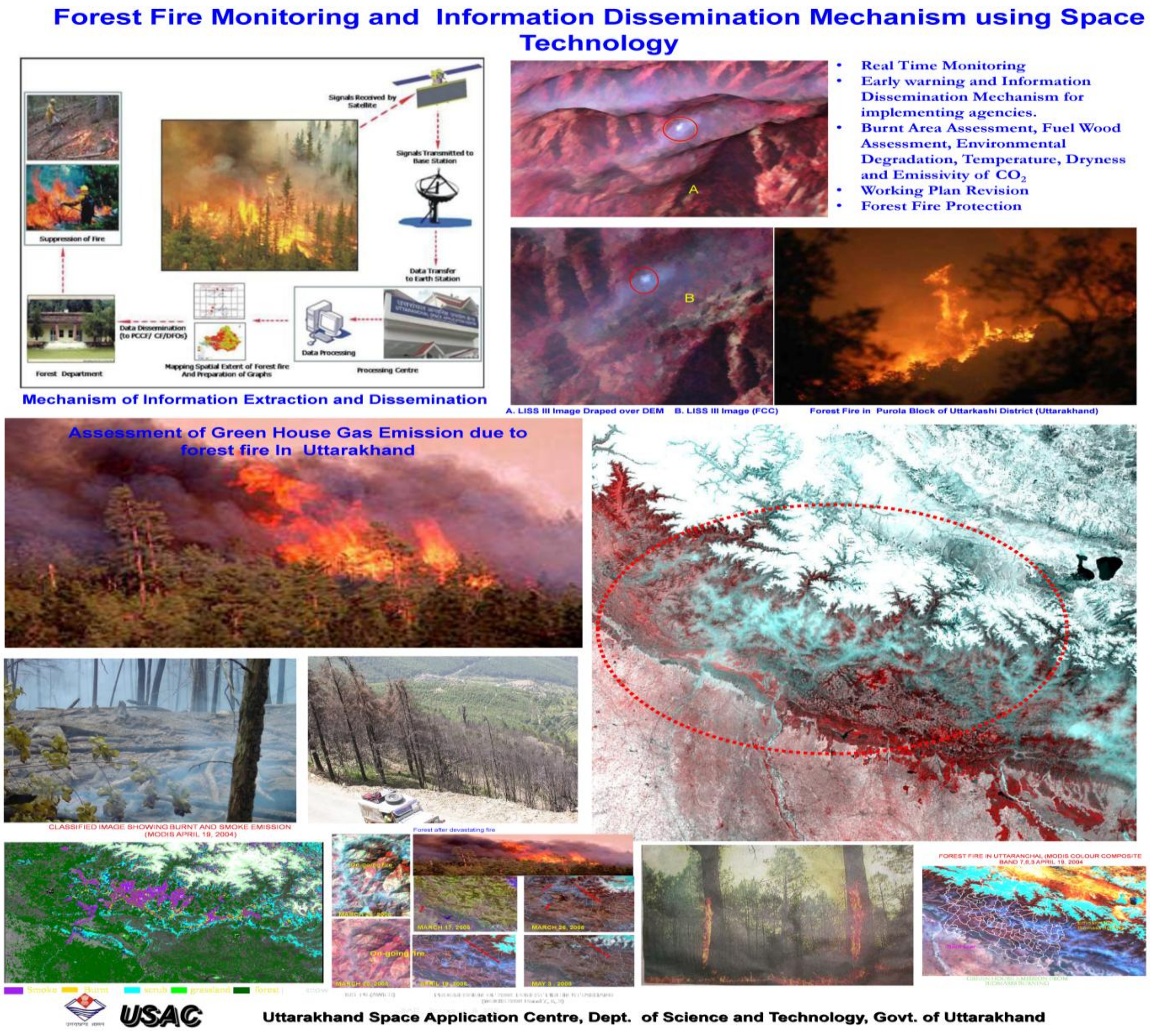

Fig. 3: Forest fire monitoring and Information dissemination mechanism using space technology

Synergy of satellite systems covering IRS P6, IRS 1D, TERRA/AQUA MODIS, NOAA AVHRR, DMSP-OLS, ENVISAT are useful in forest fire detection, real time active forest fire monitoring and near real time damage assessment and mitigation planning. Further, this information in concurrence with Geographic Information System (GIS) and ground data has been conceived as one of the powerful mechanisms in developing fire management tools. Understanding the behaviour of forest fires, the factors that contribute to making an environment, fire prone and the factors that influence fire behaviour is essential for forest fire risk zone mapping. Geographical Information System (GIS) can be used effectively to combine different forest-fire-causing factors for demarcating the forest fire risk zone map by assigning subjective weights to the classes of all the layers according to their sensitivity to fire or their fire-inducing capability (Jaiswal *et.al.*, 2001).

Being a nodal organization for exploring the potential of Geospatial techniques; Uttarakhand Space Application Centre (USAC) has been striving to provide the service to State Forest department Every year by doing real time forest fire monitoring through MODIS and AWiFS data for fire detection in active fire arealocations and disseminate in user friendly format to user departments for further actions. USAC in collaboration with NRSC, ISRO has initiated program on "Development of National Forest Fire Danger Rating Program for Western Himalaya". This project is on the verge of completion and will be critical in understanding region-specific fire vulnerability and fire damage patterns and results in development of a National Fire Danger Rating Index based on multi-spectral remote sensing data of MODIS and IRS-P6 AWiFS and region-specific field based fire vulnerability studies (Figure 1).

Pre Fire Planning (Dec-Jan)

Forest Fire prone/risk area mapping: Geographical Information System (GIS) can be used effectively to combine different forest-fire-causing factors for demarcating the forest fire risk zone map by assigning subjective weights to the classes of all the layers according to their sensitivity to fire or their fire-inducing capability (Jaiswal *et.al.*, 2001). In Central Himalaya, creation of forest fire risk zonation maps of Alaknanda Watershed facilitate user departments to concentrate on critical areas (Kimothi *et. al.*, 2006).

During Fire Action (Feb-May)

Forest Fire Detection and Monitoring: Real time forest fire monitoring through MODIS and AWiFS data for fire detection in active fire area locations and dissemination of the information in user friendly format to user departments for further actions. (Kimothi *et. al.*, 2007).

Post Fire Assessment (July-Aug)

Post Fire damage assessment, fire scar/burnt area mapping:

Damage assessment of burnt area through remote sensing and GIS and ground referencing Ground data on fuel type, fuel moisture, combustion value, biomass burnt and litter to be used to generate region-specific fire vulnerability map (Figure 2).

GEOSPATIAL TECHNOLOGY AND LANDSLIDES

Recent advances in geospatial technology have resulted in the creation of powerful tools, which empower to deal spatially with landslides disasters. Landslide hazard zonation map based on the combination of data acquired from various geological, geo-morphological and land use/cover thematic maps, which includes Tectonic Setting, Geological Setting, Slope Material (Weather Ability and Homogeneous), Discontinuity (Faults,Joints, Number of Major Joint Sets and Spacing), Slope Dimensions (Slope, Aspect, Aperture , Persistence, and Height), Hydrologic Conditions (Rainfall and Water Content), Previous Instability, Land Use , Land Cover, and Drainage Pattern. Most of the previous parameters can be extracted from remote sensing data with field check. These parameters can be converted to digital format in GIS environment. Using special algorithm, landslides hazard Zonation maps are produced (Donald, *et. al.*, 2004).

Before Landslide occurrence

Landslide hazard zonation mapping for the Himalayas of Uttaranchal and Himanchal Pradesh States were carried out using remote sensing and GIS Technology in the National remote sensing centre, Department of space, Hyderabad (Kimothi and Joshi, 2001). Development of early warning systems based on models and GPS studies carried out on real time basis may be considered as a priority issue under hazard prediction and mitigation.

During Landslide Occurrence

Real time landslide monitoring through high resolution satellite data (World view, Quick Bird, IKONOS), Cartosat-1 and IRS P6 for the assessment of area of landslide activity.

Post Landslide Occurrence

To understand the phenomena/process of long term and short term damage, two broad time frame datasets of pre and post damage period have been analyzed for monitoring active and old landslides in Rudraprayag and Uttarkashi district ((Kimothi and Joshi, 2006).

On the basis of it Landslide hazard zonation maps can be created and updated periodically considering the changes in the land use/ land cover in important urban centers.

Various programs in this direction to be carried out for further recommendations are as follows:

1. Development of early warning systems based on models and GPS studies to carried out on real time basis may be considered as a priority issue under hazard prediction and mitigation.

2. Inventory of Occurrence of landslide and other land based hazards should be updated periodically (biannually/annually).

3. Scientific research and data bases are required for greater insights into mechanism of mass wasting processes in the state.

Use of GPS and GIS/ RS needs to be encouraged for Landslide hazard zonation maps for updating while considering land use/ land cover changes.

REFERENCES

Badarinath, K.V.S., Latha, K.M., Chand, T.R.K. and Gupta, P.K. (2009). Impact of biomass burning on aerosol properties over tropical wet evergreen forests of Arunachal Pradesh, India. *Atmospheric Research, 91 (1). pp. 87-93.*

Cannon, S.H., Gartner, J.E., Michael, J.A., Bauer, M.A., Stitt, S.C., Knifong, D.L., McNamara, B.J., and Roque, Y.M.(2007). Emergency assessment of debris-flow hazards from basins burned by the 2007 Slide and Grass Valley Fires, San Bernardino County, southern California: U.S. *Geological Survey Open-File Report 2007–1416, 1 sheet.*

Dale, V. H., L. A. Joyce, S. Mcnulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, Peterson, C. J. (2001). Climate change and forest disturbances. *Bioscience 51: 723–734.*

Donald L. Turcotte, and Bruce D.(2004). MalamudbLandslides, forest fires, and earthquakes: examples of self-organized critical behavior. *Physica A 340 (2004) 580 – 589.*

Jaiswal, R.K.; Mukherjee, S.; Raju, K.D.; Saxena, R.(2002).Forest fire risk zone mapping from satellite imagery and GIS. International Journal of Applied Earth Observation and *Geoinformation 4(1) pp 1-10.*

Kimothi, M.M and Jadhav, R.N. (1998). Forest fire in the Central Himalaya: An extent, direction and spread using IRS LISS-I data. *International Journal of Remote Sensing, 19 (12) pp 2261-2274.*

Kimothi, M.M. and Joshi, J.(2006). High resolution IRS Data for Disaster monitoring and its management planning in Himalayan Mountains. *ISG newsletter 12(3&4) 71-78.*

Kimothi, M.M.(2007). Forest fire monitoring and management in Uttarakhand forests.Samaj Vigyan Shodh Patrika. Special issue (Uttarakhand-1),pp.35-47.

Rautela, P. & Thakur, V.C. (1999). Landslide hazard zonation in Kaliganga and Madhyamahshwar valleys of Garhwal Himalaya: A GIS based approach. *Him.Geol. 20(2) 31-44.*

Role of Geomatics in Forest Fire Monitoring and Danger Assessment: A Review

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INTRODUCTION

Forest fire is one of the major disasters that have tremendous impact on humans and wildlife, environment, ecosystem, weather and climate. Indian forest ecosystems especially deciduous forests and grasslands are prone to fires every year. There appears to be an increasing trend of fire activity. Forest fire quite frequently occurs during summer seasons (fig.1) and recurrent fires potentially harm vegetation dynamics of the ecosystems. While fire originated as a strictly "natural" process, the phenomenon has become decidedly anthropogenic in many parts of the world. On a global scale, the overwhelming majority of fires are now initiated by humans as a tool for forest and brush clearing, crop and pasture maintenance, fuel reduction, charcoal production, cooking, hunting, heating, and occasionally, arson. A smaller number of natural fires (or "wildfires") do occur each year, usually started by lightning.

Forest fires emanate greenhouse gases and aerosols and may be critical in the context of climate change. Fire also alters the albedo of the Earth's surface through the removal of vegetation and the deposition of ash and char. This directly affects soil temperature, which in turn alters the rates of microbial respiration and evapotranspiration. Particulate matter produced during combustion can affect cloud formation and inhibit precipitation. It is also important to recognize that changes in climate can affect changes in fire regime, a combination of the type of fire which occurs in a given region (e.g., low-intensity surface or high-intensity crown), the frequency at which fire occurs, and the seasonality of burning. There is consequently the potential for substantial feedback between fire and the environment.

Satellite remote sensing with its synoptic and temporal coverage can augment the ground operations in terms of fire detection, monitoring, damage assessment and planning the mitigation in a time and cost efficient manner. As far as global scale monitoring of biomass burning is concerned, spaceborne sensors offer the only practical way to monitor fire activity and study the impacts. One of the most important critical elements of the forest fire management system (FFMS) in the country is the real time detection of onset of fire and it's monitoring; study the rate, direction and quantitative estimation of fire spread and amount of smoke emission. Satellite data with suitable spectral bands for fire detection (Visible, SWIR, MIR and Thermal IR bands), daily or twice a day's repetivity (day and night) and bare minimum spatial resolution, which can locate the fire, can play an important role in development of country's FFMS. Geomatics also plays an important role in devising fire danger assessments.

FIRE MONITORING

A very helpful component in operational fire danger estimation is the use of remote sensing to detect wildfires in near-real-time as well as to assess those areas already burned. Satellites have been used for more than two decades, in either a research or operational mode, to monitor fire activity across the globe. National Oceanic and Atmospheric Administration (NOAA) AVHRR data has been used since 1987 to monitor large forest fire in various countries (Li *et al.* 2000, Rauste *et al.* 1997). As newer generations of satellites have appeared, improved spatial resolution has aided in the detection of fires on sub-pixel levels. Prins and Menzel (1996) discussed the use of the visible and infrared bands of Geostationary Operational Environmental Satellite (GOES-8) to monitor fires in the Western Hemisphere. GOES-9 satellite data have also proved to be useful in monitoring fires over USA. European Remote Sensing Satellite (ERS-1) SAR data has proven useful in the detection of Alaskan wildfires (Bourgeau-Chavez *et al.* 1997). The new Moderate Resolution Imaging Spectroradiometer (MODIS) sensor shows great potential for fire detection and monitoring (Kaufman et al. 1998) and even used in Indian forest fire response system along with the night time detection using DMSP-OLS (Kiran Chand *et. al.*, 2006). MODIS have also been used in agriculture residue burning characterization in India (Singh and Panigrahy, 2011).

In addition to satellite and space-borne sensors, other remote sensing methods have been employed. Ground-based Doppler radar (WSR-88D) has been used in conjunction with satellite data to monitor fire activity in Alaska (Hufford *et al.* 1998). Also, the existence of lightning detection networks can provide a near-real-time monitoring device for identification of potential new ignition areas. Geostationary satellite such as GOES with automated biomass burning algorithm (ABBA) have matured enough for providing information on large-scale forest fires on a regular basis. Proposed Indian satellite, INSAT-3D imager with 1x1 km resolution in Visible and SWIR bands and 4x4 km. in MIR and in TIR-I and TIR-II will help in detecting and monitoring of large scale forest fires, smoke and burn scar over India. The INSAT-3D fire products are being built on the experience of fire assessment using the MODIS, NOAA-AVHRR and GOES systems. The progression of large fire events can be monitored very effectively with such systems as the temporal resolution is expected to be 30 minutes. The fire products will be developed on the basis of convergence of evidence from different spectral information. The INSAT-3D fire products will provide information on the location of a fire. The fire products will be made available through IMD as daily 4 km resolution and spatially and temporally summarized products (10 km, and 8 day and monthly), more suited for use by the broader environmental management community as well as modeling community.

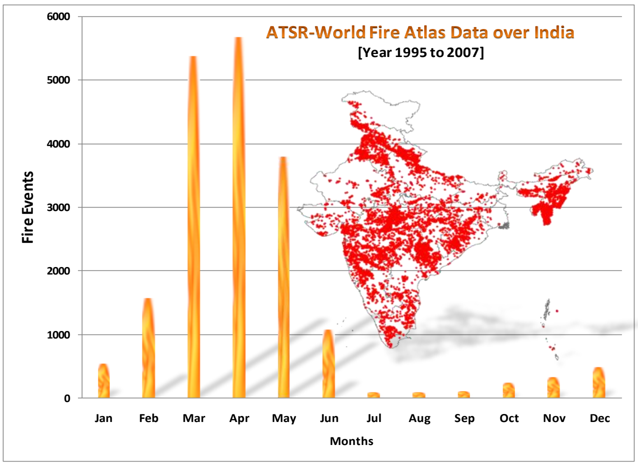

Fig.1: Month wise fire events (counts) detected by ATSR over India (includes forest fires, agricultural and other biomass burning events).

To date, a number of large scale, multi-year fire data sets have been produced using observations acquired by various satellite-based sensors. A summary of these sensors and data products is provided in Table 1.

Table 1: Summary of sensors used for fire monitoring for which long-term fire data sets have been produced.

Sensor	Satellite Orbit	Spatial Res. (km)	Day/Night
AVHRR	sun-synchronous polar	1.1	DN
GOES Imager	geostationary	4	DN
OLS	sun-synchronous polar	1.7 or 4	N
ATSR-2/AATSR	sun-synchronous polar	1	N
VIRS	precessing	2.5	DN
MODIS	sun-synchronous polar	1	DN
INSAT-3D Imager*	geostationary	4	DN

**yet to be launched.*

FIRE DANGER ASSESMENT

The re-occurrences of severe wildfires have highlighted the need for development of effective fire danger assessment tools. Field collected fire activity data, satellite based normalized difference vegetation index (NDVI), normalized difference water index (NDWI), and the meteorological Keetch–Byram drought index (KBDI) are popularly used to assess fire risks. NDWI is found better in savanna ecosystems when compared to NDVI and KBDI based on the results by Verbesselt *et al.*, 2006. Moreover, fuel water content is one of the critical factors affecting fire ignition and fire propagation, and therefore is taken into account in most fire danger and fire behaviour modelling systems (Rothermel *et al.* 1986). High moisture content increases the heat required to ignite a fuel, since some of this energy is used to evaporate water. Additionally, high values of fuel moisture entail a slow propagation, because part of the heat released by the fire front is used to absorb water from nearby fuels, and because air has got more water vapour, less O_2 will be available for combustion. However, moisture content has also been directly related to the energy required to ignite a fuel, and its role is critical for converting a surface fire into a crown fire.

Among botanists and ecologists, several methods for estimating plant water content have been commonly used: e.g. stomatal aperture, leaf water potential, relative water content (RWC), and specific water density (SWD) (Levitt 1980). However, in the forest fire literature, the most extended method of measuring plant moisture status is the fuel moisture content (FMC), defined as the proportion of fresh weight versus dry weight of the sample. This measure has been recommended by a wide range of fire researchers (Simard 1968, Viney 1991). This is not an instantaneous measurement of water content, which is also the case of the RWC and SWD, so it is difficult to be implemented in fire danger or fire behaviour systems. The FMC is computed for dead and live fuels. The former are composed by materials lying on the forest floor (litter, twigs, branches), whereas the latter are live plants (herbaceous, shrub and trees).

Several methods have been proposed for estimating FMC for fire danger applications. The most common are fieldwork (Desbois *et al.* 1997), the use of calibrated sticks (Simard 1968) and the computation of meteorological indices (Viney 1991). None of them are completely satisfactory. Field sampling is very costly and requires intense work to obtain enough spatial and temporal significance. Calibrated sticks attempt to resemble the behaviour of ideal fuels and should be good predictors of fine dead fuels, but may not be very well associated to live fuels, much less dependent of atmospheric variations. Finally, meteorological indices are easily computed, and are very appropriate for considering other variables of fire danger (wind, relative humidity, solar radiation). However, they do not directly measure vegetation status, but estimate it from atmospheric conditions, which have a direct influence on FMC of dead fuels. However, live fuels are also related to the physiological characteristics of the plants (for instance, canopy resistance and root length) and to the soil water retention capacity. Additionally, weather data may not be available from forested areas of interest, but just on rural or urban areas, and therefore extrapolation methods are applied.

The use of remote sensing methods expected to overcome some of these difficulties, since they provide temporal and spatial coverage and the data are directly derived from the vegetation cover. The main challenge in this case is to demonstrate that the effect of moisture content on plant reflectance or temperature is clearly distinguishable from other factors of spectral variation, such as pigment contents, canopy geometry, leaf area index, soil background or atmospheric effects. Many authors have attempted to prove this potentiality, both from airborne and satellite sensors. These studies have shown that plant water content is most clearly related to short-wave infrared reflectance (SWIR), ranging from 1.4 to 2.0 µm (Tucker 1980, Jackson and Ezra 1985, Ripple 1986, Cohen 1991). It is well known that these wavelengths present high water absorption peaks, and therefore SWIR reflectance is negatively related to plant water content. NOAA Advanced Very High Resolution Radiometer (AVHRR) images were used in FMC estimation, and concrete relations were found between FMC of grasslands and multi-temporal series of NDVI, derived from AVHRR images (Chladil and Nunez 1995). Less coherent were the relations between AVHRR data and FMC of shrubs (Deshayes *et al.* 1998), which are less homogeneous than grasslands and better adapted to the summer drought and show a lower range of FMC throughout the vegetative period. A study by Hardy and Burgan (1999) found similar tendencies. They estimated FMC from multi-temporal airborne data of four periods, and found good agreements between NDVI and FMC for grasslands but not for trees and shrub lands. Another group of authors did the estimation of fire danger on thermal channels, which are commonly combined with vegetation indices. Particularly good results were obtained with the water deficit index (Vidal *et al.* 1994), the orthogonal regression of NDVI and surface temperature (T_s) (Prosper-Laget *et al.*, 1995), and the single ratio of NDVI and T_s (Chuvieco *et al.* 1999).

Satellite data can only assess vegetation state (ideally, FMC), but other factors related to fire ignition or re-propagation, such as wind or human activity, cannot be directly derived from satellite observations. Fire, only occurs when an ignition cause is present, even if FMC is not critically low. On the other hand, critical levels of FMC may not necessarily lead to fires, if other factors of risk do not appear. It is understood that the evaluation of satellite and meteorological fire risk indices is essential before the indices are used for operational purposes to obtain more accurate maps of fire risk for the temporal and spatial allocation of fire prevention or fire management.

OBSERVATIONAL NEEDS AND MODELS

Forest Managers deal with both wildfire and prescribed fire, the latter becoming increasingly important as a management tool for controlling fuel buildup and restoring the landscape. Decisions, which fire managers, make depend on the temporal and spatial scales involved as well as on management objectives. There are a variety of temporal and spatial scales with which forest resource managers must deal. At one end of the spectrum, time scales can range from weeks to months, as in the case of 'risk assessment', with corresponding spatial scales involving hundreds of sq. km. An example of this type of activity is assessing the fire potential of the country early in the fire season; items such as precipitation totals, drought indices and long-range weather forecasts may be considered. At the other end of the spectrum, time scales can range from hours to days with spatial scales as small as few tens of hectares. For smaller temporal and spatial scales, once a fire occurs there are decisions that must be made regarding initial fire suppression. This may include a decision not to suppress if the fire is burning within certain constraints. If a decision is made to suppress, then information on time scales of minutes to hours be required and often at very small spatial scales. Prescribed fires usually fall into these temporal and spatial scales, and, of course, here the decision is to burn rather than to suppress, unless a burn gets unexpectedly out of control.

The user's needs in 'operational' fire danger systems, is to get routine (e.g. daily) assessments of fire danger over broad areas encompassing entire forest ranges. Fire danger ratings have traditionally been relative values or dimensionless indices relating more to fire potential than physical specifics. Fire behaviour assessments, on the other hand, are usually at smaller spatial scales, for specific landscapes, and are performed on an 'as-needed' basis. Here the outputs are specific, physical descriptions of expected fire characteristics such as flame length, rate of spread and fire intensity (some operational fire danger systems also include such outputs, although for generalized larger areas).

To obtain the best assessment of fire danger at any scale requires information about the three components of the fire environment: topography, fuel, and weather. The last component of this 'fire environment triangle' is the most dynamic and the one used in all operational fire danger systems, while the first one is the least dynamic. While not all operational fire danger systems require topographical input (slope, aspect and elevation), a number of fire models, some of which are used operationally, do. FARSITE (Finney 1998), a fire growth simulation model, utilizes Geographical Information System (GIS) with topographic data with resolutions of 25–50m; from such a database, aspect, slope and elevation are calculated and used in the model. An earlier fire behaviour model, BEHAVE (Burgan and Rothermel 1984), requires direct input of slope from the user. Finally, in a broader fire danger context, the National Fire Danger Rating System (NFDRS) requires specification of one of five slope classes (Bradshaw *et al.* 1983). Data for determining these variables can come from digital elevation models (DEMs). For example, CARTODEM made by ISRO, India and other global level DEMs (G-TOPO, SRTM-DEM and ASTER-GDEM) have also been developed. Satellite based remote sensing is being used increasingly for topographic mapping. Airborne laser sensors are also proving useful.

Most fire models require a fuel model to provide a physical description of the fuel complex that is involved in fire behaviour. Included are such parameters as loadings of live and dead fuels by category, ratios of surface area to volume, and fuel bed depth. Where one local landscape is involved, a single fuel model may suffice. However, for broad-scale fire danger rating systems and fire behaviour models covering larger geographical areas, fuel models applicable to the pixel (grid cell) in question must be used; thus, a number of different fuel models may be employed throughout the domain of calculation. While the loadings of live and dead fuels within a given fuel model can shift during the course of a year due to growth flush and senescence (and can be modelled), the physical nature of fuel complexes usually changes little over time. However, the very nature of wildfires or meteorological events may necessitate a revision in fuel model to suit the local conditions. There are a suite of 13 fuel models which are currently being used in the BEHAVE and FARSITE models (Anderson, 1982), although customisation in fuel models are necessary to suite the regional conditions.

Remote sensing can be very useful in constructing fuel model databases across large areas and for detecting dynamic changes in surface characteristics. For example, the fuel model map having different categories at a viable spatial resolution is required to be populated with land cover characteristics. Extensive ground data of experimental plots across the country and remotely sensed data [e.g. IRS-P6 LISS-III, AWiFS] could be employed in constructing land cover databases specific to fuel models at respective resolutions. Microwave SAR [RISAT-1] can also be used in mapping biomass in forests and more sensitive than optical data. Attempts at correlating live fuel moisture with SAR data have also occurred (Beaudoin et al. 1995). SAR data have also proven useful in estimating soil water content (vegetation stress) in post-burn boreal forest areas (French et al. 1996).

Of the three elements in the fire environment triangle, weather is the most dynamic and the one element common to all operational fire danger systems. Not only are current weather conditions important for the determination of current fire behaviour, but so are antecedent conditions. In addition, for future fire behaviour and risk assessment, weather forecast information is important. Typically for fire models, the crucial weather variables are temperature, relative humidity, wind speed and direction, sky cover or solar radiation, and precipitation. Depending upon the application, one must consider the appropriate temporal and spatial scales. There is really no good substitute for spatially and temporally dense *in situ* weather observations. For those geographical areas not having such weather observations, various interpolation techniques must be employed in both space and time; additional techniques to adjust for elevation can also be used. Remote sensing may eventually be able to detect some critical surface weather variables, but even then cloud cover would place a limit on which portions of the landscape could be monitored.

CONCLUSION

There is increasing interest in satellite remote sensing of forest fire from a very diverse community that includes global and regional modelers interested in emissions, deforestation and climate-impact studies, and the fire management community. This increased interest is reflected in the advancement of fire remote sensing capabilities of polar-orbiting and geostationary satellites. One of the most important critical elements of the forest fire management system in the country is the real time detection of fire and it's monitoring; study the rate, direction and quantitative estimation of fire spread. Satellite data with suitable spectral bands, good temporal resolution and bare minimum spatial resolution, which can locate the fire, can play an important role in development of country's forest fire management system. Geostationary satellite like INSAT-3D with imager data of 4x4 km. in MIR and in TIR-I and TIR-II will help in detecting and monitoring of large scale forest fires in Indian subcontinent.

With such a strong reliance on satellite data, it is important to recognize and understand a number of issues surrounding the use of these data. This is especially important in the context of wildfire since 1) there is at present lots of satellites and sensors used for fire monitoring, and 2) very few of these systems were actually designed with fires in mind, and consequently lack the specialized capabilities required for unbiased fire monitoring. Among the most important issues are as follows:

- To date, most sensors used for fire monitoring detect (and in some instances, characterize) the flaming and smoldering regions of an actively burning fire. These regions are generally much smaller and far more transient than the "burn scars" that generally persist long after the active fire has finished burning. For many applications, however, such as emissions modeling, it is necessary to know the size of the burn scar. At present there is a paucity of such information.

- Due to limitations of the instrument and the detection algorithm, and obscuration by clouds, smoke, and forest canopy, not every fire is detected. The envelope of detectable fires (in terms of their size and temperature) is dependent upon observation conditions and the particular instrument and detection algorithm being used.

- Not every fire detection is real. The frequency at which these false alarms arise is dependent upon observation conditions and the particular instrument and detection algorithm being used.

- The suite of satellites and sensors used for fire monitoring provide very different spatial and temporal sampling strategies. This can lead to inconsistencies in the respective fire data sets.

- The fire information currently provided by spaceborne sensors often does not exactly match the fire information desired by the fire community / resource managers.

- There is large demand for additional fire information beyond that provided by current active fire products. In particular, those concerned with trace gas emissions and resource management requires authentic burned area.

While this list is not exhaustive, it captures the most important elements from the perspective of long-term, global and regional fire monitoring. For some applications the list would likely be somewhat different. From the standpoint of real-time operational fire management, for example, data latency would have a much higher priority than assumed here.

Finally, for operational fire danger systems to be useful, the information should be both easily available in a user-friendly fashion and timely in its appearance. Increasing use is being made of the World Wide Web in distributing active fire and fire danger information. The Web provides quick and user-friendly access to not only fire weather conditions but also output from fire models.

REFERENCES

Anderson, H. E., 1982, Aids to determining fuel models for estimating fire behavior. General Technical Report INT-122, USDA Forest Service, Intermountain Forest and Range Experiment Station.

Beaudoin, A., Vidal, A., Desbois, N., and Devaux-Ros, C., 1995, Monitoring the water status of Mediterranean forests using ERS-1 to support fire risk prevention. Proceedings of IGARSS'95 Symposium, 10–14 July 1995, Florence, Italy (Institute of Electrical and Electronics Engineers), pp. 963–966.

Bourgeau-Chavez, L. L., Harrell, P. A., Kasischke, E. S., and French, N. H. F., 1997, The detection and mapping of Alaskan wildfires using a spaceborne imaging radar system. *International Journal of Remote Sensing*, 18, 355–373.

Bradshaw, L. S., Deeming, J. E., Burgan, R. E., and Cohen, J. D., 1983, The 1978 National Fire-Danger Rating System: technical documentation. General Technical Report INT-169, USDA Forest Service, Intermountain Forest and Range Experiment Station.

Burgan, R. E., and Rothermel, R. C., 1984, BEHAVE: fire behavior prediction and fuel modeling system—FUEL subsystem. General Technical Report INT-167, USDA Forest Service, Intermountain Forest and Range Experiment Station.

Byram, G. M., 1959, Combustion of forest fuels. In Forest Fire: Control and Use, edited by K. P. Davis (New York: McGraw-Hill), pp. 155–182.

Chladil,M. A., and Nunez,M., 1995, Assessing grasslandmoisture and biomass in Tasmania. The application of remote sensing and empirical models for a cloudy environment. International Journal of Wildland Fire, 5, 165–171.

Chuvieco, E., Deshayes, M., Stach, N., Cocero, D., and Riano, D., 1999, Short-term fire risk: foliage moisture content estimation from satellite data. In Remote Sensing of Large Wildfires in the European Mediterranean Basin, ed. by E. Chuvieco (Berlin: Springer-Verlag), pp. 17–38.

Cohen, W. B., 1991, Temporal versus spatial variation in leaf reflectance under changing water stress conditions. *International Journal of Remote Sensing*, 12, 1865–1876.

Desbois, N., Deshayes, M., and Beudoin, A., 1997, Protocol for fuel moisture content measurements. In A Review of Remote Sensing Methods for the Study of Large Wildland Fires, edited by E. Chuvieco (Alcala´ de Henares: Departamento de Geograf Ì´a, Universidad de Alcala´), pp. 61–72.

Deshayes, M., Chuvieco, E., Cocero, D., Karteris, M., Koutsias, N., and Stach, N., 1998, Evaluation of diVerent NOAA-AVHRR derived indices for fuel moisture content estimation: interest for short-term Ž re risk assessment. In III International Conference on Forest Fire Research–14th Conference on Fire and Forest Meteorology, edited by D. X. Viegas (Coimbra, Portugal, ADAI), pp. 1149–1167.

Finney, M. A., 1998, FARSITE: Fire area simulator—Model development and evaluation. Research Paper RMRS-RP-4, USDA Forest Service, Rocky Mountain Research Station.

French, N. H. F., Kasischke, E. S., Bourgeau-Chavez, L. L., and Harrell, P. A., 1996, Sensitivity of ERS-1 SAR to variations in soil water in fire-disturbed boreal forest ecosystems. International Journal of Remote Sensing, 17, 3037–3053.

Hardy, C. C., and Burgan, R. E., 1999, Evaluation of NDVI for monitoring live moisture in three vegetation types of the Western U.S. *Photogrammetric Engineering and Remote Sensing*, 65, 603–610.

Hufford, G. L., Kelley, H. L., and Sparkman, W., 1998, Use of real-time multi-satellite and radar data to support forest fire management. Preprints, Second Symposium on

Fire and Forest Meteorology, 11–16 January 1998, Phoenix, AZ, USA (Boston: American Meteorological Society), pp. 57–59.

Illera, P., Fernandez, A., and Delgado, J. A., 1996, Temporal evolution of the NDVI as an indicator of forest fire danger. *International Journal of Remote Sensing*, 17,1093–1105.

Jackson, R. D., and Ezra, C. E., 1985, Spectral response of cotton to suddenly induced water stress. *International Journal Remote Sensing*, 6, 177–185.

Kaufman, Y. J., Justice, C. O., Flynn, L. P., Kendall, J. D., Prins, E. M., Giglio, L., Ward, D. E., Menzel, W. P., and Setzer, A. W., 1998, Potential global fire monitoring from EOS–MODIS. *Journal of Geophysical Research*, 103, 32 215–32 238.

Kiran Chand T. R., Badarinath K.V.S., Krishna Prasad V., Murthy M.S.R., Elvidge C. D., and Tuttle B. T., 2006, Monitoring forest fires over the Indian region using Defense Meteorological Satellite Program-Operational Linescan System nighttime satellite data, *Remote Sensing of Environment*, 103, 165–178.

Levitt, J., 1980, Responses of Plants to Environmental Stresses. Vol. II: Water, Radiation, Salt and other Stresses (New York: Academic Press).

Li, Z., Nadon, S., and Cihlar, J., 2000, Satellite-based detection of Canadian boreal forest fires: development and application of the algorithm. International Journal of Remote Sensing, 21, 3057–3069.

Prins, E. M., and Menzel, W. P., 1996, Monitoring fire activity in the Western Hemisphere with the new generation of geostationary satellites. Preprints, 22nd Conference on Agricultural and Forest Meteorology with Symposium on Fire and Forest Meteorology, 28 Jan–2 Feb 1996, Atlanta, GA, USA (Boston: American Meteorological Society), pp. 272–275.

Prosper-Laget, V., Dougue'droit, A., and Guinot, J. P., 1995, Mapping the risk of forest fire occurrence using NOAA satellite information. EARSeL Advances in Remote Sensing, 4-3, 30–38.

Rauste, Y., Herland, E., Frelander, H., Soini, K., Kuoremaki, T., and Ruokari, A., 1997, Satellite-based forest fire detection for fire control in boreal forests. International, *Journal of Remote Sensing*, 18, 2641–2656.

Rothermel, R. C., Wilson, R. A., Morris, G. A., and Sackett, S. S., 1986, Modelling moisture content of fine dead wildland fuels: input to BEHAVE fire prediction system. Research Paper INT-359, USDA Forest Service Intermountain Research Station, Odgen, Utah.

Simard, A. J., 1968. The moisture content of forest fuels—a review of the basic concepts. FF-X-14, Forest Fire Research Institute, Ottawa, Ontario.

Singh C. P. and Panigrahy S., 2011, Characterisation of Residue Burning from Agricultural System in India using Space Based Observations, *Jr. of the Indian Society of Remote Sensing*, 39(3), 423-429.

Tucker, C. J., 1980, Remote sensing of leaf water content in the near infrared. *Remote Sensing of Environment*, 10, 23–32.

Vidal, A., and Devaux-Ros, C., 1995, Evaluating forest fire hazard with a Landsat TM derived water stress index. *Agricultural and Forest Meteorology*, 77, 207–224.

Viney, N. R., 1991, A review of fine fuel moisture modelling. *International Journal of Wildland Fire*, 1, 215–234.

Verbesselt, J., Jönsson, P., Lhermitte, S., Aardt, J.V., and Coppin, P., 2006, Evaluating Satellite and Climate Data-Derived Indices as Fire Risk Indicators in Savanna Ecosystems, IEEE Transactions on Geoscience and Remote Sensing, 44(6), 1622-1632.

Westman,W. E., and Price, C. V., 1988, Spectral changes in conifers subjected to air pollution and water stress: experimental studies. *IEEE Transactions on Geoscience and Remote Sensing*, 26, 11–20.

Harmful Algal Bloom: The silent killers of the Sea

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INTRODUCTION

Phytoplankton, the unicellular, microscopic plants are found in the well lit surface layers of most of the seas of the world. They form the base of the marine food web. More then 5000 species of marine phytoplankton exist worldwide. Most of the species undergo blooming conditions. Out of this about 2% are known to be harmful or toxic which have large and varied impacts on marine ecosystems. The blooming may take place often with cyclical regularity in any particular area when some optimum conditions of temperature, salinity, sunlight, nutrients etc. prevail in the marine environment. The bloom usually takes place rather suddenly and may spread with amazing speed, sometimes changing the colour of the surface waters into red, green or hay colour (Figure 1). This modifies the optical properties of water thus enabling the detection of blooms through remote sensing. The remote sensing analysis of the bloom depends on the type of blooms and the way they modify the signal in various bands. NOAA-AVHRR visible and thermal bands are also used in monitoring the blooms. In addition the data from the scatterometer to get information on wind so as to predict the advection of blooms.

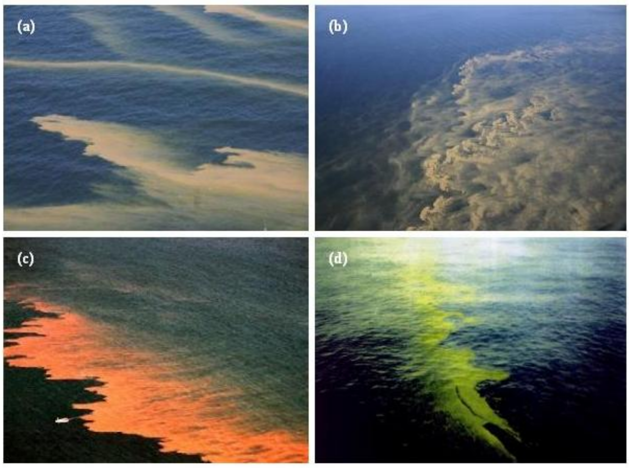

Figure 1: Shows different algal blooms. (a) and (b) are casued blue green algae, the Cynobacterium; (c) shows dianoflagellate bloom, the colouration of such blooms is the source of the term "red tide". (d) is a Coccolithophore bloom.

Factors triggering the formation of algal bloom:

Oceanographic processes like upwelling during southwest monsoon and convective cooling during winter monsoon regularly occur in the Arabian Sea, triggering transient but intensive blooms of diatoms and other phytoplankton. The spatial extent and the periods of phytoplankton blooms are the new production areas and therefore the principal generator of organic material reaching greater depths. An intense phytoplankton bloom in the northern Arabian Sea is shown in figure 2. The bloom was dominated by 1-2 species of diatoms and a dinoflagellate.

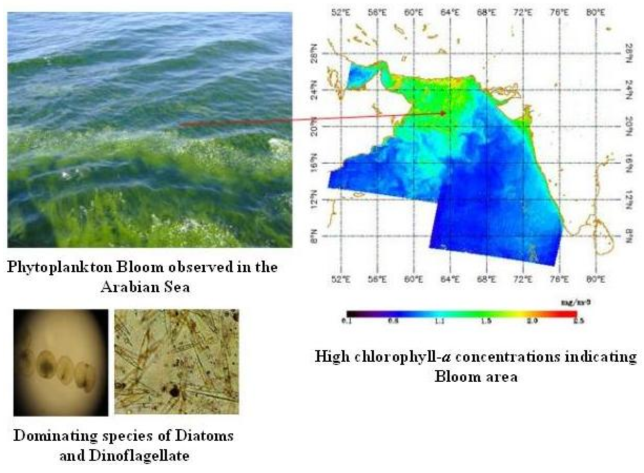

Figure 2: Showing phytoplankton bloom in natural environment, the microscopic view and as seen on OCM image.

Chemical Oceangraphic changes during the bloom:

It is observed that when both NH_4 and NO_3 are available in water, NH_4 uptake is always dominated. NH_4 concentration increases by March due to degradation of *Noctiluca* cells and other living organisms and by this time, control of NH_4 on fixation of carbon becomes much stronger and utilization of NO_3 is inhibited. This is reflected in Figure 3(B) in the form of reduced slope of a fitted straight line. Quay Dorth (1990) has described NH_4 as a preferred source of nitrogen source for uptake of carbon. NH_4 being relatively simpler form of nitrogen, this preference can be understood. It is further verified from Figure 3(A) that as NH_4 concentration increases beyond 0.8 $\mu mol.l^{-1}$ in March, uptake of NH_4 increases at a faster rate in comparison to NO_3 uptake. In January when NH_4 concentration is low, the pattern of increasing uptake rate with increase in NH_4 concentration is not seen.

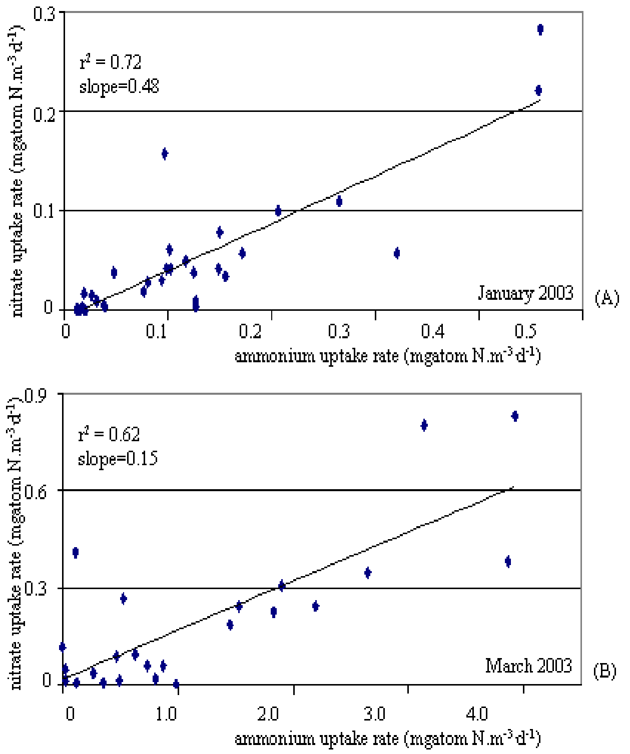

Figure 3: Pattern of ammonium and nitrate uptake during the bloom in the NEAS observed from ship cruises ORV SK-186 and FORV SS-212, (A) January, initial phase (B) March, peak phase

The harmful effect of algal bloom:

The toxicity and the impact depends on the species, their environment and the mechanism by which they exert the negative effects. The harmful algal blooms have been observed to cause adverese effects in two ways. One is through the production of toxins and and the second way is causing harm through excessive accumulation of biomass (e.g., Hypoxia-anoxia, decline in food quality for filter feeders, clogged gills). Although most species in both groups are pigmented and cause problems when they bloom, many are not pigmented and some have toxic effects at low cell densities, i.e., that is they can cause harm without blooming or without a detectable pigment signature. Various species of marine fishes, the mulluscs, marine mammals, sea turtles and indirectly the humans are affected by this bloom. They affect the developmental, immunological, neurological, respiratory, feeding and reproductive capacities of the organisms. Sometimes the effect is so severe that mass mortality of fish or mammals takes place. In 2004, hundreds of dolphins and Manatees were killed along the coast of Florida due to the ingestion of high levels of brevetoxins.

Algal bloom detection through ocean colour remote sensing:

Remote sensing platforms, by virtue of their broad synoptic coverage offer unique advantage to routinely monitor various ovean phenomena. Remote sensing of ocean colour exploit the spectral nature of the reflected solar radiation from water to quantitatively retrieve phytoplankton biomass through suitable bio-optical algorithms. Figure 2 shows IRS P4 OCM generated surface chlorophyll maps to study phytoplankton bloom in the open ocean waters of northern Arabian Sea . The blooms are detected in satellite images in the open ocean (bottom depth ~2500-3000 meters) by the virtue of their very high chlorophyll concentrations (1-5mg /m^3.). Time series of chlorophyll images can detect and determine the spatial extent of bloom in near real time thus providing a quick and effective means to monitor the blooms

Optical properties of algal bloom:

Absotrption properties are distinctive for different algal species. The phytoplankton community is equipped with pigment systems, which capture light in the visible region for organic matter synthesis. The pigment systems vary in their pigment composition and are unique for a broad group of taxa. Given below is some of the examples to describe the various pigment system and composition associated with some of the major blooming species.

i. Dianoflagellate blooms absorb light at yellow wavelengths apart from the usual absorption at blue and red wavelengths by chlorophyll-a owing to the presence of accessory pigments peridinin and carotenoids (fucoxanthin and derivatives). Most of blooms by dianoflagellates (Figure 1 (c)) are known to be harmful and occurs in the coastal areas, colouring the waters red, brown or orange.

ii. Cyanobacterium blooms like trichodesmium (Figure 1 (a&b)) are capable of nitrogen fixation and are frequently abundant in tropical oligotrophic waters. They absorb strongly at ~ 495 and ~548 owing to the presence of phycoerythrin. These pigments are also known to show fluorescence at ~560-600 nm as compared to the fluorescence of chlorophyll-a at 683-685 nm. Further they show high backscatter owing to the presence of gas vacuoles, which help them to form large surface aggregations.

iii. Coccolithophores characterized by calcareous plates show high reflectivity in all visible ranges. At high concentrations of cells and detached coccoliths, the water appears turquoise blue in colour (Figure 1(d).

References:

Backer L.C., 2002. Cyanobacterial harmful algal blooms: Developing a public health response. *Lake and Reservoir Management*, 18(1): 20-31.

Backer L.C., 2009. Impacts of Florida red tides on coastal communities. *Harmful Algae* 8:618-622.

Fleming LE, Kirkpatrick B, Backer LC, Walsh CJ, Nierenberg K, Clark J, Reich A, Hollenbeck J, Benson J, Cheng YS, Naar J, Pierce R, Bourdelais AJ, Abraham WM, Kirkpatrick G, Zaias J, Wanner A, Mendes E, Shalat S, Hoagland P, Stephan W, Bean J, Watkins S, Clarke T, Byrne M, Baden DG. 2011. Review of Florida red tide and human health effects. *Harmful Algae* 10:224-233.

Fujita, Y., 1970. Photosynthesis and plant pigments. *Bull. Plankton Soc. Japan*, 17, 20-31,

Hoagland P, Jin D, Polansky L, Kirkpatrick B, Kirkpatrick G, Fleming L, Reich A, Watkins S, Ullmann S, Backer L. 2009. The Costs of Respiratory Illnesses Arising from Florida Gulf Coast Karenia brevis Blooms. *Environmental Health Perspectives*, 117:1239-1243.

Hoepffner, N., and S. Sathyendranath, 1992. Bio-optical characteristics of coastal waters: Absorption spectra of phytoplankton and pigment distribution in the western North Atlantic, *Limnology and Oceanography*, 37, 1660-1679.

Kirkpatrick, G., Millie, D. F., Moline, M. A., Schofield, O. 2000. Absorption-based discrimination of phytoplankton species in naturally mixed populations. *Limnology and Oceanography*, 42: 467-471.

Subramaniam, A., C.W. Brown, R.R. Hood, E. J. Carpenter, D. G. Capone. 2002. Detecting Trichodesmium blooms in SeaWiFS imagery. *Deep- Sea Res*., *II*, 49: 107-121.

Mobile GIS for Assessment of Disaster

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INTRODUCTION

MMobile GIS is recent development of GPS-GIS unification and it consists of light GPS-GIS software, built in or external GPS receiver, mobile computing device and optional communication link for data exchange with backend GIS server. Mobile GIS system has created an opportunity for access and handling of Remote Sensing, GIS and GPS data in the field and it is considered useful tool for collecting in-situ data. Pre-disaster vulnerability assessment, mitigation planning and post disaster damage assessment require field data collection using mobile GIS system. Mobile GIS system is also used for near real time updating of enterprise GIS database. During the disaster phase, actionable geospatial products generated by GIS server can be consumed by mobile GIS system using terrestrial or satellite communication link for in-situ disaster management support. Few available mobile mapping / GIS systems with built in GPS are shown in figure-1.

Garmin system is a handheld GPS and can be used for waypoint search, incident marking, GPS tracking and on route navigation during disaster. Windows phone based system like ASUS offer extra advantage of cost, connectivity and suitability of porting mobile GIS software and GIS data. The mobile phone is most suitable for browser based online applications like disaster incident reporting and viewing of OGC compliant WMS (Web Map Service) products. The limitation of mobile phone is performance of GPS. Proprietary GPS-GIS unified products provide best GPS accuracy, field performance but not suitable for large scale deployment due cost constraint. This called for the configuring a modular mobile GIS system shown in figure-2 by choosing suitable GPS receiver, mobile computing platform and GPS-GIS software.

Figure-1: Mobile Mapping / GIS Systems

Figure-2: Mobile GIS System

Mobile GIS System:

Mobile GIS system is client component of client-server GIS application. Widely used client-server GIS applications are built using thin client and thick client. Thin client is browser based online application and does not require GPS-GIS software for client system. Thick client is offline standalone application and GPS-GIS software is required for client system. Mobile GIS system shown in figure-2 is standalone system configured using indigenous mobile GPS-GIS software “QPad”, DELL Pocket PC and CRUX CF GPS.

GPS-GIS Functions of QPad:

The various GPS-GIS functions supported by QPad are display of raster data (.JPG and .BMP), vector data (.SHP), GIS point, line and polygon data base creation, GPS data capture and integrating with active GIS layer, GIS layer management, browsing, navigation, query, symbology, editing, label / text placement and image map generation. Sample QPad GUI screens with design of main tools bar, browsing tools bar, editing tools bar and few supported functions are shown below in figure 3 and 4.

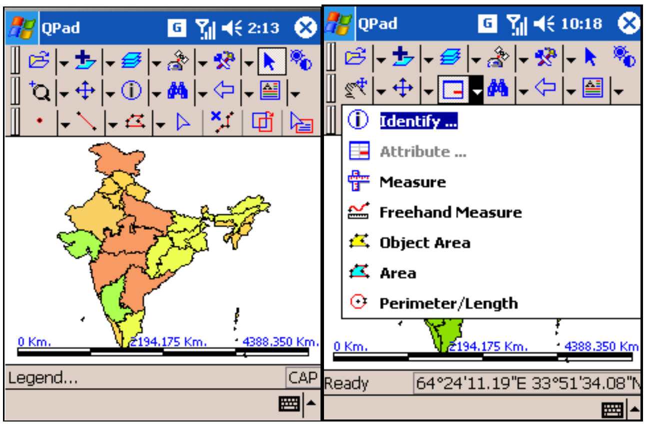


Figure-3: GUI for Display and Measurement Functions

Disaster Assessment Applications:

Mobile GIS applications pertaining to drought vulnerability assessment, monitoring of drought proofing works and flood induced damage assessment have been developed at Space Applications Centre (SAC) and demonstrated to user agencies.

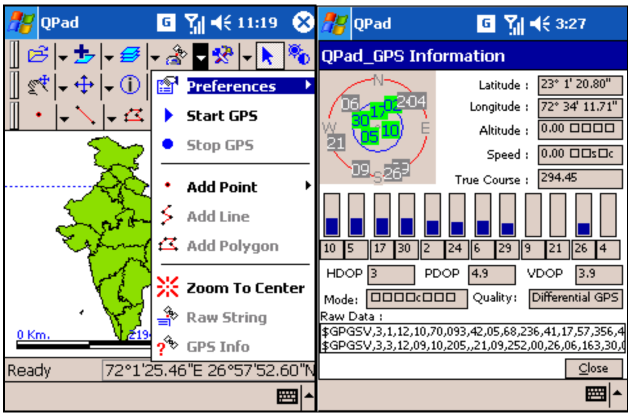
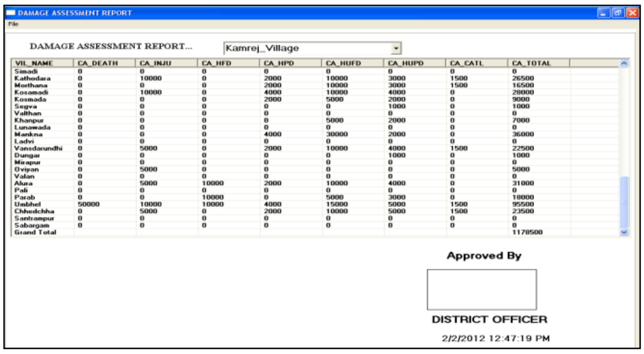
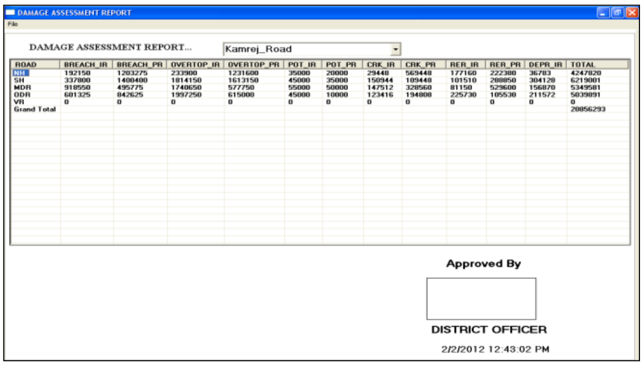


Figure-4: GUI for GPS Data View and Collection

Flood Damage Assessment:

This application was developed for roads and villages of Kamrej taluka of Surat district. GIS databases required for application development were extracted from NRDB (Natural Resources Database). Roads and village layers were restructured as per the MIS data and disaster manual of Surat district. Fictitious in-situ data (due to no flood occurrence) were collected using mobile GIS system and below mentioned

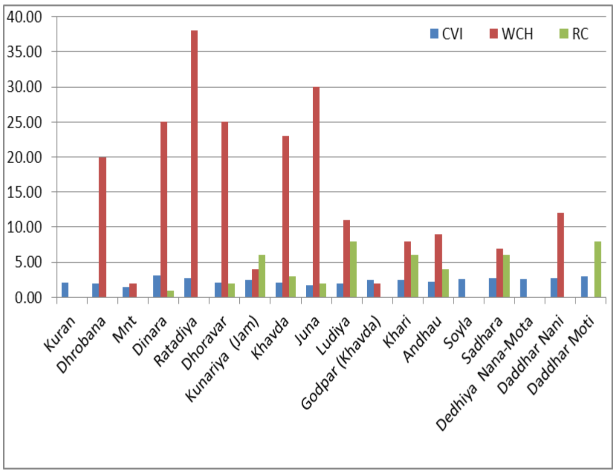


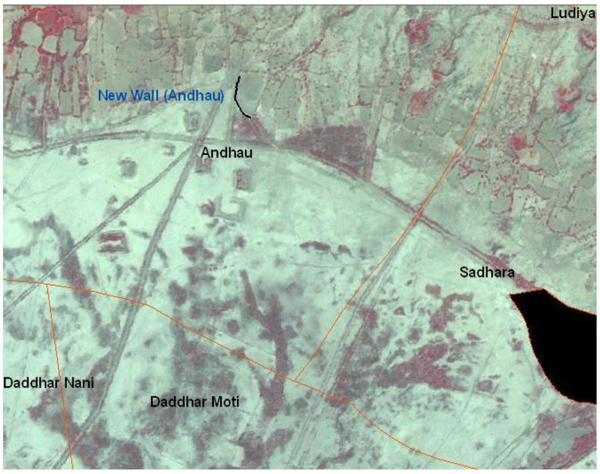


reports were generated for damage assessment of roads and loss assessment for villages.

Drought Vulnerability Assessment and Risk Reduction:

This application was developed for Khavda VRC cluster of Gujarat VRC Network. Khavda cluster comprises of 18 villages of Bhuj taluka and the region is predominantly drought affected. Mobile GIS system was used for in-situ data collection pertaining to water conservation and harvesting (WCH) structures, positions of hand pumps, wells and socio-economic data of selected villages. Mobile GIS in-situ data were sent to backend GIS server for vulnerability assessment. Vulnerability maps and reports were provided to VRC node for providing inputs for planning of drought risk reduction works under MGNREGA scheme. WCH and road connectivity works under taken for drought risk reduction were mapped using mobile GIS system. Relevant analysis chart and image map are shown below.





Communication Network in Disaster Management

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INTRODUCTION

The state-of-art Information and Communication Technology (ICT) systems play a crucial role for implementing mitigation and prevention of disasters. The use of satellite, computers, electronics, better communication facilities are going to make significant difference in disaster management. The data processing and computers are providing a useful tool in decision making in disaster. Typically, the disaster management system addresses the three distinct phases viz pre-disaster planning i.e. early warning, during disaster activities (=response) and post disaster (includes relief, rescue and rehabilitation). Satellite communication can be used for early warning besides creating awareness and education in the disaster prone areas. During the disaster activities i.e. response phase, communication is a major bottleneck in case of any major disaster particularly when the traditional network systems already in force brake down. Besides the satellite, communication and education can play a proactive role in mitigation through awareness about the types of disaster and as to how prevention measures can be taken up.

Communications provide the critical path for relief in emergency and disaster situations. Communications connect and help move logistical, rescue and first responder resources in any region of the world facing or recovering from natural or man-made disasters.

Deploying wireless communications is typically among the first priorities in any emergency response, rescue, or relief situation. However, terrestrial wireless equipment (cellular phones or land mobile radios) is only useful when communications towers and other fixed equipment are in place to connect wireless equipment to the local and global communications backbone. In the majority of emergency situations, this infrastructure has either been destroyed by the disaster (e.g. New Orleans after Hurricane Katrina) or was not available before the disaster (e.g. the earthquake in Pakistan). This reality makes it critical for local government and emergency workers to have access to a wireless communications network that is not dependant on terrestrial infrastructure.

Satellite communications provide such a solution. Satellites are the only wireless communications infrastructure that is not susceptible to damage from disasters, because the main repeaters sending and receiving signals (the satellite spacecraft) are located outside the Earth's atmosphere.

Users today have two kinds of satellite communications networks available to support emergency response activities: geostationary satellite systems (GEO) and low Earth orbit satellites (LEO). Geostationary (GEO) satellites are located 36,000 km above the Earth in a fixed position and provide service to a country or a region covering up to one third of the globe. They are capable of providing a full range of communications services, including voice, video and broadband data. These satellites operate with ground equipment ranging from very large fixed gateway antennas down to mobile terminals the size of a cellular phone. There are currently almost 300 commercial GEO satellites in orbit operated by global, regional and national satellite carriers. Even before disasters strike, these networks are used in many countries to provide seismic and flood sensing data to government agencies to enable early warning of an impending situation. Also, they broadcast disaster-warning notices and facilitate general communication and information flow between government agencies, relief organizations and the public.

LEO satellites operate in orbits between 780 km and 1,500 km (depending on the system) and provide voice and low speed data communications. These satellites can operate with handheld units about the size of a large cellular phone. As with handheld terminals that rely upon GEO satellites, the highly portable nature of LEO-based units makes them another valuable satellite solution for first responders in the field.

In order to most effectively utilize the capabilities of these systems, government agencies, relief organizations and other first responders must define as far in advance as possible what kind of terminals they will need to have in the field before and after an emergency.

Space Applications Centre (SAC) of Indian Space Research Organization (ISRO), being one of the leading institutions so far as satellite based communication application is concerned, has evolved several projects towards communication system to support disaster management. There are many projects under development to support communication during disaster. Some of the projects are discussed herewith.

OPERATIONAL SYSTEM

INSAT MSS Type D (Portable voice communication Terminal):

The MSS Type D system is used for voice communication during disaster. The portable terminal is of the size of a small briefcase weighing around 3.5 Kg including battery and antenna. Deployment of the terminal is easy. Transmit and receive frequencies of the terminal is in S band. It can be used from any location of India for emergency communication. The INSAT satellite contains specialized Mobile satellite Transponder by which communication through a small terminal is possible. It supports voice communication between terminal and terminal & EPABX (Local exchange) or PSTN as well as Mobile network.

Fig. 1: Type D terminal

Features of Terminal:-

- Portable terminal is of small briefcase size
- Weighing around 3.5 Kg including battery and antenna.
- Easy antenna deployment.
- User-friendly operation.
- Demand based channel allocation.
- It supports voice & data communication

- Voice communication between terminals and terminal & EPABX (Local exchange).
- Data communication in the form of files, short messages or e-mail.
- E-mail to & from outside world through mail server.

INSAT based Distress Alert Transmitter (DAT)

This has been developed for the fishermen who go deep into sea for fishing. The transmitter is battery operated and has built-in GPS receiver and four emergencies switches like fire, medical, boat sinking and man-overboard. In case of a distress, fisherman can manually active the transmitter, by pressing the particular emergency button. Subsequently the transmitter obtains its location through GPS receiver and directly transmits its location (latitude and longitude), its ID (Identification Code) and type of emergency to INSAT satellite which is then received in real time at Central Hub station, established by SAC, Ahmedabad at Indian Coast Guard Premises at Chennai. The terminal is low cost and affordable to fisherman. It has test transmission facility for verification of DAT health. This transmitter uses omni directional antenna which is most suitable for fishing fleet. For the power it uses primary lithium battery (7.2v/3.2ah). The unit is water proof, floatable in water and suitable for marine environment.

Fig. 2: Distress Alert Transmitter

Features:-

- Low cost affordable system with inbuilt GPS
- Battery operated, Small size & light weight
- Floatable & suitable for marine environment
- It transmits position and type of emergency with its ID.
- Very simple to operate during distress condition
- Four different types of alert available (Fire, Medical, Boat Sinking, Man Overboard)
- Once activated, Alert transmission continues at least for 24 hours (till battery lasts)

Automatic Weather Station (AWS)

Indian Space Research Organization (ISRO) has developed Automatic Weather Station (AWS) with the participation of Indian Industry. The AWS is a low cost, compact, modular, rugged and capable of operating with minimum power from battery and solar panel for extended periods in the field condition. AWS features include easy programming of sensors, front panel display, archival of one-year data. A GPS integrated with AWS provides accurate time for transmission of data. AWS can continuously record weather data like temperature, atmospheric pressure, wind speed and direction, rainfall, relative humidity, solar radiation, etc. Weather data from a large numbers of Automatic Weather Station located across the country could be collected through the Data Relay Transponder on board the ISRO's INSAT satellites. The weather information collected through AWS could be disseminated through the Village Resource Centers, being set up by ISRO in co operation with NGOs and other agencies.

Meteorological Services

The use of satellite for disseminating cyclone-warning messages to the likely affected areas has great advantage over any other method of terrestrial communication. ISRO has developed Disaster Warning System (DWS) and

Meteorological Data Dissemination (MDD) System for Indian Meteorological Department (IMD). The Disaster Warning System (DWS) system has been developed for Indian Meteorological Dept. (IMD). It provides the information about the cyclones such as areas likely to be affected, its speed, intensity and time etc.are available at Cyclone Warning Centre (CWC). Based on this, warning messages are issued. Voice messages and the codes generated reaches satellite earth station at Chingelpet from CWC at Madras through telephone communication link. Around 150 receivers have been deployed across Tamilnadu.

Meteorological Data Dissemination System (MDD) has been developed for IMD to disseminate meteorological data from Main Data Utilization Centre (MDUC) of IMD at New Delhi to Secondary Data Utilization Centers (SDUC) spread across the country. The meteorological data consists of processed cloud imagery (processed from the raw picture data received from INSAT), analyzed weather chart and Teleprinter weather data. At present, the system is operational and used by IMD and Air Force. There are around 100 receive terminals in the network as of now.

CONCLUSIONS:

The scientific community has a crucial role in providing specialized scientific and technical inputs to assist the government and communities in developing early warning systems. As it quite evident from the above discussion that satellite communication is very essential for the hazard prone areas and the community as well. Since disaster management is an integrated approach, thus, the role of scientific community becomes more crucial in designing and developing the technology for acquiring the information about the hazard prone areas; translating them into comprehensible messages and disseminate understandable warnings to those at risk.

DMSAR System Experience

D. B. Dave **Space Applications Centre (ISRO), Ahmedabad**

BACKGROUND

India is a vast country with different types of geological features. It faces different types of disasters viz. earthquakes, drought, landslides, cyclones, floods, forest fire, etc. The river banks in the northern and north-eastern India are prone to floods every year. Floods in these areas and in some other parts of India directly or indirectly affect the economy of our country in the form of natural resources, lives, property or in the form of infrastructure such as roads, houses, railways, telecom network, etc. Earthquakes also cause widespread damage to life and property. Severe cyclones in the coastal areas of Arabian Sea and Bay of Bengal and landslides in the Himalayan regions also fortify the grave of disasters in India.

SYSTEM OVERVIEW

Disaster Management Synthetic Aperture Radar (DMSAR) is the C-band airborne synthetic aperture radar operating at 5.35 GHz, developed in SAC for Disaster Management. The design of DMSAR is centered around the RISAT developed hardware. The SAR hardware was built in SAC and flown a number of times since Dec 2005. The DMSAR system is mounted on a Beechcraft aircraft as shown in figure 1, 2a and 2b. The SAR antenna can be rigidly fixed with aircraft belly inside the radome and the system operates at a nominal altitude of 8 km with a nominal velocity of 120m/s. The antenna is designed to provide the swath illumination from 65° to 85° in all the modes. At a given time only one polarization combination (either VV or HH) is operated.

Fig. 1: DMSAR system installed inside the beechcraft aircraft.

Fig. 2: (a) front view (b) rear view

Integrated INS and GPS system (IGI) is used onboard to meet the requirements of motion compensation. The IGI provides the aircraft's motion and attitude related parameters which in turn are be used to compensate and correct the motion and attitude related deviation of the aircraft during the SAR processing. The return signals are stored in compressed form using the BAQ compression techniques in the recorder. The DMSAR operates in the basic strip map mode with different resolution and swath modes as given in Table 1.

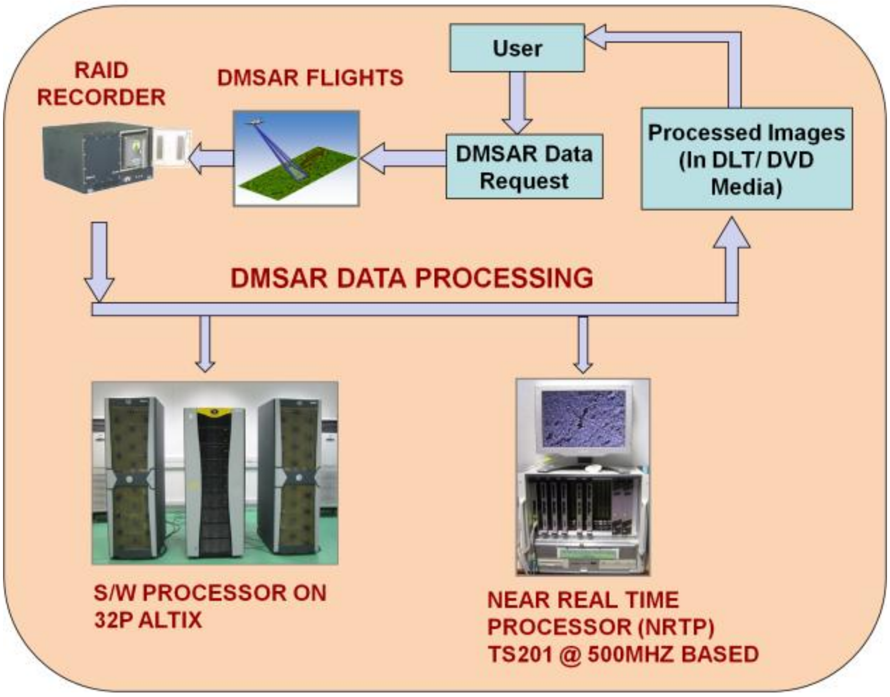

Fig 3: DMSAR data acquisition and processing

Table-1 DMSAR Modes with resolution and swath

S.No.	MODE	RESOLUTION (in meters)	Swath (in KMs)
1	HRS	1	6
2	FRS1	3	25
3	FRS2	5	50
4	MRS	10	75

Operational Scenario:

An indicative diagram in operational scenario for DMAR data acquisition and data processing is shown in figure-3. When there is a disaster or data request by users over a particular region, the flight planning is carried out and the sorties are planned. The data is recorded onboard in a RAID based recorder. After completion of sorties, the data is downloaded and processing is carried out by in-house developed processing software. It can process typical 75 Km X 75 Km image in 60 minutes in Itanium based 32 processor machine.

To provide the fast product for time critical events, a hardware based Near Real Time Processor (NRTP) with 96 DSPs is also developed. This unit takes 90 minutes to process the same image. The unit is compact and easily transportable to provide fast turnaround image at the flight site if required.

Flight Experience:

The operational capability of the system is already demonstrated during test flights during the initial phase of the development. Calibration campaigns were also planed and analysis was done to evaluate the system performance from time to time. DMSAR system is being mainly used to image the floods which are the chief cause of damage in India. A number of flood events are covered and flight campaigns were carried out in the states of Bihar, Orrisa and Gujarat. The data is collected over the flood prone regions during pre-flood season and during flood season to access the extent of inundation. As an illustration to the DMSAR utility, Figure-4 shows the image taken over Darbhanga region in 2007, where figure 4(a) is a preflood image taken on 23rd June and 4(b) is during flood image taken on 3rd August. Figure 4(c) exhibits the Flood Mask is generated out of 4(a) and 4(b) images. The black region in the image shows the permanent water bodies (i.e., also present during the preflood) and blue region shows the extent inundation.

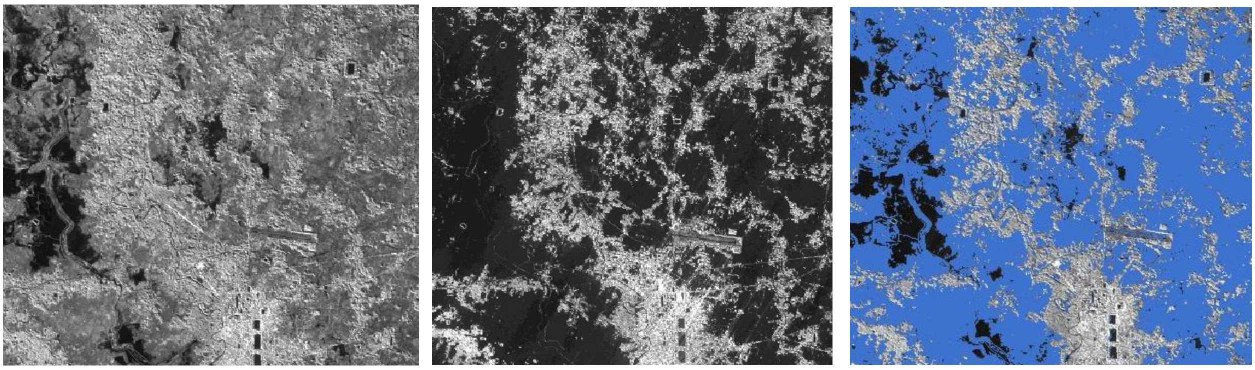

Fig 4: (a) Pre-Flood Image (b) During Flood Image (c) Image Showing Extent of Inundation

There was a devastating flood in Bihar in 2008 due to breach in the kosi river embankment. DMSAR has conducted sorties over that region to generate the image. Due to the breach, Kosi river has changed its course and caused floods in Bihar as shown in Figure 5.

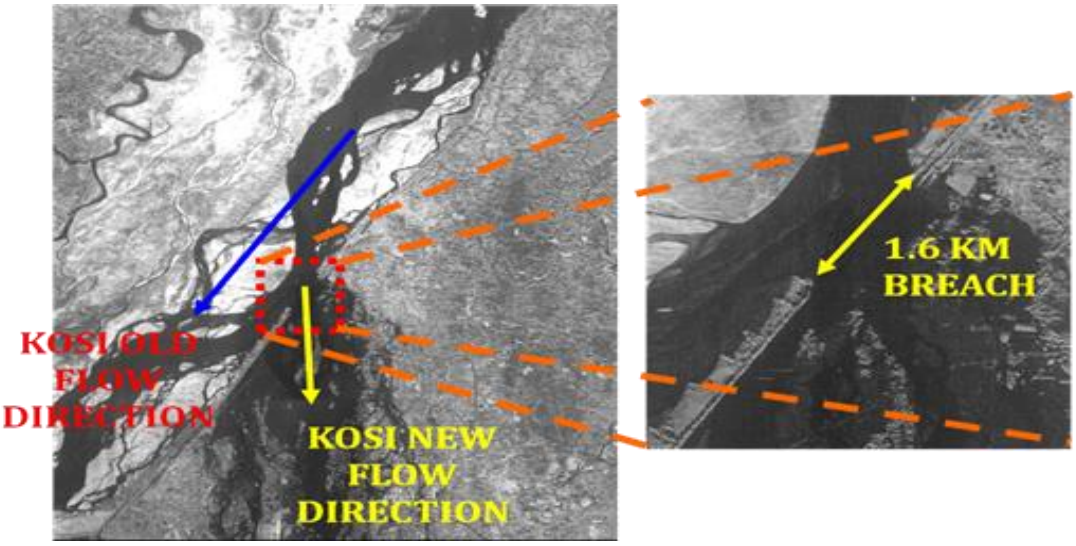

Fig 5: Breach in Kosi River Embankment

CONCLUSION

The data obtained by this system over flooded areas in the last few years has provided encouraging results and clearly authenticated the DMSAR usefulness towards the Disaster management program. Its capability for estimating the flood content as well as damage estimation and location is demonstrated with its multi resolution capability. With its inherent capability of imaging during all weathers, day and night as well as its ability to see through clouds make it a very versatile sensor for Disaster Management and support applications.

FROM ISG SECRETARIAT

Annual Convention, Awards, Millennium Lecture and ISG Fellows

Annual Convention of ISG

It was decided to have annual convention of the society along with the regional conference at Bhagalpur during February 23 – 24, 2012. The annual awards shall be presented during inaugural function of the conference on February 23, 2012 , followed by millennium lecture and have AGM of the society in the evening on same day.

Election of ISG Fellows

Presently there are six fellows and numbers can be enhanced up to two percent of the life membership. Following committee was constituted to scrutinize the nominations and recommend the names to the Executive Council of ISG.

Dr. George Joseph	-	Chairman
Prof. A.R. Dasgupta	-	Member
Dr. Prithvish Nag	-	Convener

The committee recommend Dr**. R.R. Navalgund** and **Shri Rajesh Mathur** for ISG Fellowship to the ISG - EC and Council approved the same.

Selections for ISG Awards

The society presents two National Geomatics Awards for Original and Significant Contribution in technology and Innovative Applications In the field of Geomatics.

Areas of contribution considered for the award are:
1. Geographical Information System
2. Global Positioning System
3. Photogrammetry
4. Digital Cartography

The following expert committee was constituted to scrutinize the nominations.

Prof. S.M. Ramasamy	-	Chairman
Dr. (Mrs.) Venkatachalam	-	Member
Shri R.P. Dubey	-	Convener

The committee recommend **Shri V. Tamilarasan** for Applications and **Shri B. Gopala Krishna** for Technology to the Executive Council and Council approved the same.

Millennium Lecture

Dr. Prithvish Nag is going to deliver millennium lecture on the topic **"Mapping for Disaster Risk Management"** during the conference.

ISG Chapter Award for Best Performance

ISG – Ajmer Chapter is selected for ISG Chapter award for the year 2011 for organizing Geomatics – 2011 and carrying out other activities for promotion of geomatics technology in the state of rajasthan.

President's Appreciation Medal for Contribution to the ISG

A new award is constituted for individual contribution to the ISG / Chapters. This award will be given to a member of the society, who has made noteworthy contribution to the growth of the ISG (its main body or any chapter).

The Award consists of a Medal and a Citation. The following committee was constituted to scrutinize the nominations and recommend the awardees' names to the Executive Council.

Dr. Ajai, Chief Editor, JOG	-	Chairman
Dr. Dr. R.L.N. Murthy, VP, ISG	-	Member
Dr. Shakil A. Ramshoo, Member, ISG – EC	-	Convener

The committee recommends **Shri I.C. Matieda** and **Shri M.H. Kalubarme** jointly for this award to the Executive Council and Council approved the same.

ISG FELLOWS

1. **ISG-F-1:** **Shri Pramod P. Kale, Pune**
2. **ISG-F-2:** **Dr. George Joseph, Ahmedabad**
3. **ISG-F-3:** **Dr. A.K.S. Gopalan, Secunderabad**
4. **ISG-F-4:** **Shri A.R. Dasgupta, Gandhinagar**
5. **ISG-F-5:** **Dr. Baldev Sahai, Ahmedabad**
6. **ISG-F-6:** **Dr. Prithvish Nag, Kolkata**

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L-1411	Shri Ravi Kumar Katiki *S/o. K. Venkata Ratnam* Bolletigunta, Vedangi Post, Pooduru (M.D) West Godavari-534265
L-1412	Ms. Nandita Goswami PRL Director's Bungalow Nr. IIM, Navrangpura Ahmedabad-380009
L-1413	Ms. Soma Sarkar Flat no. : A3, Plot no. B-15 Gali no. 7, Shashi Garden, Mayur Vihar Phase-1 New Delhi-110091
L-1414	Shri R. Ajith Kumar *Assistant Project Manager* RMS India Pvt. Ltd. A-7, Sector - 18 Nioda-201301
L-1415	Shri Avnish Varshney *Engineer (Modeling)* RMS India Pvt. Ltd. A-7, Sector - 18 Nioda-201301
L-1416	Shri Manish Pilliwar *Proprietor* Pilliwar & Associates 25, South Avenue Choubey Colony Raipur (C.G.)-492001
L-1417	Prof. B. Ganeshkumar *Assistant Professor* PSNA College of Engineering & Technology Dept. of Civil Engineering Dindigul-624622

Chapters Activities

Ahmedabad Chapter's Report

ISG – AC organized a two day Space Exhibition at Gandhidham along with Bhadre Educational Experts (under GTU), More than Eight Thousand school children visited the stall and had interesting interaction with ISG – AC volunteers. Shri J.G. Patel, EPSA, SAC and Dr. P.S. Thakker delivered lectures during the event.

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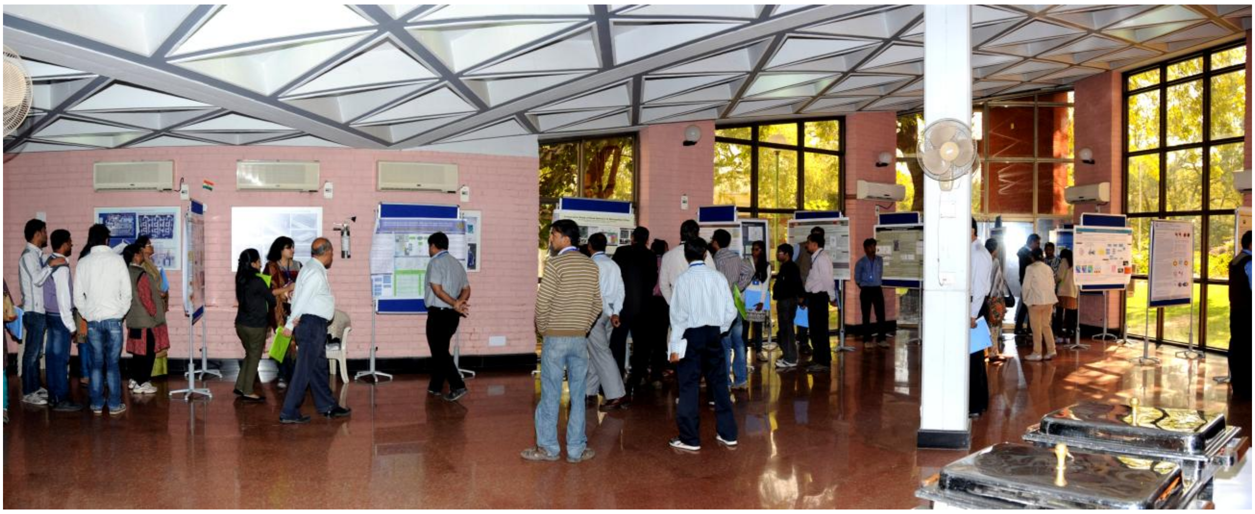
A one day Workshop on "Geomatics: A Tool in the Management of Ecosystems" was Jointly Organized by Indian Society of Geomatics, Ahmedabad Chapter and Botany Department, M.G. Science Institute, Ahmedabad, on Saturday, 8th October, 2011.

Indian Society of Geomatics – Ahmedabad chapter along with ISRS – AC, INCA – GB and IMS – Ahmedabad Chapter jointly organized Three-day environmental educational excursion to Jaisalmer and its Environs for members and their families 04 – 07 November 2011.



Indian Society of Geomatics – Ahmedabad chapter along with ISRS – AC, INCA – GB and IMS – Ahmedabad Chapter jointly organized a Workshop on the above topic on January 07, 2012. The inaugural session was Chaired by Dr. Ranganath R. Navalgund, President ISRS and Director, SAC. Many eminent personalities like Dr. Shailesh Nayak, President ISG, IMS and Secretary MoES, Dr. George Joseph, Hon. Distinguished Prof., Shri DRM Damudraiah, Chairman ISRS – AC and Dy. Director, SEDA, SAC, were present on the dais during the inaugural function.

INDIAN SOCIETY OF GEOMATICS (ISG)

(www.isgindia.org)

MEMBERSHIP APPLICATION FORM

To: The Secretary, Indian Society of Geomatics

Building No. 40, Room No. 34,

Space Applications Centre (SAC) Campus

Jodhpur Tekra, Ambawadi PO, AHMEDABAD – 380 015

Sir,

I want to become a Life Member/ Sustaining Member/ Patron Member/Annual Member of the Indian Society of Geomatics, Ahmedabad from ------------Month of --------- year. Membership fee of Rs./US$ _____ /- is being sent to you by Cash/ DD/ Cheque (In case of DD/ Cheque: No.__________, drawn on Bank _______________________________ payable at Ahmedabad. For outstation cheques add clearing charges Rs 65.00/US$ 10.00). I agree to abide by the constitution of the Society.

Date: Place:

Signature

1. Name: (Dr / Mr / Mrs/ Ms) ____
2. Address: ______________________________________

   ____

   ____ PIN: _______

   Phone: ___________ Fax: ___________ Email: __________
3. Date of Birth: __________
4. Sex (Male/Female): ______
5. Qualification: ___________
6. Designation: _____________
7. Specialisation: ___________
8. Membership in other Societies:
9. Mailing Address: _________________________________

   ____

   _________________________________ PIN: _______

Proposed by:

(Member's Name and No) Signature of Proposer

For Office Use

ISG Membership No: ISG- -

Receipt No.: **Date:**

MEMBERSHIP SUBSCRIPTION

Sr. No.	Membership Category	Admission Fee		Annual Subscription Rs. (Indian)
		Rs. (Indian)	US $ (Foreign)	
1.	Annual Member	10.00		200.00
2.	Life Member a) Admitted before 45 years of age b) Admitted after 45 years of age	 1500.00 1100.00	 250.00 200.00	
3.	Sustaining Member	---	----	2000.00
4.	Patron Member	50,000.00	2500.00	----
5.	Student Member	10.00	---	100.00

MEMBERSHIP GUIDELINES

1. Subscription for Life Membership is also accepted in two equal installments payable within duration of three months, if so desired by the applicant. In such a case, please specify that payment will be in installments and also the probable date for the second installment (within three months of the first installment).

2. A Member of the Society should countersign application of membership.

3. Subscription in DD or Cheque should be made out in the name of '**INDIAN SOCIETY OF GEOMATICS'** and payable at Ahmedabad.

4. Outstation cheques must include bank-clearing charges of Rs. 65.00/US$ 10.00.

5. For further details, contact Secretary, Indian Society of Geomatics at the address given above.

6. Financial year of the society is from April 1 to March 31.

7. ISG has chapters already established at the following places: Ahmedabad, Ajmer, Chennai, Hyderabad, Indore, Mangalore, Mumbai, New Delhi, Pune, Tiruchirappalli and Vadodara. Applicants for membership have the option to contact Secretary/Chairman of the local chapter for enrolment. Details can be found at the website of the society: www.isgindia.org

8. Journal of the society will be sent only to Patron Members, Sustaining Members and Life Members.