DELIVERABLES FROM SPACE DATA SETS FOR DISASTER MANAGEMENT – PRESENT AND FUTURE TRENDS

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ABSTRACT:

Natural disasters strike several parts of the globe at different seasons through out the year, resulting in enormous destruction of properties and untold human sufferings. Due to diverse geo-climatic conditions prevalent in different parts of the world, different types of natural disasters like floods, droughts, earthquakes, cyclones, landslides, volcanoes, etc, strike respective vulnerable areas. India is one of the world's most disaster prone countries that has witnessed devastating natural disasters in recent past like tsunami, floods, drought, earthquakes, cyclones, etc. These disasters have been causing great economic loss. The potential risk can be minimized by developing disaster early warning strategies, preparing and implementing developmental plans to provide resilience and to help in rehabilitation.Many types of disasters will have certain precursors that satellite can detect. Remote sensing also allows monitoring the event during the time of occurrence while the forces are in full swing. Satellite remote sensing systems from their vantage position have unambiguously demonstrated their capability in providing vital information and services for disaster management. The Earth observation satellites provide comprehensive and multi temporal coverage of large areas in real time and at frequent intervals. Thus they have become valuable for continuous monitoring of atmospheric as well as surface parameters related to natural disasters. Polar orbiting satellites have the advantage of providing much higher resolution imageries, even though at low temporal frequency, which could be used for detailed monitoring, damage assessment and long-term relief management. Geo-stationary satellites provide continuous and synoptic observations over large areas on weather including cyclone monitoring. The vast capabilities of communication satellites are available for timely dissemination of early warning and real-time coordination of relief operations. The advent of Very Small Aperture Terminals (VSAT) and Ultra Small Aperture Terminals (USAT) have enhanced the capability further by offering low cost, viable technological solutions towards management and mitigation of disasters. Satellite communication capabilities-fixed and mobile is vital for effective communication, especially in data collection, distress alerting, position location and co-ordinating relief operations in the field. The use of remote sensing has become an integrated, well developed and successful tool in disaster management, and the requirement for hazard mitigation and monitoring rank high in the planning of new satellites.The deliverables that can be expected from space data sets at the present scenario include high temporal revisit, high spatial resolution, stereo mapping capability, interferometric SAR and onboard processing. Since each individual satellite covers a small proportion of the Earth’s surface, a rapid response using high-resolution satellites can only be achieved with several satellites operating simultaneously. Hence, a separate constellation of satellites for disaster management was already being attempted by some countries. With the increased co-operation among the countries in the field of disaster management, the tendency in the future is towards intelligent satellite systems. These systems will be a space-based configuration for on-board integration of earth observing sensors, data processors and communication systems. These proposed sensor systems detect any changes in the data such as forest fire, flood, etc, automatically alters its coverage area, acquire and analyse data, delivers the end product to the users. Department of Space Govt. of India has launched a major programme for providing space based inputs to the nation for disaster management support. Though space data provides invaluable information during certain disasters, still there is gap with regard to earth observation, frequency, resolution, information dissemination etc. In order to full fill some of the gaps appropriate activities are being initiated. The present capabilities and the future trends in utilization of space data sets are discussed in the paper. The paper mainly focuses on the deliverables that can be expected at present scenario from space data sets which in turn provide vital inputs for efficient disaster management and it also discusses the future trends that arise with the rapid developments in different technological fronts.

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1. INTRODUCTION

1.1 Natural Disasters

Natural disasters such as earthquakes, floods, drought, tornadoes, tropical cyclones, wildfire, tsunami, volcanic eruptions and landslides affects different parts of the world with varying intensities over space and time. As per the statistics of International Strategy on Disaster Reduction there was an 18 percent rise in disasters during 2005 compared to 2004 (www.unisdr.org). This increase is mainly due to the rising numbers of floods and droughts that affect large swathes of population. About 157 million people were affected by disasters in 2005 (www.unisdr.org). resulting in damages of about 159 billion USD in the world. India ranks as the second country among disaster prone countries in terms of population affected. India experienced widespread floods, drought, landslides and earthquakes during 2005. Natural disasters are inevitable and it

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is almost impossible to fully recoup the damage caused by the disasters. But it is possible to minimize the potential risk by developing early disaster warning strategies, preparing and implementing developmental plans to provide resilience and to help in rehabilitation. Increased urbanisation in developing countries and invasion of coastal and river plain areas by agricultural, residential and industrial activities, etc., are some of the major factors that contribute to the increased vulnerability to natural hazards.

1.2 Disaster Management

Disaster management refers to the comprehensive strategy in all phases of disaster for effectively reducing the impact of disaster. Disaster management cycle consists of the following different phases: Forewarning, Relief & Rescue, Rehabilitation and Mitigation phases.

During the early warning phase of disaster, forecast will be issued in advance of occurrence of the disaster. This phase is very important in the sense that the occurrence of event is known early so that planning can be done to evacuate people and movable property. However technical expertise and facilities are required to issue the forecast. Further, the communication also plays an important role in collecting the required ground data in real time and also to disseminate the forecast and warning information. In case of flood, the occurrence of flood and its magnitude is forecasted using hydrological models or gauge to gauge correlation techniques. Based on the flood stage a flood warning is given for taking necessary actions. The forecast details will be transmitted to the concerned departments like State and district Administration, etc. The basic data requirements for floods in this phase will be meteorological & hydrological data. In case of cyclones, their movement can be monitored from formation stage over the oceans to till the landfall occurrence at frequent intervals. But the exact landfall prediction is quite difficult with the available models. Similarly, prediction of earthquake remains an elusive goal; the affected areas and destruction can be known within minutes of knowing the epicentre and magnitude using predictive models.

When a disaster event occurs the first and fore most activity that will be taken up with high priority is the relief and rescue. In the case of a disaster occurrence, relief activity will be initiated to evacuate the people and movable property, organising relief camps, air dropping of food and material, medical facilities, etc. This phase is the most critical and actions have to be taken on the spot according to the situation. Timeliness, organising resources and manpower are the essential components. The information required during this phase is extensive and critical since the actions have to race against time. The primary information will be on impact of the event, the extent of the area affected, location specific details, population affected, availability of resources for evacuation of the people & means of evacuation, quick assessment of damages.

During the rehabilitation phase, the disaster victims have to be rehabilitated, restoration of essential services, establishing communication and distribution of relief material. This phase will continue till the situation comes to normal. Actions have to be initiated to mobilise commodities to the relief camps, establishing essential requirements at relief camps etc. The information required during the phase will be the extent of damage caused by the disaster, inventory of resources, collection and compilation of reports etc.

In the mitigation phase long term and short measures will be planned for disaster mitigation. This involves preparation of master plans, hazard zonation and vulnerability analysis, location specific analysis of the disaster problem, modes and means available for disaster analysis including research etc. With the lessons learnt in the past, suitable mitigation measures will be planned and executed. The type of information required will be mainly on the nature of the disaster. In the case of flood disaster mitigation, the information requirements will be, status of the existing structural and non-structural measures, severity of the flood problem, feasibility study of the suitable flood control measure etc. This phase is important in a way it reduces the impact of the disaster saving loss of life and property.

A comprehensive disaster management system must allow to access many different kinds of information at multiple levels at many points of time. Disaster information involves more than just data and several interconnecting steps are typically required to generate the type of action–oriented products that are needed by the disaster management community. The exact steps taken depend on the disaster phase and how time critical the need is.

2. PRESENT SPACE DATA SETS

2.1 Capabilities

Satellite remote sensing systems from their vantage position have unambiguously demonstrated their capability in providing vital information and services for disaster management (Rao UR,1994). The Earth observation satellites provide comprehensive and multi temporal coverage of large areas in real time and at frequent intervals. Thus they have become valuable for continuous monitoring of atmospheric as well as surface parameters related to natural disasters. Polar orbiting satellites have the advantage of providing much higher resolution imageries, even though at low temporal frequency, which could be used for detailed monitoring, damage assessment and long-term relief management. Geo-stationary satellites provide continuous and synoptic observations over large areas on weather including cyclone monitoring. The vast capabilities of communication satellites are available for timely dissemination of early warning and real-time coordination of relief operations. The advent of Very Small Aperture Terminals (VSAT) and Ultra Small Aperture Terminals (USAT) have enhanced the capability further by offering low cost, viable technological solutions towards management and mitigation of disasters. Satellite communication capabilities-fixed and mobile is vital for effective communication, especially in data collection, distress alerting, position location and coordinating relief operations in the field. Remote sensing technology provides a database from which the evidence left behind by disasters that have occurred before can be interpreted, and combine with the other information to arrive at hazard maps, indicating which area is potentially dangerous. Using remote sensing data, such as satellite imageries and aerial photos, allows us to map the variability of terrain properties, such as vegetation, water, geology, both in space and time. Satellite images provide very useful environmental information, for a wide range of scales, from entire continents to detail of a few metre. The present space data sets consists of wide swaths with intermediate resolution and broad spectral coverage, narrow swaths with very high resolution, hyper-spectral sensors with

8~30 m Ground Sampling Distance (GSD) and Radar with 3 to 30 m GSD. Revisit capabilities varies from a few hours to days. Some of the imaging systems are capable of acquiring off-nadir data, in the cross track or/and along-track imaging mode enabling collection of high-resolution stereo data that permits the creation of accurate digital elevation models.

2.2 Indian Case Studies

Most parts of the Indian landmass is prone to several natural disasters, with the East and West coasts being affected by severe cyclones, major river systems such as Ganges, Brahmaputra by large-scale flooding and the hilly tracts of Himalayas by major landslides (Singh, 2004). Department of Space, Govt. of India has launched a major programme for providing space based inputs to the nation for disaster management support. Considering the vast potentials of space technology to provide critical services towards disaster management, Indian Space Research Organisation (ISRO) has been pursuing concerted efforts for appropriate technology development. ISRO with a well-knit space infrastructure comprising of Indian National Satellite (INSAT) and Indian Remote Sensing (IRS) series of satellites, is uniquely placed to provide services related to Disaster watch, Warning dissemination, Data collection, Monitoring and damage assessment, Vulnerability mapping, Communication support etc. A synergistic use of IRS and INSAT capabilities is planned to address several critical issues related to disaster management in the country (Hegde et al, 2004). Over the past decade, innovative use of communication and meteorological capability of INSAT system is being operationally used towards tracking, monitoring and prediction of cyclones. The recent achievements include inundation mapping of all the major floods in the country in near real time mode, drought severity assessment using satellite data on fortnightly/monthly time scales, landslide zonation of pilgrimage routes in Himalayas, monitoring of cyclones and damage assessment. The capability of Geographic Positioning System (GPS) to precisely determine the position of a location is being used to measure ground movements associated with plate tectonics. ISRO has established a Decision Support Centre (DSC) at National Remote Sensing Agency, Hyderabad. to provide timely information meeting the user needs in terms of information content, turn-around-time and format. Such information will be disseminated to the State and Central user agencies. DSC aims at networking the knowledge based institutions for effective use of the ground observations and data in conjunction with space data, to derive updated information on disaster events and provide decision support. DSC will be expected to evolve as single-window information service provider, with a long-term vision of diffusion and internalization of space applications in various facets of disaster management. Some of the deliverables on selected disasters being provided to the nation are as follows.

Floods

Floods are the most common and widespread of all-natural disasters. The most flood-prone areas in India are the Brahmaputra and Ganga basins in the Indo-Gangetic-Brahmaputra plains in north and northeast India, which carry 60 per cent of the nation's total river flow. One of the most important elements in flood disaster management is the availability of timely information for taking decisions and actions by the authorities (Miranda *et al*. 1988, Okamoto *et al*. 1998). During monsoon season, a constant watch will be kept on the flood situation in the country and all possible satellite data will be procured over flood affected areas. The procured satellite data is analysed within a few hours and flood map will be generated showing flood inundated areas and the information is being furnished to the National Disaster Management Division, Ministry of Home Affairs and other State and Central Govt. Depts. With the combination of satellites, it is possible to generate flood inundation information temporally and accurately in a scientific manner. DSC has been monitoring and mapping the major flood events that have occurred in the country using satellite remote sensing data for the last one and half decade and the information is being provided to the concerned departments. Figure 1 shows the Synthetic Aperture Radar (SAR) data of Radarsat satellite, used to study the impact of floods occurred in Bihar state located in northern part of India during October, 2007. Figure 2 provides the corresponding flood map prepared based on the analysis of the Radarsat SAR data.

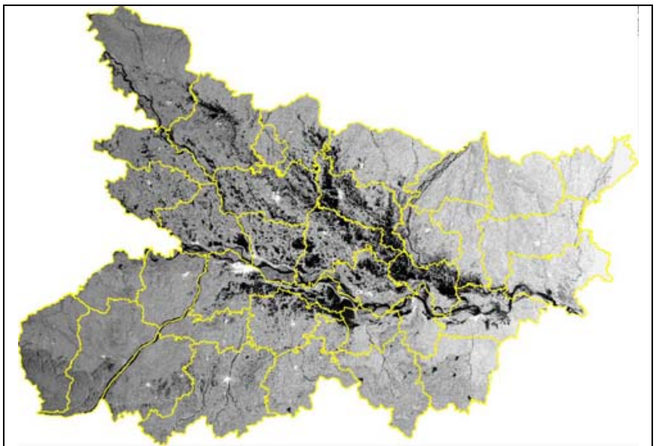

Figure-1 Radarsat SAR image of October 2007 showing flood situation in Bihar state

In addition to providing information in near real time, valuable information is being derived with regard to river configuration and flood control works for planning flood control measures. To assists the Engineers/Planners in providing latest, accurate and multi temporal information, high-resolution satellite data was used to map the river configuration and existing flood control works. For selected flood prone rivers, post flood satellite data was used for mapping the configuration of the river along with flood control embankments and major spurs. In order to provide bank protection works, vulnerable areas subjected to bank erosion along the rivers have to be monitored.

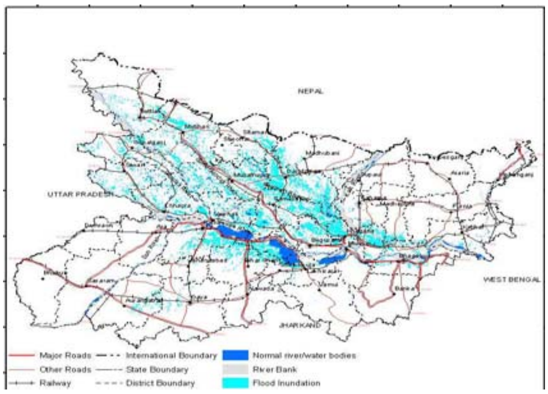

Figure-2 flood map of Bihar state

High-resolution satellite data during different time periods will be procured, classified and bank lines during different time periods will be delineated. By digitally superimposing the bank lines the erosion pockets can be easily identified. The erosion maps prepared can be effectively used for planning bank protection works and town protection works etc. Using historic flood inundation information derived from satellite data flood hazard maps are prepared for chronic flood prone rivers for panning non-structural flood control measures.

Drought

India being an agrarian country and most of the population depends basically on the agriculture. In India about 68% of total sown area of the country is drought prone (Rao D.P., 2000). Despite the significant technological advances since independence, Indian agriculture continues to be periodically affected by droughts. A most recent example is that of the country-wide severe drought of the year 2002. The conventional methods for monitoring of both causative factors as well as impact of agricultural drought suffer from various limitations such as sparse observations, subjective data etc. Unlike these point observations, satellite sensors provide direct spatial information on vegetation stress caused by drought conditions.

National Agricultural Drought Assessment and Monitoring System (NADAMS) is a remote sensing based agricultural drought monitoring mechanism in India and provide near real-time information on prevalence, severity level and persistence of agricultural drought at National/State/District level. The project covers 14 states of India which are predominantly agriculture based and prone to drought.

Monitoring of drought is restricted to Kharif season (June-Oct/November) since this season is agriculturally more important and rainfall dependent. Under NADAMS, agricultural conditions are monitored at State/District level using daily-observed coarse resolution (1.1 km) NOAA (National Oceanic and Atmospheric Administration) satellites AVHRR (Advanced Very High Resolution Radiometer) data for entire country. District-wise detailed assessment of drought is being carried out for two states of Andhra Pradesh and Karnataka using IRS WiFS /AWiFs sensor data, which has a spatial resolution of 188m / 56m and temporal revisit period of 5 days. The assessment of agricultural drought situation in each district takes into consideration; (1) seasonal Normalised Difference Vegetation Index (NDVI) progression – i.e. transformation of NDVI from the beginning of the season over agricultural areas, (2) comparison of agricultural area NDVI profile with previous normal years, (3) weekly rainfall status compared to normal, and (4) weekly progression of sown area compared to normal. The relative deviation of NDVI from that of normal and the rate of progression of NDVI during the season give the indication about the agricultural situation in the district which is then complemented by ground situation as evident from rainfall and sown area. The agricultural drought information thus derived is being provided to the user community in the form of monthly reports. Figures 3 &4 show NDVI images at National and District level derived from satellite data.

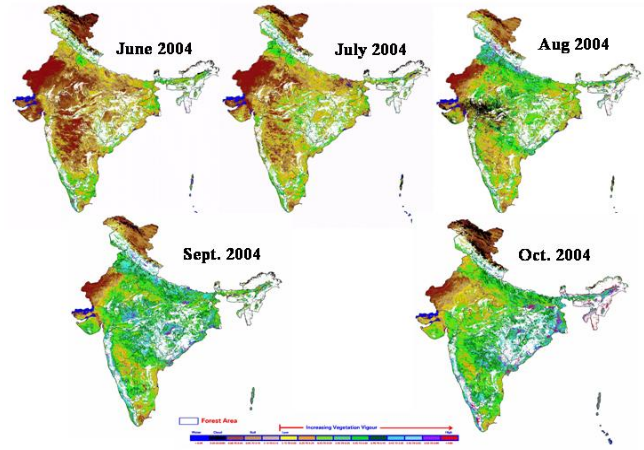

Figure 3. NDVI Image of India during 2004

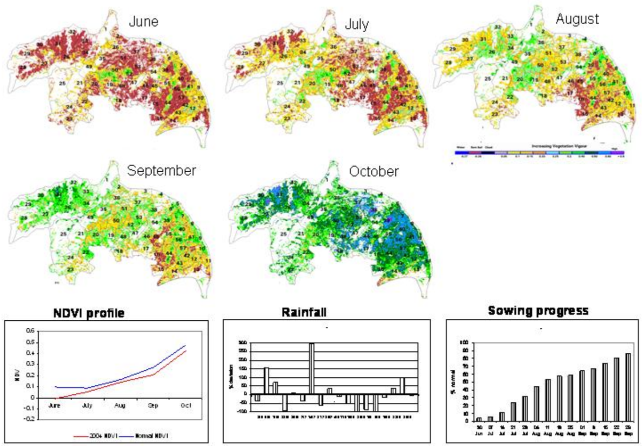

Figure 4. NDVI Image of Guntur District in Andhra Pradesh State in Southern part of India during Kharif 2004

Landslides

The main contribution of satellite data is to provide the geological details, morphological, and land use, in determining how the landslide occurs and what causes the failure. Where failure could occur can be addressed in a more regional geographic information system (GIS) analysis as a necessary first step in risk analysis. This is because the factors contributing to slope failure at a specific site are generally complex and difficult to assess with confidence. 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, suitable high-resolution remote sensing data and aerial photographs. This mapping procedure can be used to produce hazard risk maps that will assist in emergency preparedness planning and in making rational decisions regarding development and construction in areas susceptible to slope failure. Detailed slope information is essential for reliable landslide inventory maps. Currently, topographic maps and digital elevation data are used. Slope affects surface drainage and is an important factor in the stability of the land surface. Current research has shown that airborne and satellite InSAR techniques are being used to produce detailed slope information. This allows a more accurate interpretation of slope morphology and regional fracture systems with topographic expressions. One of the major geological hazards in India especially in the Himalayan region is Landslide disaster. Hazard zonation is an important step where remote sensing and GIS play a major role. For generating hazard zonation maps, the critical terrain information like the updated lithology, geological structure, geomorphology, land use / land cover and drainage derived from the satellite data needs to be integrated with other topographic data like the slope, aspect and morphology. Landslide hazard zone maps for select pilgrim routes in the Himalayan region have been prepared and management maps suggesting suitable measures for reducing the associated risk (Figure 5). Figure 6 shows Landslide affected zones near Vishnuprayag in India where a major Landslide occurred on July 06, 2004.

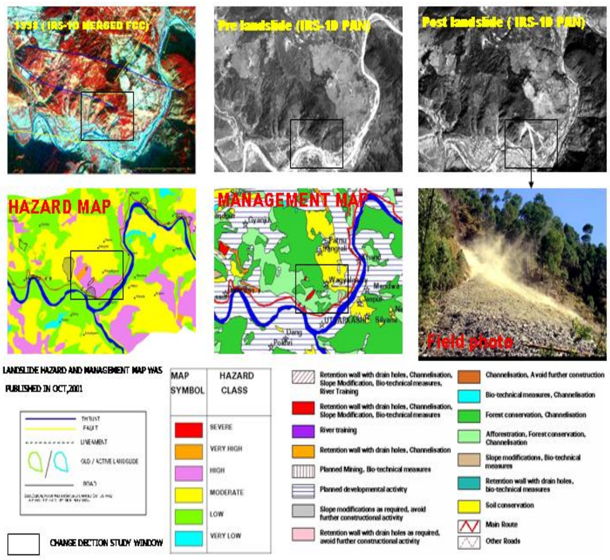

Figure 5. Landslide Hazard zonation for Uttar Kashi, India

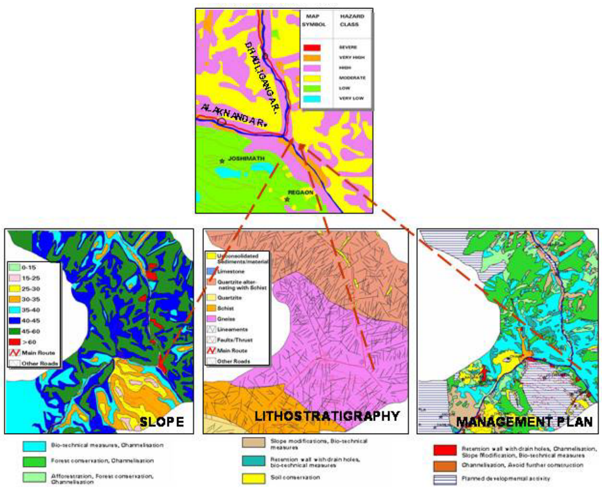

Figure 6. Landslide affected zone near Vishnuprayag in India on July 06,2004

Earthquakes

The Indian sub-continent is subjected to varying degrees of earthquake hazard demonstrated by the fact that more than 650 earthquakes having magnitude above 5 have been recorded during the last one century. Majority of these are located in the Himalayan frontal area. Currently, operational EO capabilities have some limited use in the mitigation and response phases of earthquake risk management, but not in the warning phase. Seismic hazard analysis requires an assessment of the future earthquake potential in India. It is, therefore, necessary to estimate the maximum earthquake magnitude and recurrence character that might be generated by a particular active fault. The most common uses of more detailed geologic data have been to constrain maximum earthquake magnitudes using empirical relationships between earthquake rupture dimensions and magnitude. One of the basic elements in assessing seismic hazards is to recognize seismic sources that could affect the particular location at which the hazard is being evaluated. These sources are often called seismo-tectonic sources. Defining and understanding seismo- tectonic sources is often the major part of a seismic hazard analysis and requires knowledge of the regional and local geology seismicity and tectonics. Remote sensing data can provide the basic inputs on the structural fabric of the terrain. The lineament map can be one of the important inputs for delineating the seismo-tectonic province. The area affected by earthquakes are generally large, but they are restricted to well known regions (Plate contacts). The associated surface manifestation of such disaster is Fault rupture damage due to ground shaking, liquefaction and landslides. In such scenario, the following aspects play an important role: distance from active faults, geological structure, soil types, depth of water table, topography and types of building. Toward this, satellite remote sensing plays an important role in the mapping of active faults, lineament and density of lineaments. The availability of Very High-resolution data can be made use for post-disaster assessment in the dense urban clusters. This data gives us synoptic overview of the area affected by the disaster. Such data can be made use to create a very large-scale base information of the terrain for carrying out the disaster assessment and for relief measures. It can also map some geomorphic changes, if any, in the micro-level after the earthquake for micro-seismic zonation. The impact of the recent earthquake in the Himalayas during Oct 2005 were studies using IRS-P6 and Cartosat-1 satellite data (figure 7)

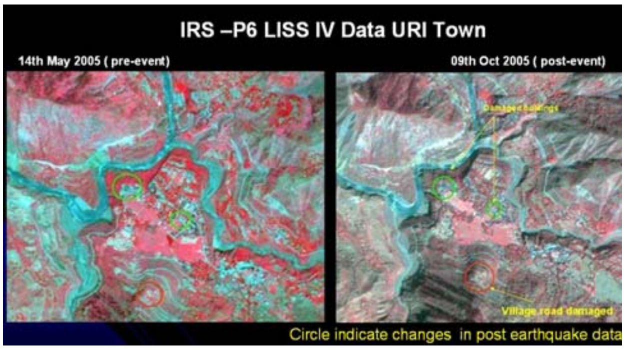

Figure 7. IRS-P6 image of pre and post earthquake scenarios

Forest Fires

Indian forest ecosystems especially deciduous forests and grasslands in India are prone to fires every year. Recurrent fires potentially harm vegetation dynamics of the ecosystems and may disturb tropic structure. Forest fires can also emanate greenhouse gases and aerosols and may be critical in the context of climate change. Hence, the fire management calls for priority in India during summer as a key forest management prerogative.

Existing fire alert systems in the country mainly depends on fire watchtowers, information collected by beat guards and communicated through wireless sets. Size and accessibility of the geographic regions dealt constrain the efficiency of such exercises. Rapid damage assessment and mitigation planning also need efficient and reliable information support.

Satellite remote sensing with its synoptic and temporal coverage can augment the ground operations in terms of fire detection, damage assessment and planning the mitigation in a time and cost efficient manner. Synergy of satellite systems are useful in forest fire detection, active fire progression monitoring, near real time damage assessment, and mitigation planning.

As part of Disaster Management Support Programme of Department of Space, National Remote Sensing Agency is providing services on Fire alerts – Value added daily active fire locations, Fire progression – High temporal resolution burnt area expansion, Burnt area assessment – Mapping episodic fire event, Mitigation planning – Geoinformatics based planning input

Indian Forest Fire Response and Assessment System: Under this system, TERRA MODIS data based fire products will be generated everyday within 4 to 5 hours of the satellite ground pass (Figure 8). DMSP OLS data acquired at different time periods will be provided by the forenoon of the next day. MODIS and DMSP fire products indicating active fire locations with overlay of state boundaries and national parks location will be provided for fire season of 2005 free of cost on daily basis to registered prospective users at the NRSA website. At present all fire products are experimental products which are under validation. These products are released to assess operational utilisation and quality improvement issues.

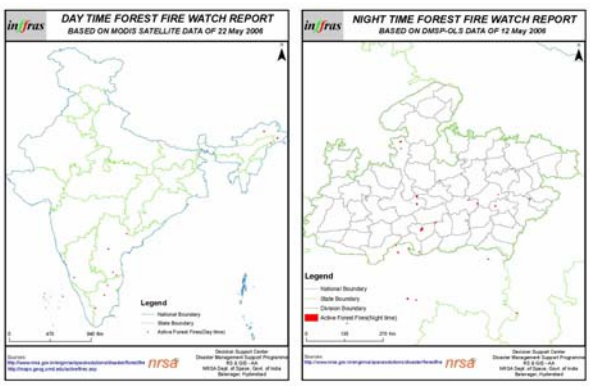

Figure 8. Forest fire locations detected from MODIS data

3. EXISTING GAPS AND FURURE TRENDS

3.1 Existing Gaps

The EO community has arrived at a set of wish list having highly diverse specifications for natural disaster management. The major feature of interests are spatial resolution, temporal resolution, spectral coverage, orbital altitude, revisit capability, width of swath, image size, stereo capability, imaging mode (sensor), data record, satellite owner and market requirements. While a comprehensive investigation and analysis has been brought out by (Zhou, 2001) and CEOS proceedings [www.ceos.org], the highlights are given below:

Spatial resolution: Panchromatic imagery with 1-3 m resolution, multi-spectral imagery with 4 m resolution and hyperspectral imagery with 8 m resolution. Radar imageries could be of 3 to 1000 m.
Swath: 4-40 km in optical imaging system, and 20-500 km for radar imaging.
Spectral coverage: 200 channels hyper-spectral imagery and radar satellites to have full polarization response functions.
Revisit: Less than three days with the ability to turn from side to side on demand towards decreasing the revisit interval.
Delivery time from acquisition to user: Imagery to be down linked in real time to ground stations located around the world.
Capability of stereo: In-tracking and cross-tracking stereoscopic capability using linear array imaging principle.
Sensor position and attitude: The navigation of sensors to be autonomous via on-board performance using positioning sensors and attitude sensors.
Imager type: 'Whisk-broom' and 'Push-broom' modes in optical satellites.
Radar satellites: To supply images with resolution from 3 to 1000 m for swath from 20 to 500 km; and in sun-synchronous orbit.

However, there are some gaps in the existing earth observation capabilities in capturing certain disaster events due its temporal and spatial domains. Coarse resolution payloads (INSAT VHRR/CCD, METEOSAT, NOAA AVHRR) by virtue of having higher repetitivity though capture to the extent, in terms of temporal dimension, but constrain lies in resolving them spatially. The events like drought, crop pests/diseases, land degradation etc., are easy to capture by the existing EO missions, while the disasters like earthquake, cyclone and floods are difficult to capture in real time. Of course, observations of the attributes such as terrain features, ecological fragility and socio-economic status do provide the valuable information especially on vulnerability and the risk. Such observations support to a certain extent developing the scientific understanding and knowledge about the various aspects of the natural disasters, which help in disaster prediction, early warning and mitigation.

The limited number of EO satellites carrying moderate resolution sensors, currently in operational provide only infrequent coverage of tropical regions and always image at the same local time of day. Many tropical regions experience frequent cloud cover that is dependent upon the time of day. For effective and timely monitoring of any region on the Earth's surface at least once each day from space is an urgent requirement in order to be able to react quickly to mitigate the effects of the disasters like cyclone, floods, earthquake, typhoon etc. Present EO satellites have been designed with general-purpose instruments to meet many wide-ranging user requirements and are not tailored to suit disaster prediction, monitoring & mitigation related requirements. It is being advocated that a composite EO satellite system comprising a network of optical and radar satellites to complement the existing EO satellites has got the potential to address the observational gaps. However it is important to examine the sensors and platforms especially the spectral bands, ground resolution and revisit period requirements necessary to address not only the existing observational gaps but also to work in synergy with the contemporary EO missions, particularly the planned/future EO missions.

In two-dimension observational frame, spatial and temporal aspects of the events are to be captured appropriately. Capturing them in real time, both in appropriate spatial as well as temporal dimensions, holds the highest value for information. Since each individual satellite covers a small proportion of the Earth's surface, a rapid response using high-resolution satellites can only be achieved with several satellites operating simultaneously. In addition, to meet the many as yet unsatisfied needs of local decision makers for local environmental information, a low-cost and sustainable constellation of EO (small, mini and micro) satellites is thus required. The Disaster Monitoring Constellation (DMC) is a novel international co-operation in space, formed through an international partnership between organization in Algeria, China, Nigeria, Turkey and the United Kingdom. Thailand and Vietnam are also in the DMC. The DMC satellites can operate alone or in tandem (www.sstl.co.uk). The success of EO in disaster management lies in harmonizing the mission parameters, such as spatial, spectral and temporal resolutions as well as the efficient turn around time of the data acquisition and development of standardized data products, and acceptability and absorption of these products through appropriate service chains. The feedback to configure user's centric EO missions should therefore come from the end user requirements down the line. The feedback should also trigger the development of appropriate EO products and services

3.2 Future Trends

Various concepts are evolving over the time to meet the demands of disaster management authorities. For example, the countries having developed EO technologies are focusing more on developing intelligent and autonomous missions. Intelligent and autonomous missions are configured with (i) various types of intelligent and smart sensors and detectors, (ii) high data rate transmission and high speed network communications, (iii) the most powerful on-board data processing capabilities, and (iv) autonomous operations and control of satellite systems (NASA Earth Science Vision Initiative and the Earth Science Enterprise Strategic Plan; www.nasa.earth.gov). Intelligent and autonomous missions are aimed essentially at enabling simultaneous, global measurements and timely analysis of EO data for real-time, mobile, professional and non-technical user communities, including disaster management users.

Currently, several advanced satellite systems, e.g. NEMO (Naval Earth Map Observer) developed by the US Navy, PROBA (Project for On-Board Autonomy) developed by the European Space Agency (ESA) and COCONUDS (CO-ordinated CONstellation of User Defined Satellites) developed by European Union, exemplify the concept of intelligent and autonomous missions. In fact, BIRD (Bispectral InfraRed Detection) developed by the German Space Agency (DLR) is also another example of an intelligent mission.

Another concept of 'Autonomous spacecraft and event driven observation' is also evolving. Spacecrafts, with several integrated autonomy technologies and algorithms towards onboard event detection, feature detection, change detection and unusualness detection, respond autonomously to capture the events and downlink to the networks. When autonomous spacecraft detects an event, e.g., a forest fire, floods, volcanoes etc the sensing satellite rotates its sensing system into position and alerts its coverage area via adjusting its system parameters in order to bring the event into the focus. The concept is well integrated in NASA NMP EO-1 spacecraft. Space autonomy technology developed as part of NASA's ASE creates the new opportunity to autonomously detect, assess, react to, and monitor dynamic events such as flooding (Felipe Ip et al, 2005).

4. CONCLUSIONS

Space technology has its own potential role in the relief, rehabilitation, mitigation and forecasting phases of disaster management. The Earth observation satellites provide comprehensive and multi temporal coverage of large areas in real time and at frequent intervals. Thus they have become valuable for continuous monitoring of atmospheric as well as surface parameters related to natural disasters. The deliverables that can be expected from space data sets at the present scenario include high temporal revisit, high spatial resolution, stereo mapping capability, interferometric SAR and onboard processing. With more advances in the space technology stored in future, with sophisticated sensors and more capabilities, it is possible for better management of natural disasters.

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