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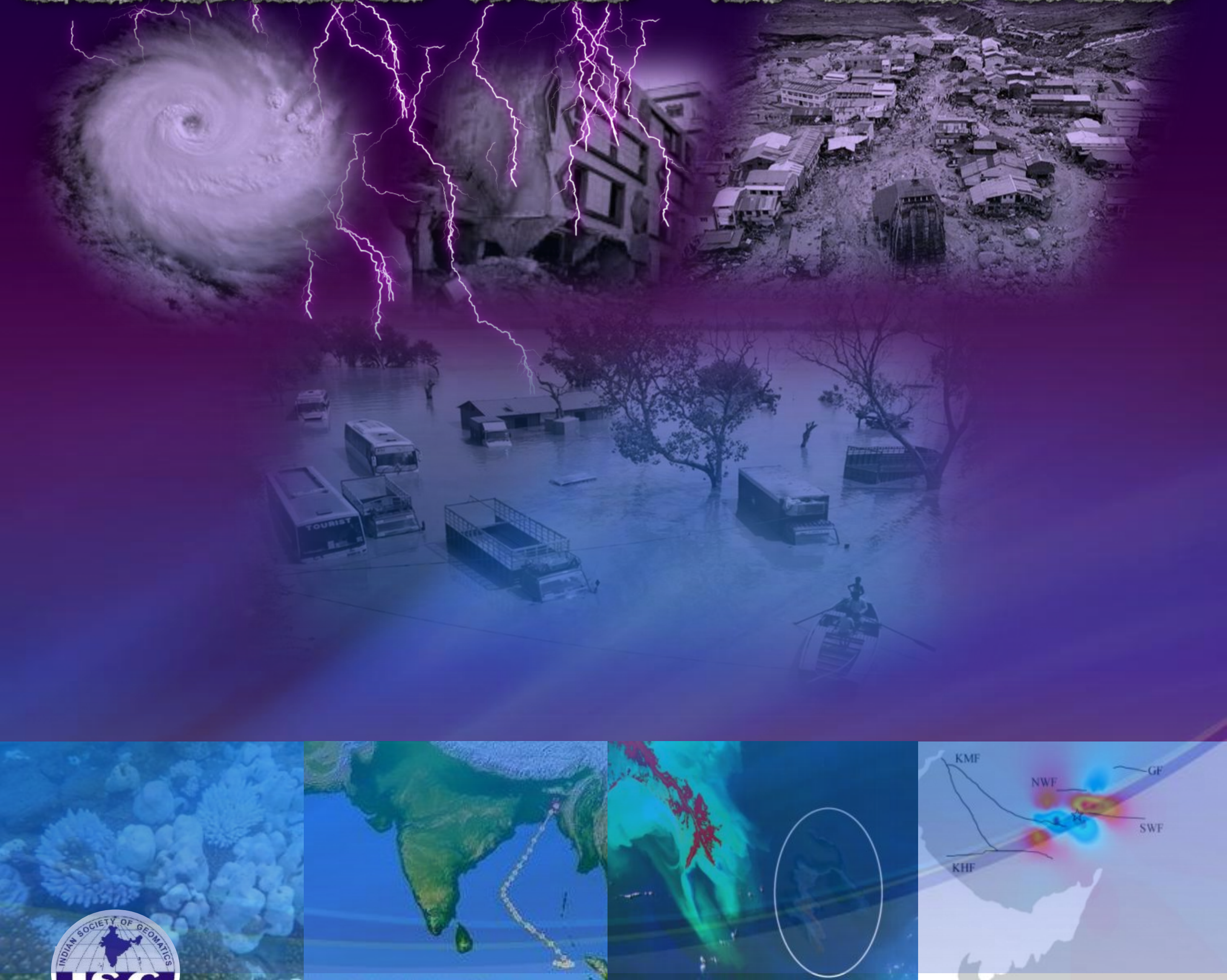
Special issue on Geomatics in Early Warning of DISASTERS



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In this Issue

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Editorial Board – ISG Newsletter

Send your contributions/comments to the Editor at the above e-mail.

Editorial

This issue of ISG Newsletter features the role of Geomatics in early warning of disasters. The theme was unanimously decided by the editorial board to highlight the need for early warning in averting or mitigating the disasters of the kind seen in Uttarakhand. The list of contributions from expert teams features a range of natural disasters related to land, ocean and atmosphere. The articles of land related disasters are given by Sreejith et al. (earthquake), A.K. Singh and Sudhakar Sharma (flood forecasting), C.P. Singh (forest fire), Gaurav Jain et al. (Urban flooding) and I.M. Bahuguna (Lake Outburst). Atmosphere and weather related disasters are covered by Prashant Kumar (forecasting), Shivani Shah and Pushpalata Shah (Cyclones), while those related to oceans are contributed by Nandini Ray Chaudhury (Coral reefs) and Ratheesh Ramakrishnan and A.S. Rajawat (oil spills). It is hoped that members will get a broad overview of role of Geomatics through these nine articles by eminent authors.

With this special issue ISG Newsletter continues its tradition of bringing out special issues of topical interests for the benefit of the members. The series has already featured in last few years many special issues on themes like 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, food and environmental security etc. Year 2010 onwards the ISG Newsletter is published in digital form and Members can download the newsletter from ISG website.

We thank all the authors for their excellent contributions. The articles have been compiled nicely by Shri C.P. Singh who has also designed a very apt cover page. We look forward to the members of ISG and other professionals to keep reading the newsletter and sending their articles for upcoming volumes of future issues.

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

R. P. Dubey
Editor

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. 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. Satellites could be more effectively utilized for searching and monitoring of variety of earthquake precursors than land-based instruments which have very limited coverage.

Space Applications Centre, (ISRO) has been involved in understanding various earthquake precursors and crustal deformation using remote sensing and GPS technology as part of activities under R&D support to Disaster Management Support (DMS) Program of Department of Space.

Initial results obtained from these studies are briefly discussed in the present article.

1) Ionospheric Precursors

Ionospheric anomalies, such as variations in the electron density a few days before earthquakes, are one of the important precursory signals of impending earthquake. It has been demonstrated by several case studies that earthquakes are preceded by electromagnetic signals detected from ground and space based measurement. Ionospheric perturbation can take place in D, E or F layer of ionosphere. Ionospheric parameters like change in critical frequency of F2 layer (f_oF2) and Total Electron Content (TEC) variation in association with earthquake can be detected by using Very High Frequency (VHF) Radio Beacon data, ground based ionosonde measurements and Global Positioning System (GPS) satellites. GPS satellites orbit the Earth at altitudes of about 20,200 km and transmit signals that propagate through the ionosphere (densely ionized part of the upper atmosphere) that exists at about 60 –1500 km above the Earth's surface. The signals from the GPS satellites travel through the ionosphere on their way to receivers on the Earth's surface. The free electrons populating this region of the atmosphere affect the propagation of the radio signals, changing their velocity and direction of travel. Radio waves that pass through the earth's ionosphere travel more slowly than their free space velocity due to the group path delay of the ionosphere. This group path delay is directly proportional to the Total Electron Content (TEC) of the ionosphere. Nowadays GPS-derived Slant Total Electron Content (STEC) data are widely used to obtain information about the state of the ionosphere.

Ionospheric perturbations are caused due to geo-chemical phenomena such as emission of radon. Prior to earthquake due to building of stress in the epicentral regions, micro-fractures are developed in the earth crust which acts as conduit for radon emission. Because of its high ionization potential, it ionizes the near surface air molecules and creates electric field. This electric field penetrates into the ionosphere to cause detectable increase in TEC of the ionosphere. Mechanism for ionospheric perturbation is presented in the form of cartoon in Figure 1.

Japan is part of the "Ring of Fire," the belt of earthquakes and volcanic activity that distinguishes the active margins of the Pacific Ocean from the passive margins of the Atlantic Ocean. The creation of Japan by subduction of the oceanic plates under the continental plates leads to island arc formation. Because of the tectonic settings of the Japan, it experiences numerous earthquakes of small and large magnitude. Subduction of oceanic plate beneath the continental plates leads to friction and failure of the plate in response of tectonic forces. This leads to release of large amount of energy in very short span of time. At SAC-ISRO, we have analyzed the dual frequency GPS derived TEC to understand the ionospheric perturbations associated with the powerful M9.0 Tohoku earthquake of Japan which occurred on 11th March 2011. Epicentre of the earthquake was located at 38.297°N, 142.372°E and its depth

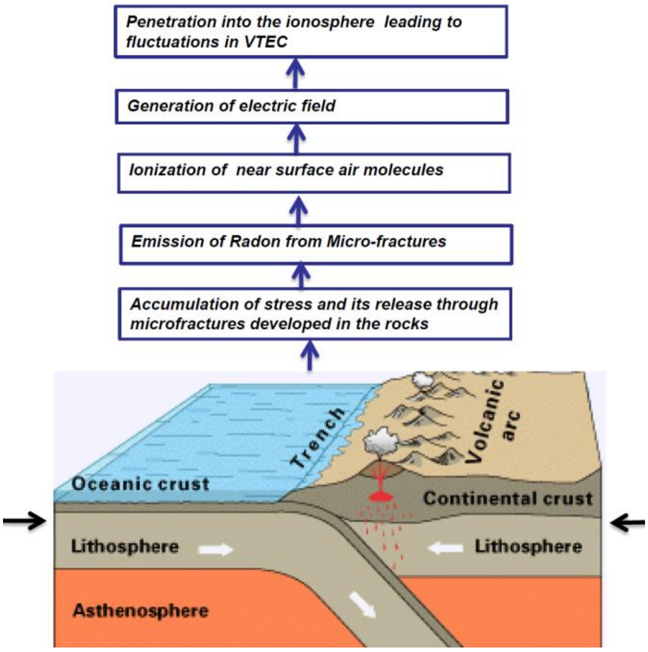

Figure 1:Mechanism of Ionospheric perturbation.

was 30 km. Data from the IGS station MIZU was used as it was nearest station available, situated at 150 km away from the epicenter of the earthquake. Forty five days data which included 30 day pre and 15 days post earthquake was used. TEC of the ionosphere is also influenced by magnetic storms and solar flares. Hence, geo-magnetically disturbed days were eliminated from the study to examine the ionospheric perturbation exclusively because of

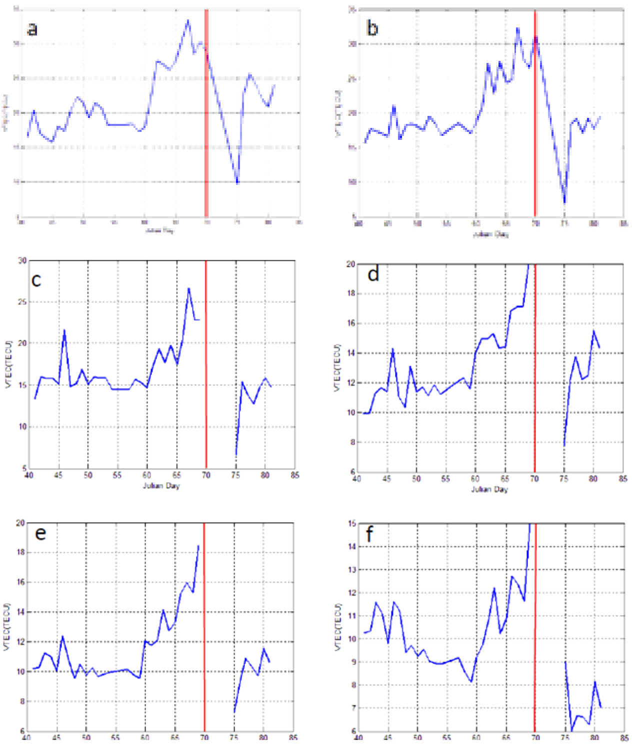

Figure 2: Ionospheric TEC variation prior to powerful M9.0 Tohoku earthquake of Japan. Anomalous TEC varition were observed 5-6 days before the earthquake. Vertical Red line shows the Julian day of earthquake occurrence. Captions (a), (b), (c), (d), (e), (f) represent TEC variation at 2 hrs interval from 2-14 hrs (UTC).

pre earthquake phenomena.

Analysis revealed anomalous increase in TEC of the order 7-15 TECU above normal, 5-6 days prior to the earthquake (Figure 2). Variation of TEC for two hour time interval between 2-14 Hrs in Universal Time Coordinate (UTC) is given in the Figure 2. Anomaly started to develop on 64th day (6th March, 2011) and continued up to 70th day (11th March, 2011) and subsided thereafter. The nature of the anomaly and its association with earthquakes occurring across the globe as evident from various research publications is highly encouraging. Therefore, in near future ionospheric perturbations can be used as an input for development of early warning system for the earthquakes.

2) 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. 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. Sensors for closely monitoring seismic prone regions and providing information about the changes in land surface temperature associated with an impending earthquake with better temporal resolution are required.

Detection of thermal anomalies is related to litho-atmospheric coupling as the causes of the thermal anomalies lie in the lithosphere and are related to the phenomenon of stress built up, which may trigger earthquake. 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).

3) Electromagnetic Precursors

It has been recently reported that 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: 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. 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.

4) 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 80 km. 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 of 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 aspect to understand the physics of earthquake processes.

A continuous long period observation of deformation along active faults could be achieved 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

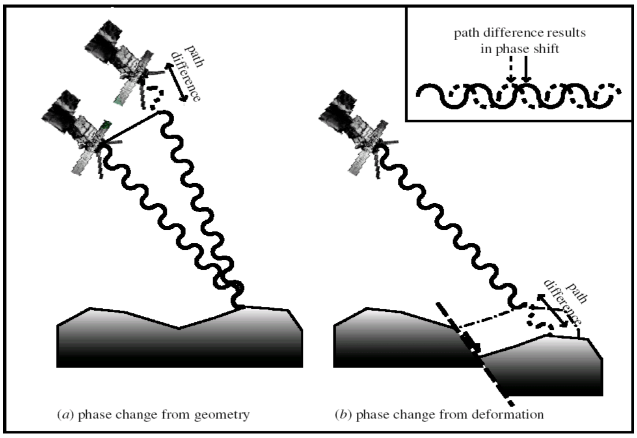

Figure 3: Cartoon showing the mapping of surface deformation using InSAR technique.

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 verity of sources like earthquakes, landslides, mining etc. The principle of measuring surface deformation using InSAR technique is described in Fig. 3.

The InSAR applications for studying earthquakes was first demonstrated for Lander's earthquake by using interferogram generated from ERS-1 SAR data sets and detecting surface movements of the order of few cm. 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, 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 casing 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 20 mm along the line of sight of the satellite over a part of Kachchh region (Figure 4). These results were validated using DGPS based field surveys, which showed comparable deformation rates (up to 13 mm/yr in vertical direction). These results are further supported by the pattern of stress changes after the 2001 Bhuj earthquake obtained by visco-elastic modelling (Figure 4). The unusually high deformation along with increased seismicity along several faults is inferred to be triggered because of a stress pulse migration by viscoelastic processes after a 20 MPa stress drop due to the 2001 Bhuj earthquake.

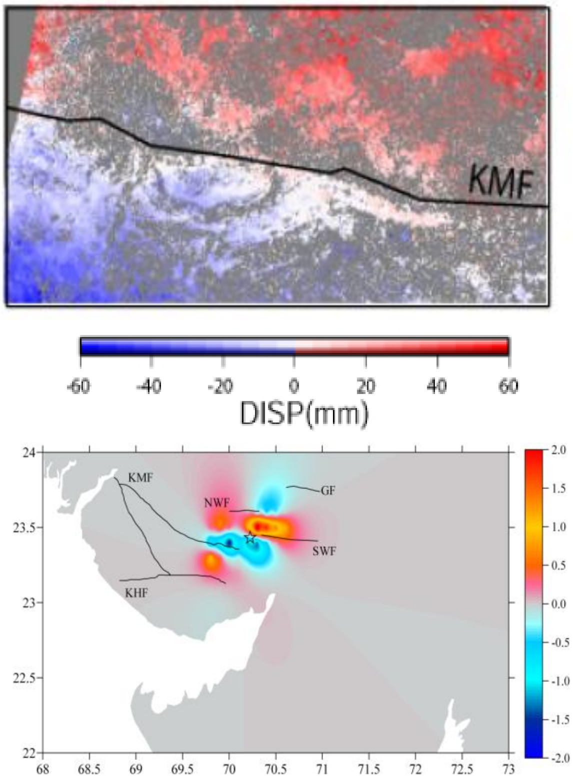

Figure 4: LOS deformation across a part of KMF generated from ENVISAT-ASAR interferogram stacking between 2005-2007. Positive values represent displacement away from the satellite. Visco-elastic stress changes in Kachchh after the 2001 Bhuj Earthquake is shown on the right side.

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.

Weather Forecasting - A Precursor to Early Warning Systems

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The loss of life and property caused by tropical cyclone, thunderstorm, heavy rainfall etc. in various parts of India are well known. These calamities affect directly or indirectly to society and their accurate prediction at varying spatio-temporal scales is strongly desired. Economy of country highly depends on accurate high resolution short, medium and long-range weather forecast. The planners, managers, decision-makers at different facets of society such as agriculture, water resources, aviation, disaster mitigation as well as common people use the weather forecast on day-to-day basis. With the availability of data from the remote-sensing satellites, the detection and continuous monitoring of these disasters is become possible. Despite of the continuous monitoring, the prediction of their further movement is also very important so that preventive and evasive actions can be taken well in advance.

Early prediction and warning of extreme weather events is crucial to mitigate societal impact. These extreme events have been widely simulated by mesoscale models but the inherent predictability of terrain-induced circulation and precipitation is still debatable (Das et al., 2006). Mesoscale predictability in complex terrain is enhanced due to deterministic interactions between synoptic-scale flows and the underlying terrain. The influence of terrain on water–vapour transport and precipitation has been the focus of numerous studies; however, after decades of efforts, the mechanisms of orographic precipitation are still poorly understood and the skilful forecasting of precipitation in mountainous areas remains elusive. Though considerable progress is made in observational networks, NWP techniques, and physical parameterization scheme, etc., weather forecasts on the regional scale have not reached up to required accuracy.

Numerical Weather Prediction (NWP) community deal with the problem of determining a physically consistent and accurate snapshot of the atmosphere. In last few decades, with rapid progress in both computing power and optimization strategies, more sophisticated constraints and more diverse observations have been included in NWP. Obtaining an accurate model initial state is recognized as one of the biggest challenges for numerical model to predict the weather events. The rapidly growing computer power has led to finer resolution NWP models, which are able to resolve mesoscale features and thus to give more precise forecasts. Continuous verification of NWP model with ground based instruments is obligatory to evaluate the quality of model forecast as well as for further feedbacks to improve the performance of numerical models in future. In higher spatial resolution, accurate representation of surface and sub-surface state is one of the important fields which highly influence the quality of weather forecast. Improvements towards accurate weather forecasting need the high-density network of measurements and sophisticated high resolution models with region specific physical parameterization schemes and advanced data assimilation techniques. However, there is still a need to explore new opportunities for model improvement through the extensive use of data from active and passive sensors.

Prediction of extreme events is challenging and requires high-resolution numerical models and mesoscale observations, high-performance computers and Doppler weather radar type of observations. Limitations in observations over oceans, orographic and desert regions are causing difficulty in improving meso-scale forecasts. With this aim to improve the regional model forecast over Indian regions, Space Applications Centre, Ahmedabad made operational the high resolution (5 km) short range (72 hour) weather forecast in experimental phase. This forecast is disseminated through MOSDAC site (www.mosdac.gov.in) which used terrestrial and meteorological data from National Centers for Environmental Prediction (NCEP) Global Telecommunications System (GTS) and assimilated conventional and satellite observations from India as well as other International agencies. Agencies like Karnataka State Disaster Management Centre (KSNDMC) are used this forecast for agricultural purposes and warnings.

With the advent of better remote sensing techniques and assimilation techniques, it will be possible to achieve better weather forecasts over smaller spatial scales also. The error in forecast is reduced and reliability will be improved if high-resolution measurement (~10 km) of atmospheric parameters and vertical profiles are provided through a meso-net observations such as Automatic Weather Station (AWS), Radiosonde/Rawinsonde (RS/RW), and Doppler weather radar. Also, education and training of local administrators to give short-notice warnings would greatly help disaster mitigation.

Reference:

Das, S., Ashrit, R., and Moncrieff, M. W., 2006: Simulation of a Himalayan cloudburst event. J. Earth Syst. Sci., 115(3), 299–313.

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Bleaching Forewarning: A Space-based Capability towards Reef Ecosystem Management

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Bleaching: Stress response of reef organisms

As a functional group, *scleractinian* reef-building corals are central to coral reef ecosystems: a major feature of the tropical oceans within 30° north and south latitudes. The global distribution of these hermatypic corals coincides with seawater temperatures ranging between 16° C to 34.4 ° C (Kleypas et al., 1999). Reef-building corals as well as numerous species of reef-dwelling invertebrate organisms (like sea anemones, snails, clams, sponges and even some single-celled ciliates) are host to unicellular microalgae commonly referred as 'zooxanthellae' due to their yellow-brown colour (Stambler, 2011). Zooxanthellae are mainly classified as dinoflagellate algae belonging to the genus *Symbiodinium* sp. Ecological success of corals and other reef invertebrates in nutrient-poor or oligotrophic environment is widely attributed to this unique symbiosis between host organisms and their endo-symbiont microalgae. Autotrophic zooxanthellae photosynthesize and contribute photosynthates (sugars, amino acids, etc.) to their invertebrate hosts while hosts in addition to shelter supply zooxanthellae crucial plant nutrients (ammonia and phosphate) from their waste metabolism (Lesser, 2004). For their life, colour and skeletal growth, corals and many of the reef invertebrates depend on zooxanthellae.

In cases of environmental stresses like high seawater temperature and high solar radiation zooxanthellae's photosynthetic machinery gets damaged and leads to cellular damage in the symbionts and/or their hosts (Baker et al., 2008). This in turn leads to the expulsion of zooxanthellae from their hosts and eventually the symbiosis breaks down. The loss of zooxanthellae (and/or a reduction in their pigment concentrations) as a result of this process is referred to as 'bleaching' (Baker et al., 2008). Bleaching leads to visible paling/fading/whitening of the host organism as the yellow-brown pigment of the symbiont is lost. Reef-scale bleaching events not only confine to the principal reef-builders or the corals but also involve numerous other invertebrates (Figure 1). Accordingly, *coral reef bleaching* is considered to be a better descriptor of these reef scale events rather than the restrictive term: *coral bleaching* (Baker et al., 2008). Bleaching may occur at local scales or as *Mass Bleaching* at geographic scales that may involve entire reef systems and geographic realms (Hoegh-Guldberg, 1999). A key characteristic of mass bleaching events is that the host tissue remains on the skeleton but is relatively free of zooxanthellae (Hoegh-Guldberg, 1999).

Elevated seawater temperature is known to be the most common driver of mass bleaching events followed by other known causes of high solar radiation and a lethal combination of both (Baker et al., 2008; Lesser, 2004; Hoegh-Guldberg, 1999; Brown, 1997; Glynn, 1993). Other stressors like decreased seawater temperature or cold stress, heavy downpour, bacterial infection and coral diseases, excessive sedimentation, marine pollution, exposure and desiccation have also been documented (Lesser, 2004; Brown, 1997; Glynn, 1993) as factors leading to more restricted coral bleaching and successive coral mortality. However, the physiological and cellular mechanisms by which these stressors cause coral bleaching are not yet well understood (Baker et al., 2008). The worldwide phenomenon of mass bleaching has more been an effect of combination of abnormally high seawater temperatures and high solar irradiance (Veron et al., 2009; Hoegh-Guldberg, 1999).

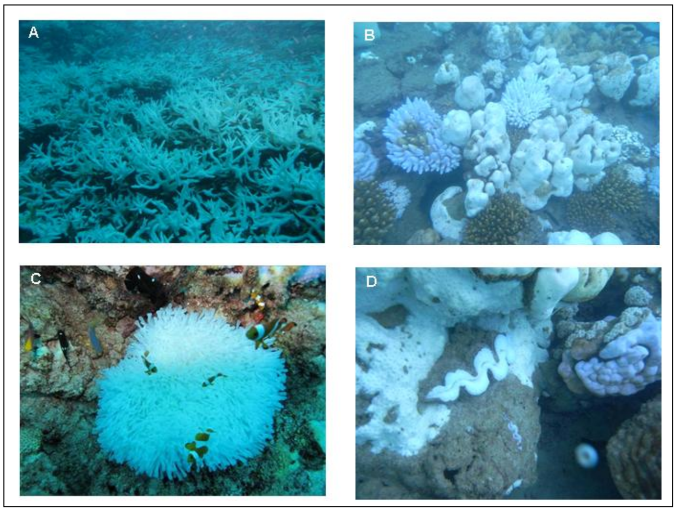

Figure 1: Figure 1. In situ photographs of Mass Bleaching observed in Andaman reefs, India, April-May, 2010: A) Mass bleaching of branching coral species Acropora, B) Mass bleaching of massive (Porites sp.) and branching (Acropora sp.) corals, C) Fully bleached Sea-Anemone and D) Fully bleached Giant Clam

Mass Bleaching: How far a predictable disaster?

The number and severity of mass bleaching events have been considered as a biological signal of the consequences of global climate change on world's coral reefs (Lesser, 2004; Hughes, 2000). Global warming through its evil twins: ocean warming and acidification has now overtaken all other stress-impacts (in importance) on tropical coral reefs. It is the principal cause of widespread and increasingly severe mass bleaching events (Veron et al., 2009; Hoegh-Guldberg et al., 2007; Hughes et al., 2003). Mass bleaching events can be considered as catastrophic expressions of environmental or more precisely climate change disasters with reference to their episodic nature, magnitude (geographical and ecological scales), intensity (mass mortality effect on reef corals and other taxa) and frequency in spatio-temporal domain. What makes mass bleaching unique from other environmental disasters is their relatively slow and long-term impact on humankind.

Coral reefs are high-value ecosystem for many of the tropical nations owing to their intrinsic contribution to coastline protection, human subsistence and commercial exploitation in marine tourism and fisheries (Hoegh-Guldberg et al., 2007; Sheppard, 2003). According to Global Coral Reef Monitoring Network's (GCRMN) latest estimate, the world has already lost 19% of its functional coral reef area while an additional 35% of reef area is seriously threatened (Wilkinson, 2008). It has also been reported that one-third of the reef building corals face extinction risk from climate change and localized environmental impacts (Carpenter et al., 2008). Climate change is expected to fundamentally alter the attractiveness of coral reefs through inevitable reduction in biodiversity and may affect the economic interest of tourism (Hoegh-Guldberg et al., 2007). Productivity of reef-based fisheries at subsistence, industrial or even for aquarium trade will also be affected due to declining reef rugosity (Hoegh-Guldberg et al., 2007). With acidic and warmer oceans, reef accretion is expected to reduce and hence natural advantage of coastline protection from increasingly fragile reef frameworks will also get reduced. Loss of coral reefs not only gets limited to the loss of these essential ecosystem goods and services to humankind but would encompass extinction of a large part of earth's total biodiversity – an experience unprecedented in human history (Veron et al., 2009).

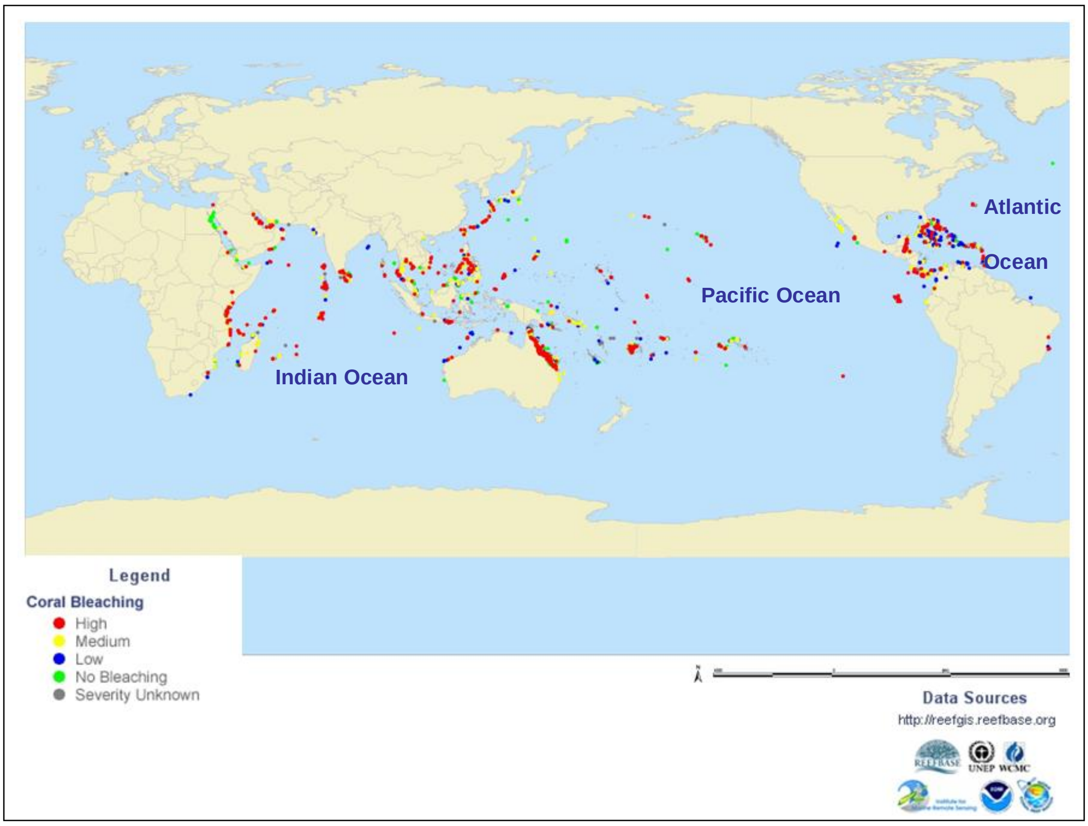

Figure 2: Figure 2. Reefbase data on locations of worldwide bleaching records and their severity. (Since January, 1963 to July, 2013) (Adapted from http://www.reefbase.org)

Mass mortalities of corals from major reef regions have been reported since 1870s (Glynn, 1993). However, the earliest comprehensive report of temperature-related bleaching came from a study on the Great Barrier Reef of Australia from 1928 to 1929 by Yonge and Nichols in 1931 (Lesser, 2011). Yonge and Nichols recorded a mass bleaching event during the Austral summer of 1929 when the seawater temperatures reached 35.1° C and surmised that elevated seawater temperature was the main cause of coral mortality. They further carried out controlled experiments on coral samples of *Favia* species and reported that the duration and the intensity of thermal stress were the critical factors affecting both bleaching and mortality. The number of coral reef bleaching reports (Figure 2) associated with elevated seawater temperatures) has increased dramatically since the early 1980s (Lesser, 2011; Veron et al., 2009; Baker et al., 2008; Hoegh-Guldberg, 2007; Lesser 2004; Hughes et al., 2003; Hoegh-Guldberg, 1999; Brown, 1997; Glynn 1993). Over the last three decades, the phenomenon of mass bleaching has been studied in detail from different academic perspectives (Lesser, 2011; Baker et al., 2008). In 1990s correlative field studies from different parts of the world consolidated the strong association between 'warmer than normal conditions' and the incidences of mass bleaching (Hoegh-Guldberg, 1999; Brown, 1997; Goreau and Hayes, 1994; Glynn, 1993). This strong correlation made prediction of mass bleaching events a reality which subsequently placed coral reef bleaching and climate change squarely at the center of the coral reef conservation debate.

Satellite Bleaching Alert! : A success story

January, 1997 ushered in a new era in coral reef bleaching prediction when USA's National Oceanic and Atmospheric Administration (NOAA)/ National Environmental Satellite Data and Information Service (NESDIS) established an interactive website to predict global bleaching 'HotSpot'(s). NOAA/NESDIS' prediction of 1998 mass bleaching episode specially with reference to Great Barrier Reef, Australia became the historic success story of this experimental attempt when reports of *in situ* mass bleaching started flooding Coral Health and Monitoring (CHAM) Network within a week's time (Hoegh-Guldberg, 1999). NOAA/NESDIS' 'HotSpot' suite of products are the most graphic examples of space borne remote sensing data getting translated into a meaningful data product for coral reef management and conservation. This 'HotSpot' suite of products popularized the application of Advanced Very High Resolution Radiometer (AVHRR) sensor onboard NOAA's Polar-orbiting Operational Environmental Satellite (POES) series which forms the backbone of United State's Low Earth Orbit (LEO) meteorological programme. AVHRR sensor is a broad-band, four or five channel across-track scanner, sensing in the visible, near-infrared and thermal infrared portions of the electromagnetic spectrum with a spatial resolution of 1.1 km at nadir. The POES satellite system offers the advantage of daily global coverage and thus AVHRR sensor can provide daily information on global day and night time Sea Surface Temperature (SST). The at-sensor radiance observations are converted into surface temperatures of seawater in degree Celsius using a multi-channel algorithm. In simple terms, this method uses the relative radiances obtained in the near-infrared and thermal infrared regions to correct for atmospheric attenuation and calculate the ocean surface temperature. The cloudy areas are detected by their comparatively cold temperatures and masked out. The satellite SST algorithms are calibrated and routinely validated against the in situ buoy data to ensure their accuracy.

NOAA's Coral Reef Watch (CRW) (http://coralreefwatch.noaa.gov) operational SST product which goes as an input to generate global bleaching HotSpot maps uses only nighttime satellite SST observations. Daytime SST observations are excluded to eliminate the diurnal variation caused by solar heating of the near-surface skin interface (10-20 µm) during the day and to avoid contamination from solar glare. It has been observed that when compared with day-time and day-night blended SST, nighttime SST provides more conservative and stable estimate of thermal stress triggering coral bleaching. The spatial resolution of this dataset is 0.5 x 0.5 degree. The product is updated bi-weekly once on Monday morning and next on Thursday morning. This SST product is used for bi-weekly SST Anomaly product generation. SST Anomaly is recorded for those pixels where the current SST is found to be higher than the long-term (ten years) mean SST or the

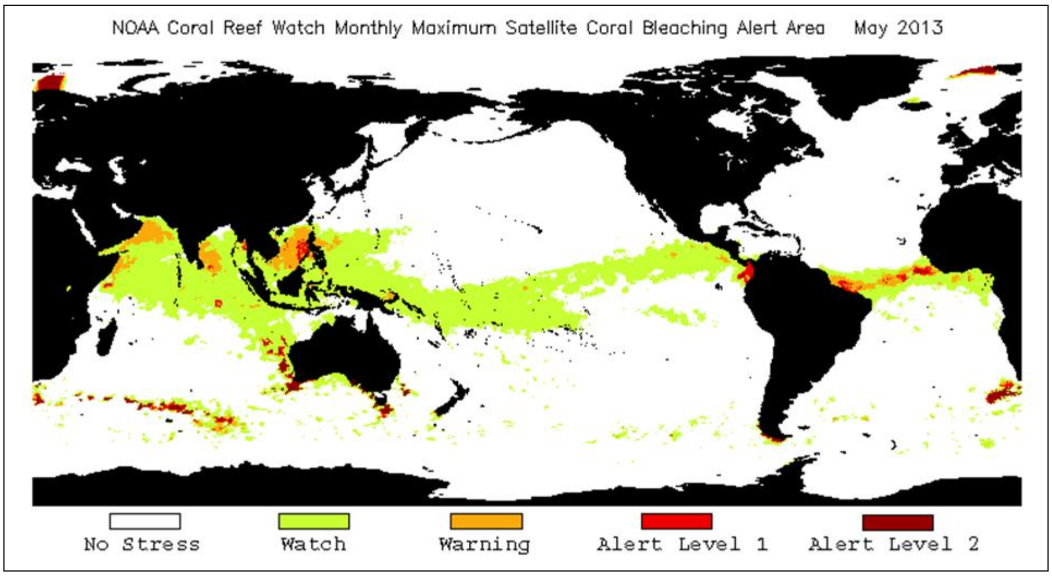

Figure 3: NOAA CRW global product of Coral Bleaching Alert Area for May, 2013, (Source: http://coralreefwatch.noaa.gov/satellite/composites/monthly/images/crw_oper50km_monthlymax_alertarea)

"climatology". This climatology is static in time but varies in space (Liu and Strong, 2003). Next in chain is the concept of 'Bleaching threshold' (BT) which is defined as the SST condition exceeding the climatological mean temperature of the climatologically hottest month (popularly referred to as Maximum Monthly Mean or MMM climatology) by 1° C. Based on this the global Bleaching HotSpot maps/products are generated where pixels equaling BT become Bleaching HotSpot(s) while the rest of the pixels which record SSTs exceeding the MMM climatology indicate only thermal stress. These data products were outcome of works pioneered by Goreau and Hayes (1994) and Montgomery and Strong (1994).

HotSpot values indeed provide a spatial measure of the intensity of thermal stress but do not consider the cumulative effect of that thermal stress on a biological system like coral reefs (Liu and Strong, 2003). In order to monitor this cumulative effect new thermal stress indices like "Degree Heating Month" (DHM) (Goreau and Hayes, 1994), "Degree days" (DD) (Podesta´ and Glynn, 1997) started getting developed (Baker et al., 2008). Liu et al., (2003) developed a Degree Heating Week (DHW) index which measures accumulated thermal stress over a 12-week period by calculating the number of degree-weeks by which SST exceeds the mean annual maximum temperature: 2 DHW is equivalent to either 2 weeks continuous time when the SST remains 1°C above the mean summer maximum or 1 week time when the SST remains 2°C above the mean summer maximum. DHWs have been fairly successful in predicting coral bleaching events barring their sensitivity to the baseline definition of mean summer maxima and have been incorporated into NOAA's CRW programme as an operational product. DHW values reaching 8.0 signal a likelihood of widespread bleaching event followed by coral mortality (Liu and Strong, 2003). NOAA/NESDIS' 'Bleaching Alert Area' maps (Figure 3) classify the global ocean pixels into five classes of bleaching alerts (as No Stress, Watch, Warning, Alert Level 1 and 2). The first two classes consider only HotSpot values while the latter three classes consider HotSpot and DHW criteria in combination.

In July, 2005, CRW launched an automated operational Satellite Bleaching Alert (SBA) e-mail based system for 24 reef sites (subscribed virtual stations) of the world. This attempt demonstrated the potential of synergistic use of space data in near-real time ecosystem management. By 14th March, 2013 CRW has upgraded and expanded their SBA system to include 227 virtual stations across the global reef sites. Three point locations or stations from coral reef regions of India (Lakshadweep, North Andaman and Great Nicobar) have so far been covered in CRW's 227 virtual station's network!

Indian initiatives on Bleaching Forewarning:

As a maritime nation, Indian coast is blessed with strategically located coral reef systems: both in its continental shelf and oceanic settings in Arabian Sea and Bay of Bengal. Amidst the threats of coastal development, fringing reefs thrive in Gulf of Kachchh and Gulf Mannar while far from the Indian peninsula, Indian island groups of Andaman and Nicobar and atolls of Lakshadweep foster great reef biodiversity. Indian coral reefs share sixty genera of reef-building corals out of one hundred and eleven genera reported in the world (Venkataraman, 2003) and thus share 54% of global coral diversity at genera level. Indian coral reefs have experienced twenty-nine widespread bleaching events since 1989 with intense bleaching in 1998 and 2002 (Vivekanandan et al., 2009) and in 2010. Reefbase data of worldwide bleaching records classify Andaman, Gulf of Mannar and Lakshadweep reef regions as sites of high bleaching events while already degraded reefs of Gulf of Kachchh are depicted as reefs recording medium to low bleaching (Figure 2). The unprecedented MCB event of 1997-98 had greatly destroyed the live coral cover of shallow water coral reefs of India (Wilkinson, 2000; Venkataraman, 2011). Field surveys conducted during or after the bleaching events reported a 20% to 30% reduction of live coral cover in Gulf of Kachchh and Gulf of Mannar, 20% to 30% in Lakshadweep and less than 10% in Andaman and Nicobar Islands (Venkataraman, 2011). In the last decade Indian reef regions experienced local to regional scale, severe bleaching episodes during 2002 (Gulf of Mannar: Kumaraguru et al., 2003; Andaman: Krishnan et al., 2011), 2004-05 (Gulf of Kachchh: Bahuguna, 2008) and in 2010 (Andaman: Krishnan et al., 2011; Lakshadweep: Ajith Kumar and Balasubramanian, 2012).

Space Applications Centre (SAC) of Indian Space Research Organisation (ISRO) has developed a two-stage conceptual model on coral reef health (Ajai et al., 2012; Bahuguna et al., 2008). This two-stage Coral Reef Health Model has been conceptualized and designed to assess reef health using an archive of multi-spectral IRS satellite imageries as well as field / *in situ* data. In order to evolve a multi-metric, holistic approach to test the diverse conditions of Indian coral reef regions, certain ecological as well as environmental parameters have been chosen as Operational Ecosystem Reference Points (OERPs) in the design of Coral Reef Health Model. In this model, ecological and environmental parameters in the form of Operational Ecosystem Reference Points or OERPs, collectively define a Reef Health Index (RHI). On the basis of RHI, an early Warning Index (WI) can be generated using the environmental parameters for the concerned reef in order to adopt proper management action. Conceptually the model involves critical reef health parameters for Indian reefs and can assess reef health considering both reef-habitat and

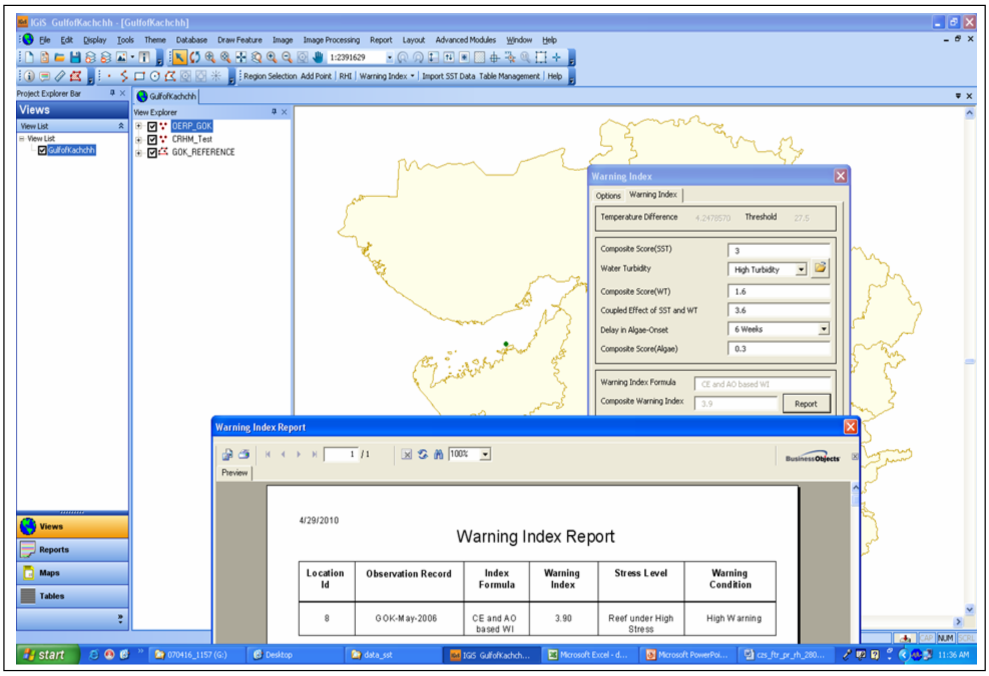

Figure 4: Screen-shot of Coral Reef Health Model run on IGIS software and generation of Warning Index Report (Source: Ajai et al., 2012).

environmental conditions.

The OERPs have been classified into Environmental, Ecological and Damage Indicators. Each OERP has been assigned a weightage (Wt) that adds up to 100% scaled to 1 for simplifying the computation purpose. As per the scaled condition of the parameter, each parametric condition is then ranked into categories. Rank x Weightage gives Composite Scores (CS) of OERPs that go as an input to generate the respective indices. In the first stage, the model computes a 7-parameter based Ecological Index and 4-parameter based Damage Index. Additively these two indices give a holistic statement on reef health condition in the form of Reef Health Index (RHI). The model can also generate a 3- parameter based Warning Index for the stressed, degrading and degraded reefs specifying different levels of alert actions for reef managers and planners.

The model has been customized on IGIS software platform using Visual Basic scripting language and Visual Basic Development Tool (version 6.4). User can run, prepare and provide inputs to the model and generate Report on Reef Health Index (RHI) and subsequently on Warning Index (WI) for particular point-location of the concerned reef (Ajai et al., 2012; Figure 4). The report has the provision of hard copy printing as well as e-mail attachment. This multi-parameter based reef health model concept is first of its kind in the world. The model has a potential to be operationally utilized for generating periodic reef health bulletins. This multi-parameter, reef health model concept is first of its kind in the world as it considers the impact of oceanographic parameters concurrent to the ecosystem health unlike bleaching forecast models focusing only on SST parameter.

Indian National Centre for Ocean Information Services (INCOIS), Hyderabad has experimentally established a Coral Bleaching Alert System link (http://www.incois.gov.in/Incois/coralwarning.jsp) under Advisory Services based on NOAA’s CRW product generation protocols. Bi-weekly products of HotSpot (Figure 5), DHW (at 1° x 1° and ~ 0.5° x 0.5° resolution) and time series plots of SST, generated from NOAA AVHRR daily night-time SST are available since 2010 for the five major coral reef regions of India. Web-

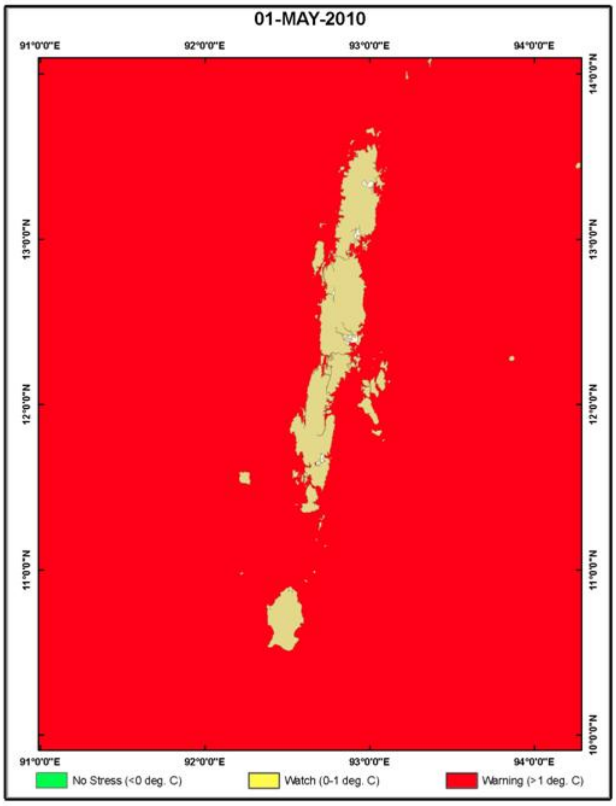

Figure 5: HotSpot Map of Andaman Islands showing Warning status during Mass Bleaching episode of April-May, 2010 (Source: http://www.incois.gov.in/Incois/coralwarning.jsp)

release of the complete annual cycle of DHW and time series SST plot products from 2011 to 2013 is however awaited from this link.

Currently SAC, ISRO is working towards determining region-specific, bleaching thresholds for Indian coral reef regions by analyzing historic SST datasets following MMM climatology and MMMmax climatology models. Considering the current scenario of ocean warming there is a definite need of defining a more dynamic Bleaching Threshold as compared to the existing, static threshold. A more robust satellite bleaching alert system can be developed based upon these dynamic bleaching thresholds which will take into account the spatio-temporal variability of regional responses to global bleaching events.

Bleaching prediction: Trajectories for future

The field of bleaching prediction whose theoretical and operational development spans over two decades is still evolving. The significant challenges this young field encounters today come from a wide array of unanswered questions. The predictive power of global bleaching from satellite observations is continuously debated with respect to spatial and temporal resolution of the input data, climatology and observational time period (Logan et al., 2012; Donner, 2009). The usage of static thermal threshold (i.e. 1° C above climatological summer maximum) under MMM climatology model of bleaching prediction has already been challenged by an alternate method of MMMmax climatology (Donner, 2009) which shows greater robustness in terms of variability statistics (Logan et al., 2012). Predictive modeling of mass bleaching gets also limited by i) insufficient real time data of *in situ* seawater temperatures corresponding to satellite SSTs during bleaching events; ii) marginal knowledge on species specific bleaching response; iii) decoupling capability of thermal stress from other, coincident environmental stresses like photo-bleaching, pollution, diseases, etc.

Prediction of recurrence frequency and intensity of global mass bleaching events has found a new dimension in climate modeling when analysed in the light of coupled atmosphere-ocean General Circulation Models (GCM) and IPCC (Intergovernmental Panel on Climate Change) projections on different climate change scenarios. The model outputs have indicated that mass bleaching of corals remains the most severe threat for global tropical reefs for the next thirty to forty years even under the most optimistic climate scenarios (Donner, 2009; Veron et al., 2009; Baker et al., 2008; Hoegh-Guldberg et al., 2007; Donner et al., 2005; Sheppard, 2003; Hoegh-Guldberg, 1999). Global mass bleaching episodes have coincided with intensified El Niño-Southern Oscillation (ENSO) events: the principal source of inter-annual global climate variability (Lough, 2011; Parry et al., 2007). Projected frequency of mass bleaching episodes breaching the recurrence interval of ENSO events however remains an interesting debate. Another aspect that needs crucial attention in future bleaching modeling and predictions is adaptation and acclimatization of corals and their endo-symbionts to thermal stress (Thompson and Woesik, 2009, McClanahan et al., 2007).

Forewarning of mass bleaching events presents a horizon of hope for the people associated with the protection aspect of this beautiful but fragile ecosystem: the reef managers. Improvisation in the existing models of bleaching prediction is always a welcome step to ensure timely and effective management strategies for real-time ecosystem management. From management perspective, mass bleaching events consequent upon climate-driven warming rather present a limited capacity to reduce perturbations or disturbances on reef ecosystem (Mumby and Steneck, 2011). However, at the same time its forewarning on a spatial framework can help in planning complementary approaches (like reducing human stress, physical closure of the protected reef area, ecological interventions like reduction in sea urchin population, etc.) to speed up reef recovery and strengthen resilience in the long run.

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Early Warning Systems – Cyclone Tracking, Prediction and Alerting

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Weather related Natural disasters come in a variety of shades and forms viz. drought, landslides, cloud bursts, cyclones, torrential rains, earthquakes, volcanoes, tsunamis, heat waves and so on. Each of these has an extremely destructive and devastating impact on humans, animals, infrastructures, land resources, biodiversity and ecology. To rein in the negative impact of each of these disasters early warning systems need to be positioned such that the damages are minimized and disaster mitigation is well organized. The table below indicates the rising trend of number of affected people in Asia and Pacific region due to natural disasters.

> *We cannot stop natural disasters but we can arm ourselves with knowledge: so many lives wouldn't have to be lost if there was enough disaster preparedness*
> - ***Petra Nemcova***

In today's technology driven world the early warning systems comprise of satellite data in real time, indigenous knowledge, geographic information systems, remote sensing techniques and communication mechanisms like the web, emails and SMS.

All Early Warning Systems (EWS) must address "five Ws" (Glantz 2004):

1. What is happening with respect to the hazard(s) of concern?
2. Why is this threat in the first place (i.e., what are the underlying causes for potential adverse impacts)?
3. When is it likely to impact (providing as much lead time as possible to at-risk populations)?
4. Which are the regions / locations most at risk?
5. Who are the people most at risk (i.e., who needs to be warned)?

To be effective, EWS must be people-centered and must integrate four elements:

1) Knowledge of risks

2) Technical monitoring and warning service

3) Dissemination of warnings to those at risk

4) Public awareness and preparedness to act (UN 2006).

Failure in any one of these four elements may cause failure of the entire Early Warning System (Grasso 2012).

World Meteorological Organization

The World Meteorological Organization (WMO) helps coordinate the efforts of national governments and supports climate monitoring through the Global Observing System, the Global Telecommunications System and the Global Data Processing and Forecasting System. The WMO's observing system includes 14 satellites, more than 10000 manned and automatic surface weather stations, 1000 upper air stations, some 7000 ships, 100 moored and over 1000 drifting buoys, and hundreds of weather radars measure daily key parameters of the atmosphere, land and ocean surface. In addition, over 3000 commercial aircraft provide more than 150000 observations each day. Through establishment of standards, guidelines and procedures for collection, quality control, data formatting and archiving data, the WMO has further helped national governments enhance EWS capacity (Jones and Mason 2012). The WMO is currently trying to strengthen climate observations, research and information management systems by creating a Global Climate Services Framework. The primary goal of the Framework will be to ensure greater availability of access to and use of climate services for all countries (WMO 2011). While this information can be used to support EWS, strengthening EWS is not a specific goal of the Framework.

Tropical cyclones (TCs) are the most powerful and destructive meteorological systems that severely impact the life and property due to high torrential rains, high winds, surge and flooding. Information related to Tropical cyclones is extremely useful to various user communities and also to the Disaster Management System. The prior information of the cyclone evolution can be used as an alarm for the alert and taking precautionary measures. Accurate prediction of Tropical Cyclogenesis, structure, intensity changes and track is critical to civilian activities,

Figure 1: MOSDAC home page with cyclone warning for Mahasen

offshore operations, and naval missions in coastal areas. Also, extending the lead time and reliability of cyclone forecasts is important for saving lives and reducing economic damages. Timely availability of the information about cyclone formation probability (the cyclogenesis) in the Indian Ocean, location and intensity of cyclones, and predictions of their tracks can have significant impact on the decision making at the time of cyclone-related hazards. There is a serious need to develop a platform that can provide up-to-date, and accurate information on various parameters of a cyclone in real-time. It is also necessary that such information is easily comprehensible by a variety of potential user groups.

Keeping in view the above requirements, Space Applications Centre has developed a real-time, web-based system for monitoring and prediction

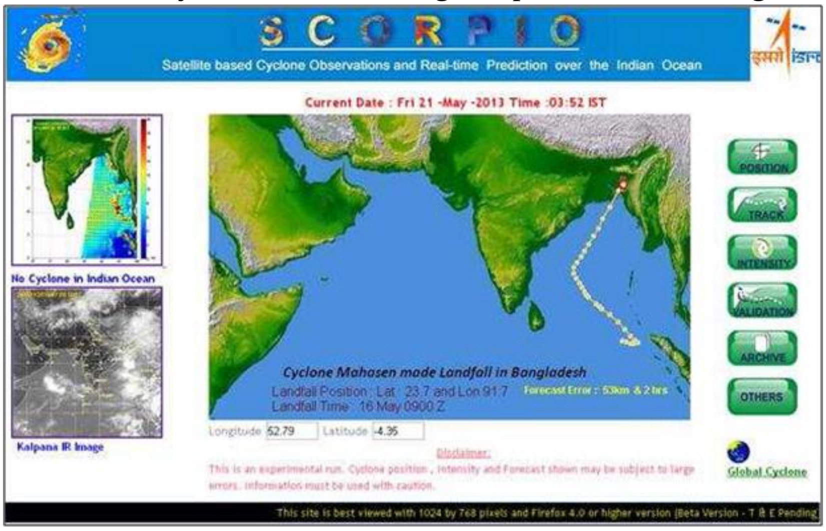

Figure 2: SCORPIO home page with Mahasen cyclone track

of tropical cyclones over the Indian Ocean, and is nicknamed as SCORPIO (**Satellite based Cyclone Observation and Real-time Prediction over Indian Ocean**) and hosted on www.mosdac.gov.in. Considering the criticality of timeliness for cyclone warning and prediction, the SCORPIO system is designed to operate in near total automation. The automated processing of Oceansat-2 scatterometer (OSCAT) derived wind fields for the North Indian Ocean is used to predict the genesis of the tropical cyclone system with a lead time of ~60–90 hours. Oceansat-2 is ISRO's second satellite in the series of Indian Remote Sensing (IRS) satellites dedicated to ocean research, launched on 23rd September 2009. This lead time or early warning of 24 – 90 hours helps to reduce the impact of cyclone-related hazards.

SCORPIO web site: Major components of SCORPIO system are the following: (a) detection of cyclogenesis over the Indian Ocean using round-the-clock automated analysis of OSCAT surface wind vectors. Once a convective system is detected to be a potential case of cyclogenesis, a number of other algorithms are activated that include (b) fixing the location and estimation of intensity using 30-minute KALPANA infrared images, and (c) prediction of the cyclone track for up to 120-hours using a Lagrangian Advection Model that uses high resolution (0.5°) global forecast model fields as input. Algorithms required to implement steps (a) to (c) have been developed at the Space Applications Centre during the past many years and have been thoroughly tested for the real-time cases, and are constantly updated for the new satellite sensors.

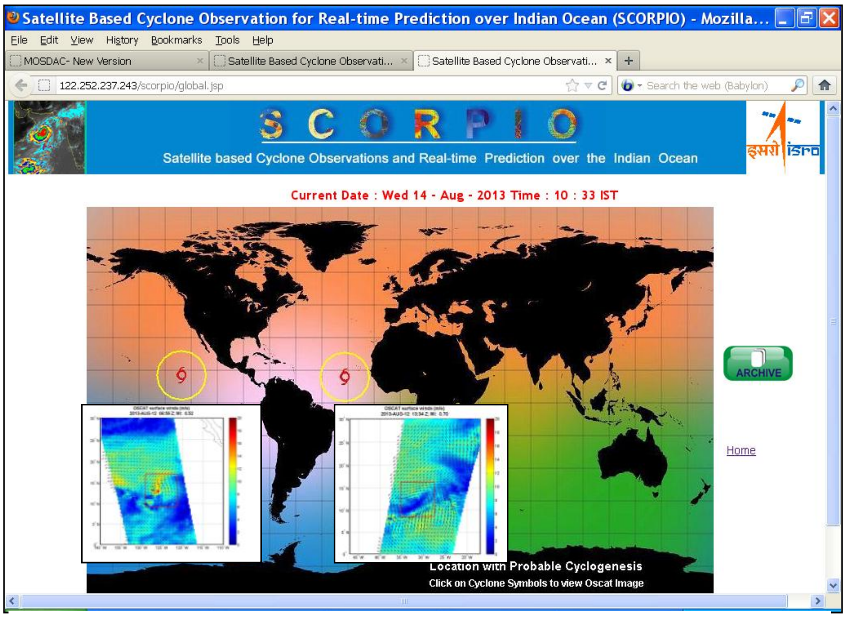

Figure 3: Global cyclogenesis page

SCORPIO also operates in the global ocean for cyclogenesis prediction only. Recently the process of generation of automatic alert messages on MOSDAC website home page as well as disseminating the cyclone warnings through e-mail to select user-groups is implemented in SCORPIO. In the future SCORPIO will be integrated with a GIS based system which will give an estimate of the affected cities, area of cities, total infrastructure damage, estimated damage to agriculture at district level etc.

Validation Table for Tropical Cyclone MAHASEN w.r.t JTWC Real-Time Reported Observed Values

Forecast Track Error (km) by Coupled-HWRF Model and JTWC Forecast at Same Valid Time

Forecast Initial Time	10 May 18Z		11 May 18Z		12 May 18Z		13 May 18Z		14 May 18Z		15 May 18Z	
orecast Hour	HWRF	JTWC	HWRF	JTWC	HWRF	JTWC	HWRF	JTWC	HWRF	JTWC	HWRF	JTWC
12	118.73	86.39	122.80	70.51	70.17	39.50	43.12	44.53	38.85	61.51	146.01	179.09
24	88.96	83.85	133.92	132.78	151.34	127.16	54.85	88.55	68.76	139.90		
36	95.13	77.44	178.78	119.39	203.41	130.84	38.82	134.60	259.61	370.57		
48	198.12	119.44	303.63	129.73	262.52	101.93	22.24	207.21				
72	472.38	630.12	453.50	536.84	334.44	394.49						
96	726.52		564.13									
120	1020.15											

Landfall Position Error: 53 km [wrt. 14 May 18 Z forecast]
Landfall Time Error: 3 hours

Forecast Track Error (km) by SAC-Lagrangian Advection Model and JTWC Forecast at Same Valid Time

Forecast Initial Time	11 May 00Z		12 May 00Z		13 May 00Z		14 May 00Z		15 May 00Z	
Forecast Hour	SAC-Model	JTWC	SAC-Model	JTWC	SAC-Model	JTWC	SAC-Model	JTWC	SAC-Model	JTWC
12	185.37	95.30	86.43	163.73	107.43	112.40	41.21	76.02	17.01	34.99
24	147.79	46.86	127.14	152.05	171.01	185.07	34.27	107.28	56.95	157.06
36	203.96	49.57	227.55	85.3	172.55	145.02	27.20	157.95		
48	242.37	80.82	271.46	86.3	200.82	129.71	24.66	282.81		
72	261.71	755.47	379.43	448.87	177.47	301.56				
96	113.50		373.95							
120	51.44									

Landfall position Error: 53 km [wrt. 15 May 00 Z forecast]
Landfall time Error: 2 hour

Figure 4: Validation results of Mahasen Cyclone

Recently Tracked Cyclones: SCORPIO site was made operational from April 2011. During the period from April 2011 till August 2013, SCORPIO has tracked four cyclones in Real-time in the Indian Ocean namely 'Thane', 'Nilam', 'Murjan' and 'Mahasen'. The track forecast position validation results for each day forecast are also available on the SCORPIO website.

CONCLUSION:

Looking into the number of cyclones forming in the Bay of Bengal and Arabian Sea it is extremely essential to have such automated warning systems that form an essential Decision Support System to Administrators. Also, GIS based systems with up to date geo databases, land use maps and collateral data sets provide a framework for assessing the damage, estimating the loss in produce/crop and quantifying the mitigation efforts. Human lives and animals can be saved, and safer farming land can be identified and developed.

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Disasters due to Oil Spills: Use of satellite data and Numerical Models in predicting Dispersion

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INTRODUCTION

About 4 million tonnes of oil contaminate the world's ocean each year. Around a half is derived from shipping and other marine activities and half from land-based sources. Large spills of oil and related petroleum products in the marine environment can have serious biological and economic impacts. Public and media scrutiny is usually intense following a spill, with demands that the location and extent of the oil spill be identified. Therefore, the detection of oil slicks is an important objective for both exploration and environmental applications. For exploration, persistent and recurrent oil slicks can point to the presence of undersea oil seeps; and for environmental applications, early detection of anthropogenic oil slicks can make possible timely protection of critical habitats and help identify pollutants and their sources. Natural seeps may be a boon for oil companies looking for new deposits to tap, but harmful for marine life. Oil spills continuously pollute marine environments and pose a big threat towards marine and coastal ecosystems. Although, the accidental seepages contribute only 7% of the total marine oil pollution on a global basis, they spill out an enormous amount of oil in relatively lesser time. Accidental 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. Therefore, there is a need to find methods to detect and monitor oil pollution, in an efficient and cost effective way. Remote sensing has proved to be an excellent tool for this. Traditionally aircraft and ships have carried out monitoring, but since the task needs large spatial and temporal coverage, this is both difficult and expensive. Satellite imagery has the ability to look at large areas in an effective way with a reasonably good frequency. Oil slicks on the open ocean can be detected and monitored using remote sensing techniques round the clock. With knowledge of slick locations and movement, response personnel can more effectively plan countermeasures in an effort to lessen the effects of the pollution.

DETECTION OF MARINE OIL SPILL

Multispectral image

Oil-spills in marine environment has a complex optical property where high absorption is observed in the shorter wavelength region while high Fresnel's reflectance exists at the air-oil interface due to high refractive index of the oil. Another major physical, thereby optical alternation of sea surface by oil-spill is the dampening of sea surface roughness due to its high viscosity. Rather than any unique spectral signature, oil-spills in optical images are mostly observed to cause either enhancement or reduction in radiation compared to the surroundings.

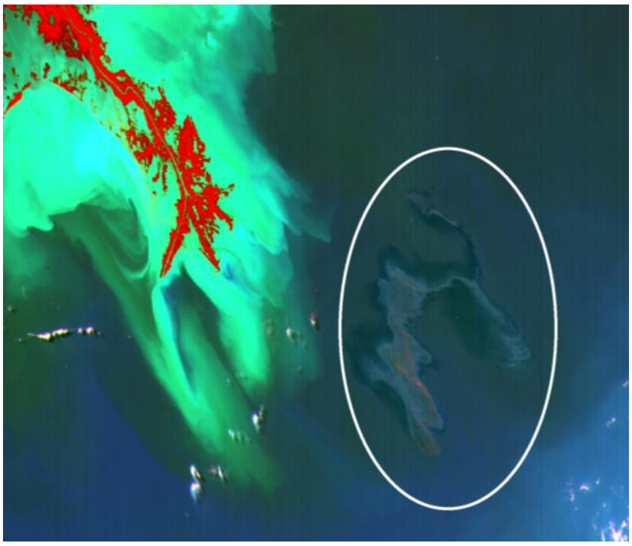

Figure 1: False Color Composite of OCM over Gulf of Mexico on 20 April 2010; inset showing the oil-spill region

Slick surface has a different probable distribution of facet slope involved in specular reflection of sunlight towards the sensor and they modify the reflected radiance pattern by narrowing it angular distribution.

OCM-2 image of 25 April 2010, over Gulf of Mexico subsumed the region affected by Deepwater Horizon (DH) accidental oil-spill (Fig. 1). The DH oil-spill also referred to as the Gulf of Mexico oil-spill, is an accidental oil-spill in the Gulf of Mexico.

Water leaving radiances (L_w) are computed for each spectral bands using a new approach, in which the aerosol path radiance (L_a) is calculated for the region excluding the oil affected region and L_a is spatially interpolated and atmospheric correction is done. Percentage of variation in L_w along the transect AB in Fig. 2(i) from the mean value of L_w in the unaffected region is computed and plotted in Fig. 2 (ii). For the NIR bands the enhancement in the radiance are of the order of 100 % at the oil-spill region. The other spectral bands also shows similar trend in variations, but the range are very small compared to that of NIR bands and are not shown in the figure.

The spatial profile shows concurrent positive and negative contrast made by the oil-spill. The arrow mark within the figure shows the region where negative contrast is observed. The dark and bright region of the oil-spill is observed from figure 3 (i), showing band-7 of the OCM image. Dark region is observed to be all along the periphery of the oil affected region.

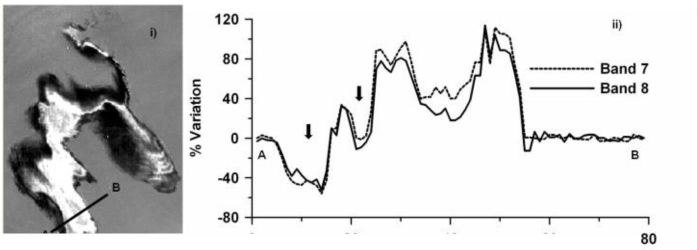

Figure 2: i) Band 7 of OCM depicting the oil-spill region ii) percentage of variation in the water leaving radiance at NIR bands for each pixels along the transect AB

Contrast is defined as the difference between the radiance at the spill region and the clear ocean water which is normalized to the radiance at the clear ocean water. The calculated spectral variation of contrast for the brighter and darker spill region is given in Fig. 3. Even though the ranges are different, the contrast form a mirror like representation of each other, with higher contrast (both positive and negative) at longer wavelength with maximum at 745 nm and lower contrast at the shorter wavelength region.

With the same look angle and illumination conditions, DH oil-spill is observed to show both negative and positive contrast. The differences in the oil-water interface have possibly influenced different contrast among the oil-spill regions. Oil-spills forms emulsions with marine water or can form a thin surface layer over the ocean surface. The two possibilities alter the optical properties of the marine water in different ways. Emulsions have higher Fresnel's reflection, and at the air-oil interface high reflection might occur which enhance the sensor received radiance. When oil forms a surface layer, it reduces the surface roughness and thus decreases the sun glint reflected towards the sensor (particularly for this specific scene where the sensor is away from the direction of specular reflection).

Synthetic Aperture Radar

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

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

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

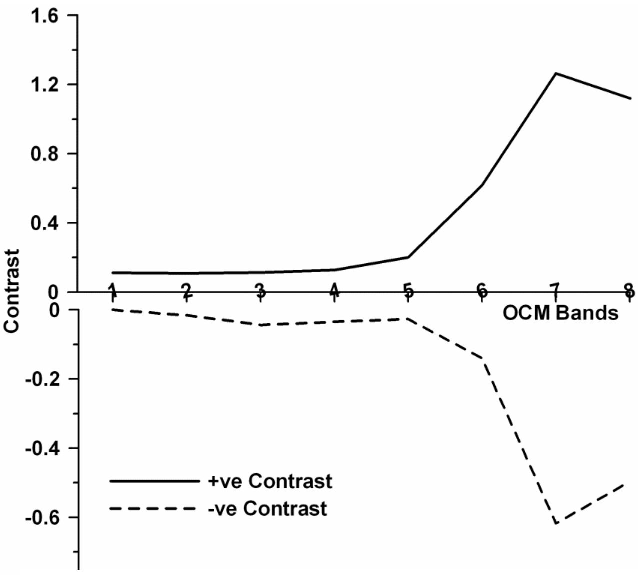

Figure 3: Contrast calculated for brighter and darker regions within the oil-spill

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 can also be 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 may 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 using SAR images (Fig. 4). Dark spot detection is followed by feature extraction. Features of the dark spot are grouped into three, 1) shape: representing the geometry and orientation of the slick, 2) contrast or homogeneity: referring to the physical behavior of the spill and the 3) contextual features. Classification techniques are developed to discriminate the dark region into oil spill or lookalike based on the characteristics of the features extracted from the 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.

PREDICTING DISPERSION USING NUMERICAL MODELS

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.

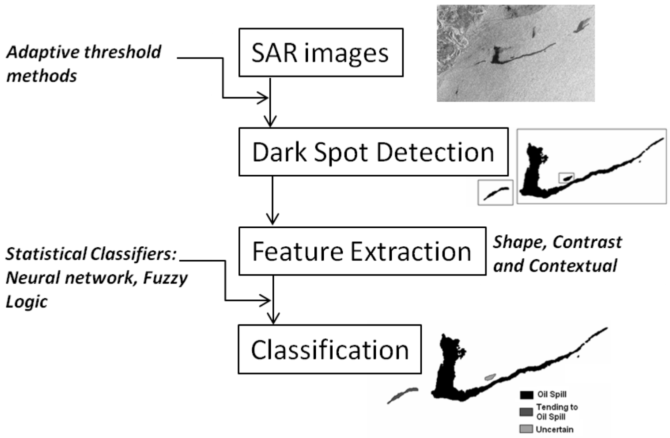

Figure 4: Schematic diagram for oil spill detection using SAR images

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 was carried out 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.

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

MIKE-21 SA (Spill Analysis) module is used to simulate the trajectory of the accidental oil spill. The currents in the near shore region have been simulated using MIKE-21 HD (Hydrodynamic) module. Digital hydrographic chart from CMAP is used to create the bathymetry for the region. Tidal elevations (predicted using FES-99) and NCEP model winds have been given as the open boundary conditions.

RESULTS

Oil spill simulation studies have been carried out

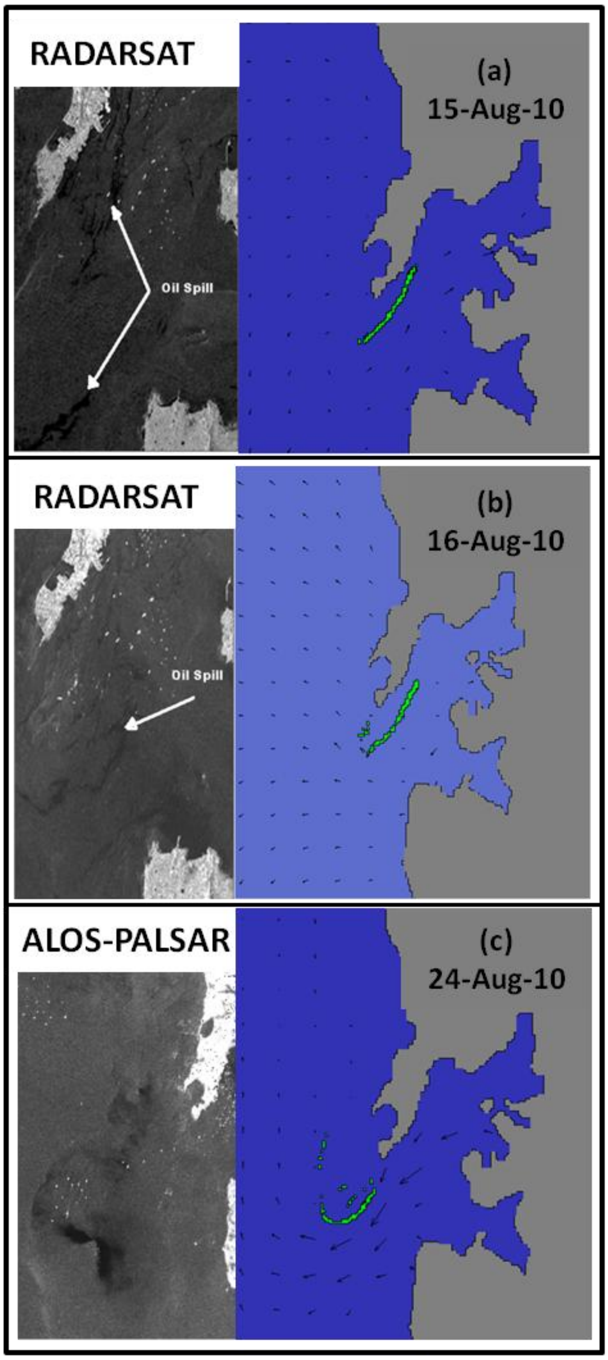

Figure 5: Oil spill detected from SAR images and corresponding simulated spill trajectories. a) RADASAT SAR; 15-Aug-10. b) RADARSAT SAR; 16-Aug-10. c) ALOS PALSAR; 24-Aug-10.

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. Fig. 5 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 have been observed within the creeks of Mumbai. The model also has recreated the spill scenario, where the spills are 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 has been 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.

The data needs for oil spill detection are for all time, all weather conditions with high frequency coverage. The geostationary satellites like NOAA (AVHRR) provide information but the spatial resolution becomes a limitation and only very large oil slick dispersions can be detected. The available polar satellite data excludes ultraviolet portion due to the problem of atmospheric scattering. At present, data in UV provides useful information from airborne platforms to detect oil slicks and limited studies have reported detection of oil spills from other parts of the optical region. Thermal IR as well passive microwave data also has constraints of spatial resolution, although for large oil slicks their potentials have been demonstrated. Radar optimised for oil spills is useful in oil spill remote sensing, particularly for search of large areas and for night-time or bad weather work. However, the technique is highly prone to false targets and is limited to a narrow range of wind speeds.

Flood Forecasting using inter-gauge relationship for small un-gauged catchment of India

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ABSTRACT

Flooding has been considered as one of the most dangerous and costly disaster in terms of property damage and human casualties. Flood forecasting system can help in controlling damage by giving prior warning to concerned authorities. In presented research work, Flood forecasting model has been developed for Lower Tapi Basin, India which has suffered severe flooding causalities at regular interval. flood calculation and gauge to gauge relationship has been established using manning's formula for developing flood forecasting model. The whole system or module is developed in C# computer programming with ASP.net framework. The methodology has been applied for a pilot ungauged watershed Varekhadi in lower Tapi basin India. The developed model is validated between two gauge stations i.e. Visdalia and Godsamba for 2011 Monsoon data. It has been observed in research that when the current water level at Visdalia is 2.5m and the increment of water level at godsamba is 3.42 m after water reach there in 3.15 hours which is within.

INTRODUCTION

In India most of the watersheds up to 500km2 geographical area can be classified as ungauged catchments (Singh et al 2011). These watersheds have no past data records on depth, discharge and rainfall. The development of relationship between rainfall-runoff and flood forecasting systems are limited. Research literature cites few methods on flood forecasting for ungauged catchments, which retired to understand the hydrological process and behavior of the catchment. There are difrent methods have been adopted by most of researcher for calculating flood. Caudhary P & Sankarasubramanian A (2009) were used Muskingum rating equation for flood forecasting at Tar-pamlico river basin in North Carolina. They found that model is efficient in developing and updating hourly to daily flood forecast. Tate E, Cauwenberghs K (2010) were described and developed of a new flood forecasting system for Demar basin in Belgium. The system takes telemetry data from a large number of meteorological, hydrological and hydraulics data along with radar rainfall forecasted data. The system is very innovative in terms of fast operation, accurate, real time flood forecasting and flood mapping based on high resolution digital ground model. A flood forecasting system has been developed by

Rahman et al, (2012) using MIKE11 river-modeling for the Jamuneswari river catchment of the Northwestern part of Bangladesh. Solaimani K. (2011) has used one dimensional hydraulics model HEC-RAS for developing a multidate GIS based flood forecasting system. He has produced flood hazard map for diferent return period 2, 5, 10 , 25, 50, 100 and 200 years for Neka river in Northern part of Iran.

Manning's equation has been in continuous use from estimating river stage-discharge and flood forecasting Bao et al. (2011). They used Manning's formula for real-time river stage forecasting for Fuchun rivers and found good correlation in real time flood forecast. Manning's equation which requires determination of physical characteristics of a catchment. Zhang at el. (2004) for research study in Yangtza River, China have estimated hydrological parameters and developed a stage-discharge rating curve using very high resolution quickbird-2 satellite images.

Empirical equations for depth-discharge were developed for two sites viz. Hankou (1.488x106 km^2 area) and Luoshan (1.296x106 km^2 area). Woldemichael et al. (2010) in their research work used satellite based surface water and ocean topography (SWOT) data for estimation of water elevation for large braided river such as Brahmputra. The authors calculated river cross-section using bathymetry data and Manning's roughness coefficient to produce discharge. Manning's equation has been in continuous use from estimating river stage-discharge forecasting. Bao et al. (2011) used Manning's formula for real-time river stage forecasting. They considered Minjiang and Fuchun rivers for analysis and found good correction in real time discharge than river stage forecasting.

The use of remote sensing and GIS for hydrological parameters estimation has increased considerably in recent years. In the research work carried by Maghrebi at el. (2010) and Rahimpour el al. (2006) has developed stage-discharge curve by using fixed-point velocity measurement in open channel through current meter data. Maghrebi at el. (2010) produced isovel contours for estimation of discharge using a single point measurement. They worked with acoustic Doppler current profiler for measuring velocity profiles and then calculating the discharge. The discharge results thus obtained from field measurements have better accuracy as against satellite data. However, it is not possible to measure all hydrological parameters in field at each and every location. Therefore, remote sensing and GIS technology overweight field measurements.

METHODOLOGY & MODEL DESCRIPTION

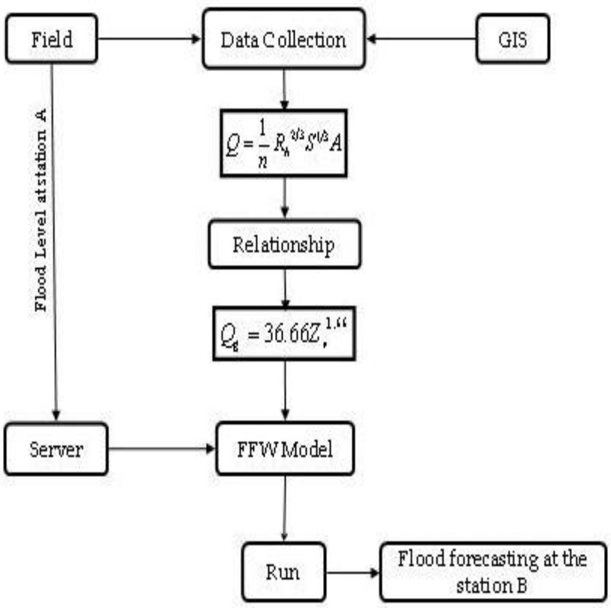

Figure 1: Flowchart of Methodology.

In this research paper manning's formula has been used for flood calculation and gauge to gauge relationship has been used for flood forecasting. The whole system or modular developed in C# computer programming with ASP.net framework. The methodology (fig.1) has been applied for a pilot ungauged watershed Varekhadi in lower Tapi basin India.

There are several flow estimation methods for ungauged catchments such as rational method, SCS-curve number method, cook's method and unit hydrograph method but according to literature review Manning's method is good for discharge estimation in our catchment's physical conditions.

Manning's equation is

$$V = \frac{1}{n} R_h^{2/3} S^{1/2} \text{ ....(1)}$$

Where:

V = Flow Velocity (m/s), R_h = Hydraulic radius, S = Longitudnal slope, n = Roughness coefficient,

The hydraulic radius is a measure of a channel flow efficiency. Flow speed along the channel depends on its cross-sectional shape (among other factors), and the hydraulic radius is a characterization of the channel that intends to capture such efficiency. Based on the 'constant shear stress at the boundary' assumption hydraulic radius is defined as the ratio of the channel's cross-sectional area of the flow to its wetted perimeter

$$R_h = \frac{A}{P} \text{ ....(2)}$$

where:

A = cross sectional area of flow (m^2); P = wetted perimeter of the cross section (m).

If the hydraulic radius is greater, the efficiency of the river channel is also greater and the less likely the river is to flood. Stage-discharge curves have been developed for above two stations using these formulas.

$$Q = V.A \text{ ....(3)}$$

Calculate flow depth at Godsamba from equation-

$$D_g = aD_v - b \text{ ....(4)}$$

Where:

D_g = water depth of Godsamba, D_v = water depth of Visdalia, a,b= coffieceant and their value 1.68 & 0.79 respectively.

This equation calculated the water depth at Godsamba after 3:00 to 3:15 hours (aprox.). In other words, it can be stated that the travel time of water is 3:00 to 3:15 hours. Therefore, flood can be forecasted before 3 hours to manage & settle of the people whose living in low-lying area.

Flood forecasting model at godsamba station has been developed using inter-gauge relationship.

$$Q_g = 36.66 D_v^{1.66} \text{ ....(5)}$$

STUDY AREA

Tapi basin covers a geographical area of 65145 km^2 and is the second largest India's westward draining Inter-state River in Arabian Sea. Basin covers three states having an area of 51504 km^2 in Maharashtra, 9804 km^2 in Madhya Pradesh, and 3837 km^2 in the Gujarat. The Tapi river basin can be classified in three zones, viz. Upper Tapi basin, Middle Tapi Basin, and Lower Tapi Basin (LTB). The area between Ukai Dam to Arabian Sea has been considered as LTB, mainly occupying Surat and Hazira twin city along with tens of small towns and villages along the river course. The Surat and Hazira twin cities are almost 106km downstream of Ukai Dam, and have been affected by recurrence floods. One among the major cause of flood in LTB attributes to early peak discharge from various tributaries such as Varekhadi, Anjana khadi, Serul khadi, Mau khadi, and Gal khadi. Therefore, Vare kadi watershed has been considered as pilot project for establishment of hydro-meteorological network.

Varekhadi watershed a tributary of Tapi river located 40km upstream of Surat city near Mandvi has been a pilot project area (refer Figure 1). The geographic coordinates of the study area are $21^0$14'N $73^0$07'E to $21^0$30'N $73^0$30'E as lower left and upper right corners. The main river has 48km length and occupying geographical area of 437km^2. The watershed has important features including an urban centre Zankhwaw, 150 rural villages, two storage reservoirs (Amli as major and Issar as minor). The estimated reservoir storage capacity of Amli dam has been 37.54 million-m^3 while Issar has very limited capacity. The dam storage has been created through building a dam. The Amli dam is mainly used for irrigation post-monsoon and flood control during-monsoon season. The right bank canal from Kakrapar weir located 30km upstream passes through vare khadi watershed which has around 76km^2 irrigation command area.

The Landsat 7ETM+ satellite derived land cover categories in the watershed has been built-up (4%), agriculture (32%), forest (29%), fellow (14%), water bodies (2%) and waste land (20%) as derived by Singh et al (2011). The field derived soil type and soil texture analysis for 32 samples analyzed in laboratory classify the watershed into two hydrological soil groups B and C (Singh et al, 2011). The estimated monsoon season annual rainfall has been 1376mm, minimum and maximum temperature of 22°C and 40°C respectively. The relative humidity values in the watershed have been 89% and 32% as maximum and minimum limits.

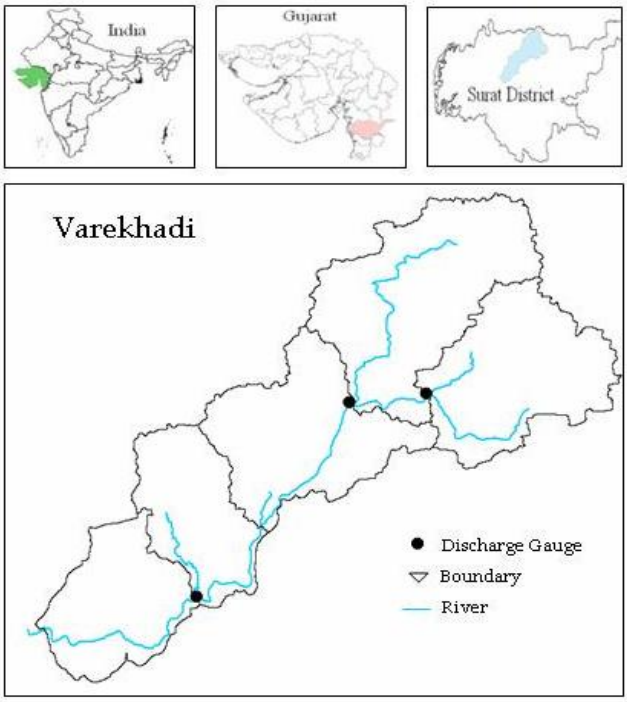

Figure 2: Study area (Varekhadi).

As described earlier, quick flood response from Vare khadi watershed has been a problem leading to floods in low laying areas near Wareli village at the confluence of Vare khadi and Tapi River. The August 2006 flood in Surat and Hazira towns has been attributed to quick response from major sub-watersheds/ tributaries resulting 300 people being killed and US$ 4.5

billion value property damage (Singh et al, 2009).

FLOOD EVENT OF 7-14 AUGUST 2006

The flood event of 7-14 August 2006 estimated a damage of Indian Rupees 2,420 crore due to flooding of industrial units, damage to the agricultural crops, and infrastructure being washed-away in Surat and Hazira twin cities as well as 13-14 villages along Tapi river. The list of villages being submerged during 2006 floods has been given as Table-3. LTB house several important textile, diamond processing, petro-chemicals, and engineering & logistics. They have been severely paralyzed for almost 10-15 days raising a big question on survival of these industries. The urban residential localities in Surat city located on or near Tapi river bank were severely flooded, swallowing almost 300 human lives and affecting their habitat. The city drainage systems were over flowing owing to high intensity rainfall resulting into over flowing of storm water. In addition, excessive water release from Ukai dam has been carried out, as the reservoir level was touching danger mark. Therefore, dam water release was unavoidable based on old operating rules. The residents in Surat city and 13-14 villages located near Tapi river bank, could not be evacuated on time from low lying areas. The water has been logged in various zones of Surat city such as South zone (Vesu, Athwa), and West zone (Rander, Pankaj Nagar, Jahangirnagar, Palgaon, and Jainwadi) during flood of August 2006.

PARAMETER ESTIMATION

Geo-database

The geo-database for Vare khadi watershed has been created using topological maps, remote sensing images and field surveys. Topographical maps at 1:50000 scales were collated from Survey of India. The topo-maps have been geo-reference, digitized and assigned attribute properties for themes such as contours, level points, streams, and watershed boundary. Landsat 7ETM+ satellite image of 21 Nov 2001 has been used for classification of land use and land cover classes in the watershed. Trimble Geo-explorer XT global positioning system (GPS) has been used for carrying out field surveys along the river channel and data sparse regions in the watershed. A digital elevation model (DEM) for 15m cell size and 2.5m vertical accuracy for Vare khadi has been generated. The accuracy assessment carried on

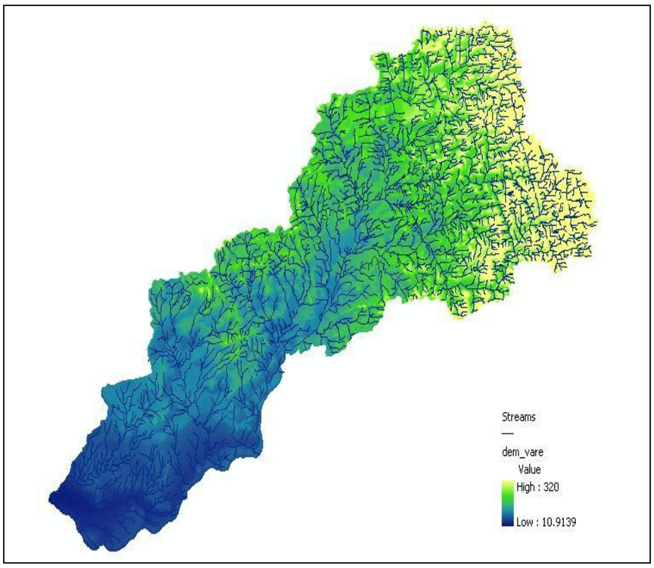

Figure 3: Digital Elevation Model (15m)

DEM for selected locations shows a good fit and has been in coherence with actual elevation values. The DEM has been considered as basis for delineation of sub-watersheds boundary, sub-watershed areas and river slopes. The extracted DEM for Vade khadi watershed along with streams has been shown below in Figure 3.

Installation of Stream Gauge Sensors

Vare khadi has no discharge measurement gauging station and is classified as ungauged watershed. This is being a remote location it has been proposed to install automatic sensors with data logger capabilities. WL-16U stream gauge sensors of 25m cable from Global Water USA were procured and installed in field during June 2010. The sensor has 0.1mm measurement accuracy, and can record 10 reading per second. Three discharge sites viz. Amli, Visdalia and Godsamba have been selected as marked in Figure 1, and considering the site selection criteria as listed under methodology.

It was decided to collect discharge data from all the stations at a time interval of 30sec. The data logger at other end of sensor cable can store up to 80,000 values, which can be imported in laptop computer by connecting through a USB type-B cable. The output data has standard spread sheet format as *.csv (comma separated by values) and output is acquired in excel format using window-XP compatible water level logger software and data import through computer, and installed sensor on bridge peer. The output file can be imported in Microsoft excel or ASCII format for further analysis. The data output can be further imported in major hydrological models for rainfall-runoff modeling.

Filed Surveys

Global positioning system (GPS) having sub-meter accuracy was used for carrying out field surveys. The field surveys were conducted along river course and across the selected river cross-sections. The regions having sparse elevations have been surveyed using GPS having 2.5m vertical accuracy. The river cross sections were surveyed using differential-level having 0.5mm vertical accuracy. The differential leveling has been aimed to achieve the enhanced accuracy in cross-section. The cross-section levels obtained from differential-leveling were integrated into levels for generation of DEM.

The field data collection survey has been carried out for Visdalia and Godsamba using differential level. The cross-section reference levels (RL's) have been plotted for both stations; they are plotted at 3m horizontal interval with chainage on X-axis The river width at Visdalia and Godsamba cross-section was observed as 35m and 45m respectively. The survey findings from

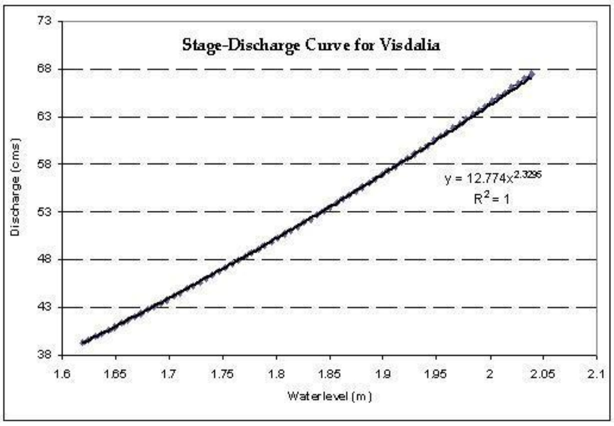

Figure 4a: Stage-Discharge curve for Visdalia

river cross-sections have been employed for development of stage-area, stage-area-perimeter and stage-discharge curves. It was possible to analyze the longitudinal slope between discharge stations. The longitudinal slope and hydraulic radius have been calculated for each section to determine flow velocity based on Manning's equation.

The flow velocity found to be varying and has been in the range of 1.32-1.71m/s for Visdalia and 1.63-2.32m/s for Godsamba. This shows that flow velocity has been in upper range as compared to normal river velocity. It has to be noted that flow velocity increases with increase in river depth, resulting in increased discharge. The river discharge at both locations has been calculated for every velocity, and has been found in the range of 29.50-67.47m3/s for Visdalia and 65.52-162.65m3/s for Godsamba (refer Figure 4(a) and 4(b)).

The root mean square error (R^2) for both stations has been in the same range as depth-area curve. The empirical equations developed for each discharge stations are given below as equation (6) Q_v for Visdalia and equation (7) Q_g for Godsamba;

$$Q_v = 12.77(W_L)^{2.32} \qquad (6)$$

$$Q_g = 13.25(W_L)^{2.62} \qquad (7)$$

Gauge to gauge relationship

The inter-gauge relationship between Visdalia an upstream station at 85m RL and Godsamba a downstream station at 35m RL has been studied. Both the stations are located 17km apart where discharge measurements are being carried out since June 2010. It has been estimated that time

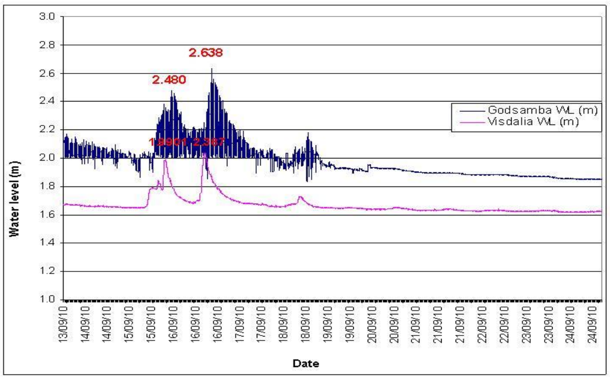

Figure 5: Gauge to gauge relationship.

to flow for various stage levels have been in the range of 1.30hours to 2.32hours depending upon flow velocity. The actual measurements are depicted in Figure 9 below as light dotted line (Visdalia) and dark line (Godsamba).

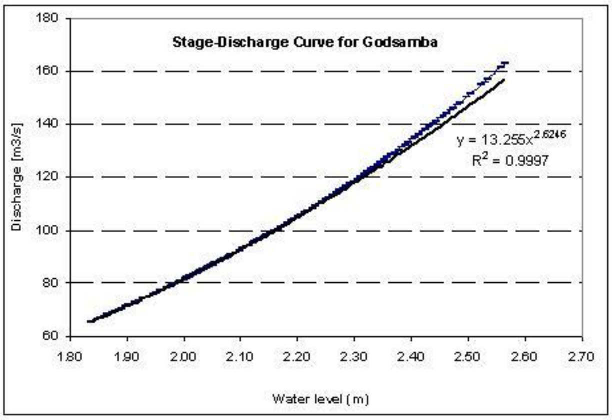

Figure 4b: Stage Discharge Curve for Godsamba

RESULT & ANALYSIS

Table1: Hydrological parameter for 2010 monsoon

Parameters	Visdalia		Godsamba	
	Min	Max	Min	Max
Depth (m)	1.418	2.038	1.84	2.56
Perimeter (m)	54.82	66.83	72.05	75.67
Area (m^2)	22.00	39.45	39.95	69.99
Hydraulic Radius (m)	0.40	0.59	0.55	0.93
Velocity (m/s)	1.32	1.71	1.63	2.32
Discharge (m^3/s)	29.50	67.47	65.52	162.65

The water level data at 2-gauging sites viz. Visdalia and Godsamba have been collected during June-Sept 2010. The river cross-sections at both locations were surveyed using GPS and differential-leveling. Later the depth-area relationship at both discharge stations has been established and equations been developed. The polynomial trend line for both stations shows very good fit having root mean square error (R^2) in the range of 0.9953 and 0.9989 for Visdalia and Godsamba respectively.

Flood forecasting model was developed based on inter gauge relationship between Visdalia and Godsambha bridge site as shown in figure 6.

This model was developed using discharge data

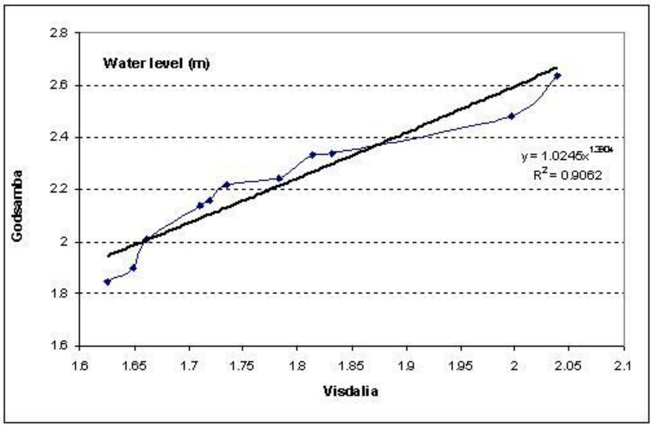

Figure 6: Correlation between to station.

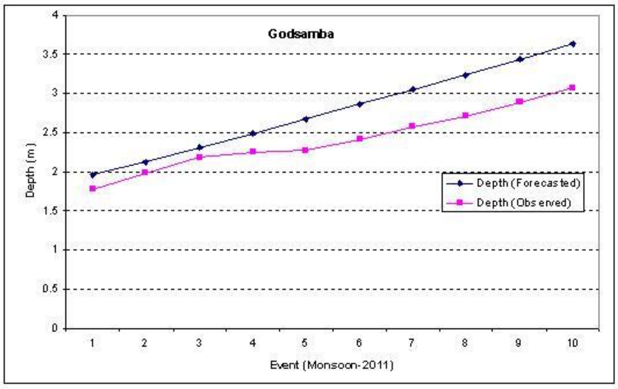

Figure 7: Result validations.

of 2010 monsoon. Later validity of model was confirmed considering various events of 2011 monsoon. After analyzing the output of model and comparing it with 2011 monsoon data, it was observed that model shows good fit as shown in figure 7

CONCLUSION:

Attempt will be made in this research work to develop a Hydrological Model which will help Tapi Basin (flood affected area) in flood forecasting and warning system. Hydrological relationship between various stations will be created in form of mathematical equation. That formula along with database will be used and computer programmed has been developed using ASP.Net.

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Forest Fire Risk Alarm System: An Approach

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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 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. A smaller number of natural fires (or "wildfires") do occur each year, usually started by lightning.

Fire 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 important to also 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 fires occur, and the seasonality of burning. There is consequently the potential for substantial feedback between fire and the environment.

Due to its synoptic and temporal coverage as well as capability to detect active fire and burnt scars satellite remote sensing offer the only practical way to monitor fire activity, study the impacts and support ground operations. One of the most important critical elements of the forest fire management system (FFMS) in the country is the real time detection onset of fire and it's monitoring; study the rate, direction and quantitative estimation of fire spread and amount of smoke emission. However, combining all critical parameters responsible for making conditions conducive for fire through geomatics can enable us in devising country's own fire risk assessments system.

A very helpful component in operational fire risk assessment is the use of remote sensing to detect wildfires in near-real-time as well as to assess those areas already burned for creating a history of fire events. 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). Now with newer generations of satellites, having improved spatial resolution and specific channels for fire detection has aided in the detection of fires on sub-pixel levels. The Geostationary Operational Environmental Satellite (GOES-8) has been used to monitor fires in the Western Hemisphere (Prins and Menzel 1996). The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor have shown 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).

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 is going to help in detecting and monitoring of large scale forest fires, smoke and burn scar over India. The progression of large fire events can be monitored very effectively with such systems as the temporal resolution is 30 minutes. 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 fire risk modeling community.

FOREST FIRE RISK ASSESMENT

The re-occurrences of severe wildfires have highlighted the need for development of effective fire risk assessment models. 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. 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. The most extended and common 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). 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 intensive sampling work. Calibrated sticks may not be well associated to live fuels. 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.

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. Many 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.

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. Therefore topographic and orographic factors along with socioeconomic factors are used in GIS based models to know the static ignition potentials. 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.

Therefore, an integrated system for forest fire risk alarm can be developed along following broad lines:

- Development of dynamic ignition potential model using static and dynamic factors
- Development of remote sensing based fire propagation danger potential index
- Investigating relationship between onset of fire and phenophases of forests

Alarm System: An Approach:

Fire risk could be assessed based on long term history of fire occurrence, location characteristics in relation to vegetation cover and type, climate, topography and socio-economic pressure. Forest fire risk will be derived through remote sensing, GIS, empirical and statistical modelling methods to provide integrated output from time variant and invariant factors. The methodology flowchart is given in fig.1.

The forest fire risks factors fall into two categories:

1. Structural (static) factors

1.1. Topographic factors

1.2. Socio-economic factors

1.3. Fuel types

2. Dynamic factors

2.1. Meteorological factors

2.2. Phenology driven vegetation stress factors

Fuel types, topography, and socio-economic factors will mainly be used for making static fire indices (e.g. fuel type, elevation, slope, aspect and accessibility index). Moreover, 10 years of satellite based active fire history using MOD14 and ATSR/AATSR products will be used in a Climate Space Model (CSM) to come out with probability of fire danger. The model output is expected to take care of recurrent fire incidences.

Dynamic indices which are short-term indices will be used to assess the probability of fire ignition and spread. The fire-ignition potential is one of the critical factors that depend on intrinsic substrate flammability properties and extrinsic factors catalyzing the fire spread. The intrinsic substrate properties depend on vegetation type, phenological patterns, and forest desiccation and fuel load. These factors will be derived directly from meteorological variables, or indirectly by the effect that these variables have on vegetation. Indices that are computed from meteorological variables are referred to as meteorological fire risk indices. On the other hand, the remote sensing based indices that evaluate the status of the vegetation are the so-called vegetation stress fire risk indices. Time series vegetation indices will be used for phenological assessment and spatial pheno-phases will also be used in the model to come out with dynamic ignition potential index. The logical combination of the static and dynamic indices will be used for making fire risk alarm system on daily basis.

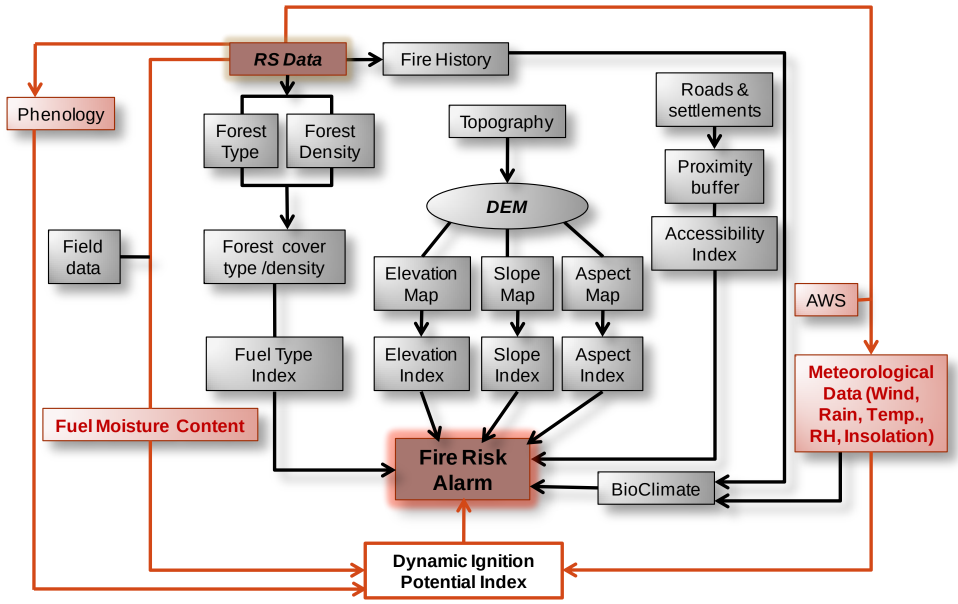

Figure 1: Concept flowchart of Fire Risk Alarm System.

DISCUSSIONS

Managers of forests 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 risk alarm systems, is to get routine (e.g. daily) assessments of fire risk over broad areas encompassing entire forest ranges. Fire risk 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, fuels, 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.

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] can 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 and risk assessment from a very diverse community that includes global and regional modellers 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.

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 risk assessment, 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. The judicious use of satellites and biophysical parameters is a key for the success of such systems.

Finally, for operational fire risk alarm 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.

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Geomatics for Urban Storm Water Management and Modelling

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INTRODUCTION

Urban floods are the floods occurring in urban areas, primarily caused by heavy rainfall overwhelming the capacity of drainage network. Urban areas are paved by roads and are covered by impervious surfaces such as buildings etc. Therefore infiltration into ground water is significantly lowered resulting into increased runoff. This runoff has to be channelled by drainage network for reducing flooding as it is known that if the inflow exceeds the drainage capacity, the excess water may flood the streets and low lying areas in the city.

Urban storm water flow models attempt to simulate the rainfall-runoff processes in urban areas. Urban catchments respond considerably faster to rainfall than rural catchments due to their impervious nature. The existence of surface and sub-surface storm water drainage network drastically alters the flow trajectories in urban areas. Urban storm water flow models therefore invariably includes hydrological models for estimation of surface and sub-surface runoff, and hydraulic models for routing storm water flows through the drainage network.

Storm Water Management Model (SWMM), developed by the US Environmental Protection Agency (EPA), is a comprehensive computer model for simulating hydrological and hydraulic processes operating in an urban watershed. The model however requires detailed information characterizing urban catchments and the underlying storm water drainage infrastructure.

This study developed an approach for simulating rainfall-runoff processes in part of Surat city using SWMM and Geo-informatics. Cartosat-1 Stereo pair was used for deriving Digital Elevation Model (DEM) of the study area, while the merged product of Cartosat-1 PAN with IRS P6 LISS-IV, was used to map land cover at 1:10,000 scale. Remote sensing data along with Geographic Information Systems (GIS) were applied to retrieve various parameters characterizing urban catchment as required by SWMM for dynamic rainfall-runoff simulation in part of Surat city. This article highlights the methods and salient findings of the work related to urban storm water modeling under SAC TDP/R&D project titled “Development of Urban Storm Water Model and Transportation Planning” (Jain et al, 2013).

URBAN CATCHMENT

Urban drainage basin is sub-divided into smaller hydrological units called sub-catchment areas, on the basis of surface topography and drainage system elements. The runoff generated on each sub-catchment area is discharged through its outlet point, to either a node of the drainage network or to any other sub-catchment area. All land parcels in the study area are identified as sub-catchment areas, and discharge their storm water runoff over roads. Roads are further segmented into small sub-catchment areas and their respective discharge outlets are assigned either on the adjoining road segments at lower elevation, or to the nearest drainage network node. Thus, the storm water runoff in an urban catchment originating at land parcels, flows to roads, subsequently enters into the drainage network, and is finally discharged into the river.

RUNOFF ESTIMATION

A sub-catchment area is treated as a non-linear reservoir. The inflow to this “reservoir” is from precipitation, while outflow is commonly in form of evaporation, depression storage, infiltration, and surface runoff. Surface runoff per unit area (Q) occurs only when the depth of water (d) in the "reservoir" exceeds the maximum depression storage (d_p). The outflow due to excess precipitation is computed using Manning's equation as given below:

$$Q = \frac{W}{n}(d - d_p)^{5/3} S^{1/2} \qquad \text{------- (1)}$$

Where, W is the characteristic width, n is Manning’s coefficient of roughness, and S is the slope.

The sub-catchment area is divided into pervious and impervious sub-areas. The dominant pervious and impervious surfaces on each sub-catchment area are used to estimate respective Manning’s coefficient for pervious and impervious surfaces. The percentage of impervious land cover on each sub-catchment is determined from the remote sensing data. Impervious surfaces do not permit infiltration of rainfall into upper soil zone, while in pervious areas infiltration is modelled using Horton’s equation:

$$f = f_c + (f_0 - f_c)e^{-\beta t} \qquad \text{------- (2)}$$

Where, f is infiltration capacity of soil at time t, f_0 is initial infiltration rate, f_c is constant infiltration rate, and β is the decay constant.

A portion of rainfall received by the sub-catchments is stored as depression storage (d_p) in both pervious and impervious surfaces. The depth of depression storage on pervious and impervious surfaces is estimated on the basis of land cover. An impervious area can further have two types of sub-areas, depending on whether depression storage is permitted or otherwise. The area covered by buildings, which is mapped as building footprints using high resolution satellite data, is identified as impervious area without depression storage.

The average percent slope (S) of each sub-catchment is derived from the DEM. The characteristic width (W) of the overland flow path for sheet flow runoff is estimated as ratio of sub-catchment area, to the average maximum overland flow length. The maximum overland flow length is the length of the flow path from farthest drainage point of the sub-catchment before the flow becomes channelized. The obstruction to flow path due to buildings is also considered while computing the flow length.

The depth of water over the sub-catchment (d) is continuously updated with time (t in seconds) by solving a water balance equation over the sub-catchment, and the surface runoff (Q) on each sub-catchment is thus estimated.

FLOW MODELING

The storm water infrastructure comprises of the network of sub-surface drains connected by manholes, which eventually discharges into the receiving water bodies such as Rivers. The storm water flow in the drainage network is modeled as one-dimensional gradually-varied unsteady flow represented by Saint Venant's equations. Saint Venant's equations are approximations of the momentum and continuity equations given below:

1. **Continuity equation**

$$\frac{\partial y}{\partial t} + \frac{\partial (uy)}{\partial x} = q \qquad \text{------- (3)}$$

2. **Momentum equation**

$$\frac{1}{g}\frac{\partial u}{\partial t} + \frac{u}{g}\frac{\partial u}{\partial x} + \frac{\partial y}{\partial x} = S_0 - S_f - \frac{q}{g}\frac{u}{y} \qquad \text{------- (4)}$$

Where, u is flow velocity, y is water depth, x is the distance, t is the time, q is lateral inflow per unit length perpendicular to the channel, g is acceleration due to gravity, S_0 is the bed slope, and S_f is the friction slope. These differential equations of the flow are solved by SWMM using finite difference method.

SIMULATION

The spatial datasets of sub-catchment areas (polygon features), conduits (line features), nodes (point features), and outfalls (point features), are converted into SWMM input file using an interchange tool developed at SAC (**Error! Reference source not found.**). The tool converted the Shape files of input datasets into the input file format (.INP file) of SWMM. The rainfall time series and tidal curves are updated after opening the INP file in SWMM. Simulation

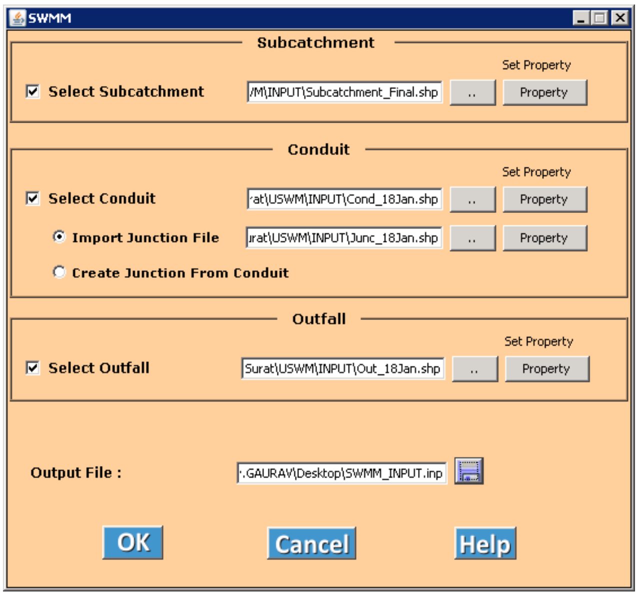

Figure 1: Shapefile to INP conversion tool.

for the period 4th to 6th September 2012 was carried out to estimate sub-catchment runoff, node depth, node inflow, node surcharge, node flooding, link flow, link surcharge, and outfall loading.

SALIENT RESULTS

The study area received 118.0 mm of precipitation during the 72 hour simulation period, which generated 212.8 ha-m of surface runoff after losing 28% of the inflows to evaporation and infiltration. The model further estimated that 25% of the surface runoff entered into the storm water drainage network as wet weather inflow, thereby discharging 65.6 ha-m of storm water to Tapi River. The runoff coefficient (ratio of total runoff to the total precipitation) of vacant land and agricultural areas is less than 0.6 while that for heavily built-up areas and paved roads is more than 0.9 (**Error! Reference source not found.**).

When the water level in a node rises above the top of highest conduit, the closed conduit becomes full and acts as conduit under pressure, leading to node surcharging. Surcharging may increase the capacity of storm water drain, but it is not desirable and serves as a fore-warning for flooding. Further increase in water level may lead to overflow at a node, resulting into flooding and inundation. The model provides an estimate of duration and time of occurrence of surcharging as well as flooding. It was observed that 263 nodes in drainage network out of 356 nodes, surcharged for more than one hour during the simulation period while 19 of these nodes were even flooded for more than an hour. **Error! Reference source not found.** shows that the nodes in upper reaches of the drainage network are more vulnerable to flooding, owing to smaller sizes of the conduits.

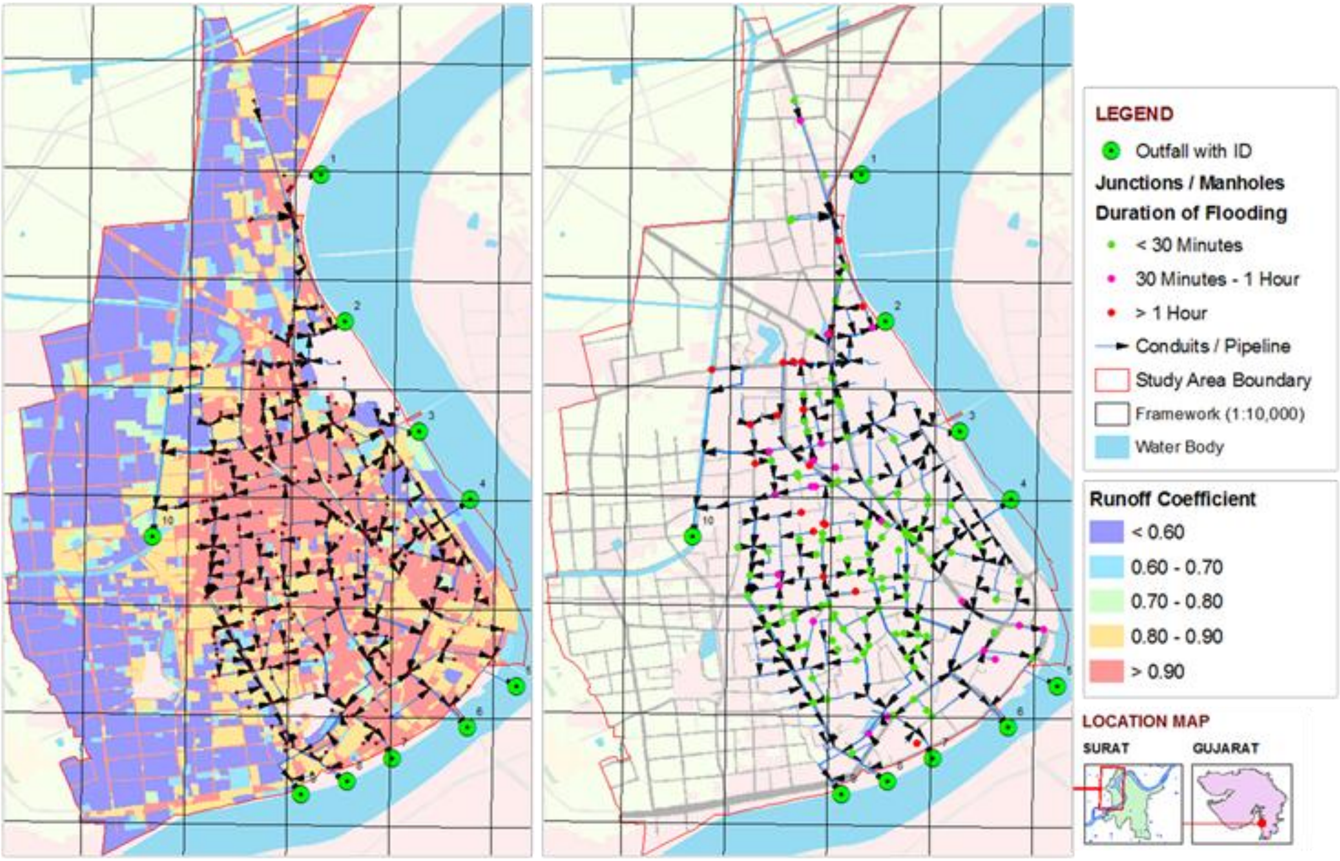

Figure 2: Runoff Coefficient of Sub-catchments and Duration of Flooding at Nodes for South-West Zone of Surat City

WAY FORWARD

Urban storm water flow models may prove to be immensely beneficial in ascertaining the effects of various storm water management strategies, and evaluating the storm- readiness and climate resilience of the cities. The availability of very high resolution images from Cartosat series satellites, coupled with very high resolution DEM as obtained from ALTM, offers opportunities for using space-borne technologies for dynamic rainfall-runoff simulations in urban areas.

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Geomatics in Early Assessment of Himalayan Lakes Outburst Hazards

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INTRODUCTION

In the snow and glaciated regions of Himalayas five major types of lakes can be recognized on the surface: lakes which occur (i) in natural depressions of mountainous terrain and are by fed by snow-melt (ii) in the depressions in the peri-glacial area, (iii) on the surface of the glacier, (iv) at the terminus of the glacier due to damming by the moraines (sediments of large size brought by glacier flow), (v) due to the obstruction of glacier melt of a tributary glacier by glacier ice of main glacier and(vi) in natural depressions that get melt from snow and glacier ice through underground movement of water. Among all these lakes Moraine-Dammed Lakes (MDL) are vital to mankind as glacial lakes outburst floods (GLOFs) caused by this category of lakes are a common phenomenon in the glaciated terrain of the world. These floods can cause extensive damage to the natural environment and human property; as it can drain extremely rapidly and relatively small lake can cause dramatic floods. Many events of GLOFs have been reported in North America, Europe and in the Himalayas. These lakes are located at high altitudes where there are no human activities and as a result growth or decay of such glacial lakes and dangers arising out of it do not come in the view of human eyes.

The expansion or reduction of these lakes can be attributed to rate of glacier melting at the snout. Expanding lakes can also cause further retreat of glaciers due to calving at the snout and the increased heat balance of lakes. Several reports of the retreat of glaciers in Himalayas have come to the light in the recent years. Since many of the Himalayan glaciers are moraine-covered and when debris covered glaciers melt rapidly, a lot of debris accumulates near the snout, which can give rise to formation of newer moraine-dammed lakes.

The problem can be averted with two pronged strategy: a) draining out of lakes slowly and b) generating an alarm to mitigate the disaster and minimizing the risk. It is the availability of high temporal and high resolution images from low earth orbiting satellites, which has revealed the occurrence, expansion or reduction of a large number of such lakes occurring in glaciated terrains. Remote sensing coupled with Geomatics can be efficiently used for spatial and temporal monitoring of high altitude lakes and identifying of the potential lakes which can cause disaster downstream.

ROLE OF REMOTE SENSING AND GEOMATICS

Remote sensing images from high spatial resolution to high temporal images should be effectively used to identify hazardous lakes in order to make mitigation plans. Figure 1 shows a

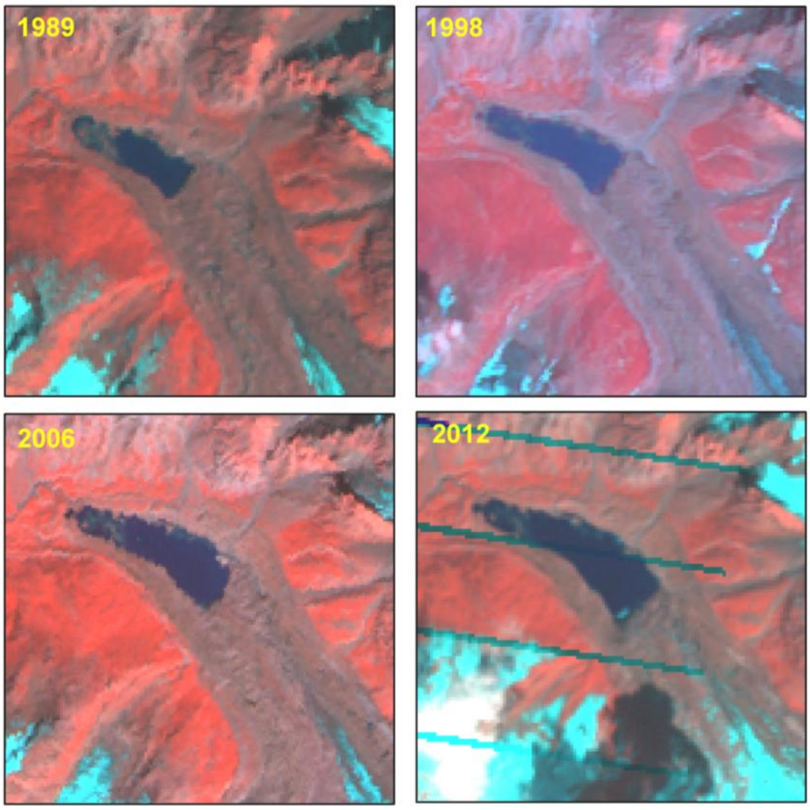

Figure 1: Changes in Moraine-dammed lake in Bhaga basin, Himachal Pradesh.

growth of lake in Bhaga basin of Himachal Pradesh which shows a continuous growth of a moraine-dammed lake in front of a glacier. The images used are Landsat TM and IRS LISS III images.

Geodatabase of Himalayan Moraine-dammed lakes

A Geodatabase of glaciers and associated features has been created based on the inventory carried out under a joint programme on "Himalayan Snow and Glacier Studies " of Department of Space (DOS) and Ministry of Environment and Forests , Government of India (MoEF). The major objective is to carry out systematic inventory of the glaciers occurring in the Indus, the Ganga and the Brahmaputra basins. The inventory aims at:

- Preparation of glacier inventory maps at 1:50,000 scale
- Preparation of glacier inventory data sheet
- Creation of (spatial / non spatial) digital database in GIS

The above input is used for the development of Himalayan Snow and Glacier Information System (HGIS). The database will also be used for the Natural Resources Data Base (NRDB). Altitude information is generated from standard Digital Elevation Model (DEM) available from satellite data of Shuttle Radar Terrain Mapping Mission (SRTM). Geocoded IRS LISS III data on 1:50,000 scale, from period July to end of September has been used.

The glacier inventory map depicts the presence of glaciers and their distribution in space. The significant glacier morphological features for each of the glacier are mapped and appropriately represented on the map by a pre-defined colour scheme. The mapped glacier features comprise of glacier boundary with separate accumulation area and ablation area. The ablation area is further divided into ablation area ice exposed and ablation area debris covered. The Moraines like median, lateral and terminal moraines present on the glacier are separately mapped and delineated. The supra-glacier and pro-glacial lakes occurring on the glaciers have been also delineated. The de-glaciated valley associated with the glacier is also delineated along with the associated moraines both lateral and terminal moraines and the moraine dammed lake/s. This dataset can become benchmark for further monitoring of lakes in Himalaya and information on these lakes can be used as baseline information for taking up action plans to avert any disaster arising from bursting these lakes.

Change detection of MDLs in Nepal and Bhutan

A study on the changes in the moraine-dammed and pro-glacial lakes was carried out for the area covering Nepal and Bhutan, since these regions have higher concentration of such lakes. AWiFS data of 2005 and Landsat data of 1989/1990 were used to find the changes in the spread of lakes. The salient results of this monitoring are following:

1) In the Landsat data of 1988/1990, fifty three MDLs/proglacial lakes were identified. There are a few other lakes which could be identified but area could not be compared as those lakes appear partially covered with snow either in the Landsat or in the AWiFS data. There was no increase in the number of MDLs in the study area over the period of observations and monitoring. The lakes range in area from 1.6 ha to 121.9 ha in the data of 1988/1990 with one exception which has area of 567.5 ha. Total area of all MDLs was found to be 2037.7 ha. Fourty MDLs show increase in area whereas 13 MDLs show decrease in area (figure 2). Total increase in area of lakes was found to be 424.43 ha with mean increase of 10.48 ha. And total decrease was found to be 24.8 ha with mean as 1.91 ha. The mean area of lakes which show increase is 58.30 ha and which show decrease are 16.50 ha. This results shows that increase in area of lakes is much more than decrease in area of lakes. This may be due to higher melting rates over the period of observations. The results also indicate that loss in area is shown by smaller lakes which together are not significant from the point of analysis. Figure 3 is an example of an increase in one of the lake.

2) For each glacier for which MDL has been mapped loss/gain in area of glacier is estimated based on map of glacier extent in 1988/1990 and 2005/2007. Change in water spread of lake is correlated with retreat of glaciers (or loss in area of glaciers). There is an understanding that higher melt gives rise to glacier retreat and thus increase in area of lakes.

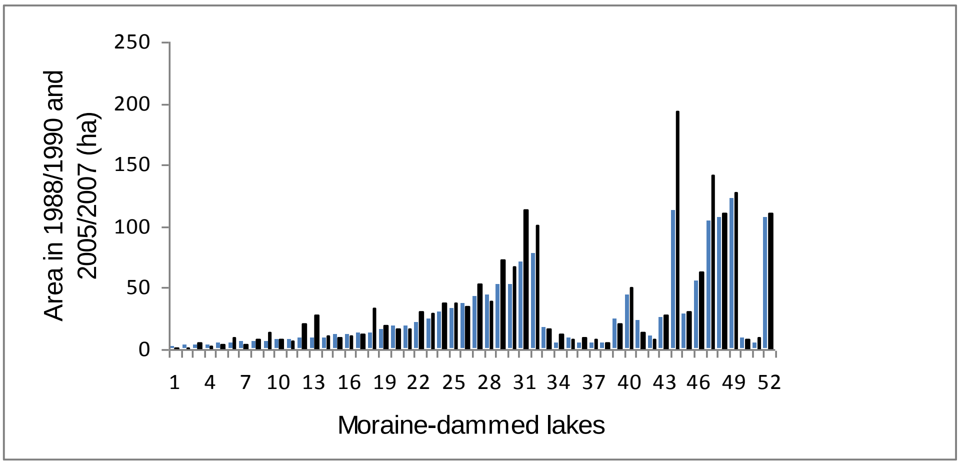

Figure 2: Bars show change in area of MDLs for 52 MDLs. The largest MDL having 567.5 ha area in 1988 and 584.1 ha in 2005 is not included in this figure.

A good correlation has been found between change in area of lakes and retreat of glaciers. Figure 4 shows the correlation of retreat and change in area of lakes. Glaciers retreat either because of higher rate of melting or lower rates

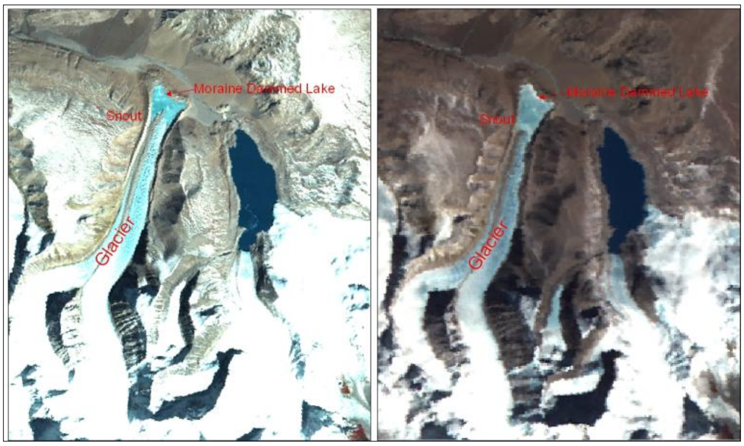

Figure 3: Increase in area of Glacial Lake as seen on Landsat TM of 1989 (left) and corresponding IRS AWiFS of 2005 imagery.

of snow accumulation.

3) The spatial resolution of AWiFS data is 56 m and Landsat data is 30m. Assuming the probability of water spread in a mixed pixel to be half, the area error of each pixel can be taken or 0.0529 ha (considering the half pixel of AWiFS data.). The error gets multiplied as the water spread of waterbody increases.

Road Ahead

Using the database available for Himalayan moraine-dammed lakes as base line information, additional inputs are required to mitigate any disaster arising from bursting of glacial lakes. The specific tasks can be summarised as following.

Identification of potentially dangerous lakes based on monitoring

i. Calculation of glacier surface gradients from DEMs to identify those below the empirically-derived threshold of lake development (<2°);

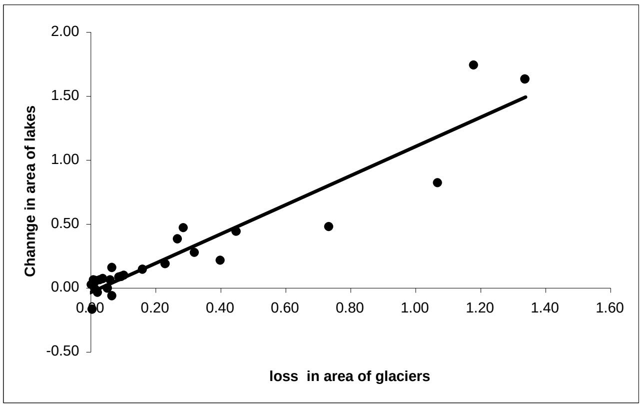

Figure 4: Relationship between change in area of moraine dammed lakes and loss in area of the glaciers (r =0.9423)

ii. Calculation of glacier surface elevation changes from multi-temporal, medium-resolution DEMs;

iii. Measurement of glacier flow using feature tracking algorithms and InSAR to detect stagnating glacier tongues;

iv. Measurement of moraine geometry (e.g. width: height ratio) from high-resolution satellite images and DEMs;

v. Ice avalanches as direct hazards and triggers for lake outbursts: Detection of steep glaciers and areas vulnerable to ice avalanches using spectral data and DTMs. Calculation of ice avalanche volumes using multi-temporal elevation data(stereo AP);

vi. Models of debris flows from lake outbursts, based on DTM data and empirical relationships;

vii. Integration of weather parameters with terrain models;

viii. Floods from glacial lakes: Inputs for numerical flood models derived from DTMs and empirical relationships, including lake volumes, dam geometry, and valley floor geometry;

ix. Glacier surges, that may lead to the formation of ice dams and/or enhanced englacial water storage, possibly released at surge end. Surface features (such as heavy crevassing and looped moraines), that are suggestive of surge-type behaviour are visible on medium-resolution imagery. Optical feature-tracking algorithms applied to derive velocity fields on surging glacier tongues;

x. Stable glacier length changes: Advances may inundate land, override infrastructure, generate boulder falls, initiate mass movements on unstable moraines, dam rivers to form lakes etc. delineation of glacier margins using multispectral classification techniques and morphometric parameters;

xi. Installation of Early Warning System Components at potentially dangerous lakes: The Early Warning System consists of one Central Control Station, Siren Stations and Hydro-Met Monitoring Stations: these stations include stations for monitoring water level (AWLS) and stations monitoring for water level and weather combined (AWS). The System is divided into two geographical areas: the Upper Sites near the glacial lakes, the source of the GLOF, and the Lower Sites where the majority of the population is located.

APPROACH FOR MINIMIZING LAKE OUTBURSTS DISASTERS

An approach has been suggested in an UN report (2006) for strategic planning for creating an alert system to tackle the hazards from GLOFs. The summary of the approach have been enlisted as below. These include use of latest technology, planning at Government level and interactions among various stakeholders.

- Stakeholder government agencies and regional partners identified and roles clarified.
- Single national government organisation responsible for co-ordinating risk assessment.
- Standards for systematic collection, assessment and sharing of risk data.
- Database (GIS) for storage of spatial and non-spatial information including maintenance plan.
- Process for regular review, update and peer review of risk data and information.
- Engagement strategy for local communities.
- Types of threats and their susceptibilities (location) identified.
- Sites of likely lake formation in the future identified.
- GLOF hazards assessed: probability of occurrence, magnitude, run-out distances and inundation extents.

- Identify vulnerable targets in hazard zones (communities, industry, infrastructure etc.).
- Assess social–cultural-economic issues and activities that may increase vulnerability.
- Assess possible interaction of hazards and vulnerabilities.
- Stakeholder consultation to ensure information is comprehensive.
- Risk information integrated into local risk management plans and warning messages.
- Standardized processes, roles and responsibilities of monitoring and warning organizations established.
- Processes for acquisition, assessment, review and dissemination of monitoring data and information.
- Protocols in place to define communication responsibilities; partners aware of protocols.
- Links formed to existing national committee(s) responsible for disaster risk management and early warnings.
- Warning centres staffed and equipped.
- Data routinely archived and accessible for verification and research purposes.
- Measurement parameters and specifications documented.
- Plans and documents for monitoring networks available and peer reviewed.
- Technical equipment, suited to local conditions and circumstances, in place and personnel trained in its use and maintenance.
- Data received, processes and available in meaningful formats and timely manner.
- Data analysis, predictions and warning generation based on accepted scientific and technical methods.
- Warnings generated and disseminated in an efficient and timely manner and in a format suited to user needs.
- Plan implemented to monitor and evaluate operational processes.
- Recognized authorities empowered to disseminate warning messages.
- Functions, roles and responsibilities of each actor in the warning process specified in legislation or government policy.
- Recognized authorities empowered to disseminate warning messages.
- Functions, roles and responsibilities of each actor in the warning process specified in legislation or government policy.
- Volunteer network trained and empowered
- To receive and disseminate hazard warnings.
- Volunteer network trained and empowered to receive and disseminate hazard warnings.
- Communication and dissemination

technology tailored to the needs of individual vulnerable groups.

- Warnings communication technology reaches the entire population(e.g. including seasonal populations)

- Communication system is two-way and interactive to allow for verification that warnings have been received.

- Warning alerts and messages tailored to the specific needs of those at risk (e.g. for those of different socio-cultural backgrounds; for private sector)

- Warning alerts clearly recognizable and consistent over time and include follow-up actions when required.

- Warnings specific about the nature of the hazard and its likely impacts.

- Mechanisms in place to inform the community when the warning has ended ("all clear").

- Warnings generated and distributed by credible sources (e.g. government and/or community leaders).

- Perception of risk and warning service analysed to predict responses.

- False alarms minimized and improvements communicated to maintain trust.

- GLOF preparedness and response plans targeted to the individual needs of the vulnerable groups, and empowered by law.

- Up-to-date emergency preparedness and response plans developed, disseminated to vulnerable groups, and practiced.

- Previous GLOF events and responses analysed, and lessons learnt incorporated into plans and capacity building strategies.

- Strategies implemented to maintain preparedness for recurrent hazard events.

- Community and volunteer education and training Programmes developed and implemented.

- Simple information on hazards, vulnerabilities, risks, and preparedness disseminated to the vulnerable and decision-makers.

- Vulnerable groups educated about warning systems and how to respond.

- Community trained to recognise simple hazard signals to allow immediate response.

- On-going public awareness and education built in to school/university curricula.

- Public and industry awareness and education campaigns tailored to the specific need of each audience and reviewed regularly.

CONCLUSIONS

High spatial and temporal resolution should be effectively used to identify hazardous lakes in order to make mitigation plans. A large amount of data acquired from series of Indian remote sensing satellites has been archived. This data ranging from 1 m resolution in polar orbiting satellites to 1 km in geostationary satellites will be very useful to update the spatial distribution of all the lakes located in glaciated terrains. The spatial and temporal variability of the lakes together with weather information, terrain models and human settlements can be integrated to generate the possible disaster scenarios from Lake Outburst. Remote sensing can not only be used to identify, and monitoring the lakes but also in preparing information layers required for generating alert systems. What is required is a dedicated institution to look after this kind of task and responsibility of disseminating the information.

Early warning system for Tsunami in India

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INTRODUCTION

The analysis of historical earthquakes and instrumental observations reveal the complex nature of tectonic plate movements and crustal deformation in and around India that cause devastating earthquakes accompanied sometimes by catastrophic tsunamis. However, until December 2004, not many people in India were aware of tsunami and its devastating capacity to washout coastal areas. The great Sumatra earthquake (Mw 9.3) of 26th December, 2004 generated a tsunami which exposed the vulnerability of the Indian coastline and caused unprecedented loss of life and damage to property in the Indian Ocean rim countries. The tsunami was considered as one of the deadliest natural hazards in the history, killing over 2,30,000 people in fourteen countries. In India it claimed 10,745 lives according to official estimates. In the wake of the this catastrophic tsunami, in 2005, the Ministry of Earth Sciences (MoES), Government of India, established Indian Tsunami Early Warning System at Indian National Centre for Ocean Information Services (INCOIS) with responsibility to provide early warnings to tsunamis and storm surges operates on 24x7 basis. The other major participating institutions in this are NIOT, ICMAM, IMD, SOI and NRSC. The Centre detects, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Indian Ocean Basin using its land and ocean based networks (Figure 1). A database of all possible earthquake scenarios for the Indian Ocean is used to identify the regions under risk at the time of event and timely tsunami advisories are disseminated to the vulnerable community following a Standard Operating Procedure (SOP) by means of various available communication methods.

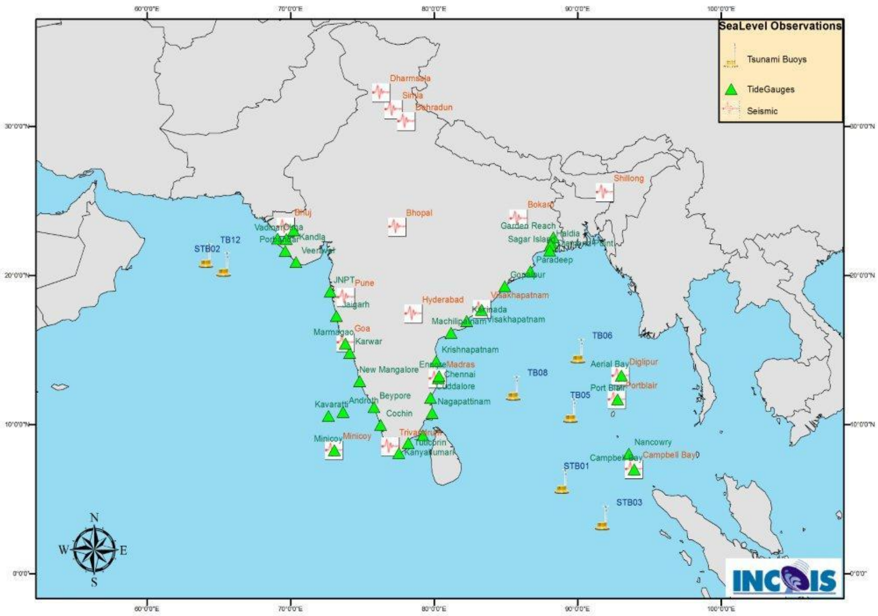


Figure 5: Locations of Observational networks of ITEWC

TSUNAMI THREAT ASSESSMENT

The devastating December, 2004 tsunami was generated at Andaman-Sumatra subduction zone. The 1945 tsunami in the Arabian sea was generated at the Makran subduction zone. The analysis of great earthquakes from the past, seismo-tectonic settings and inter-plate motions indicate that the east and west coasts of India as well as its island regions are likely to be affected by tsunamis generated by these two potential tsunamigenic subduction zones. Volcanic eruptions along the Sunda Arc also can cause tsunami eg. Krakatau Volcano. Keeping this in view, for the mitigation of tsunami disaster the Indian Tsunami Early Warning System (ITEWS) has been equipped with a core observational network and necessary communication and computational systems for data transmission and reception, which was set up in a record time.

OBSERVATIONAL NETWORKS

The Indian Tsunami Early Warning System's (ITEWS) observation network comprises a real-time network of seismic stations, Bottom Pressure Recorders (BPR), Tide gauges and 24X7 operational tsunami warning centre to detect tsunamigenic earthquakes, to monitor tsunamis and to provide timely advisories to vulnerable community by means of latest communication methods.

Seismic Network

The ITEWS consists of 17 broadband seismic stations spread over Indian mainland and the Island region. The data from all these stations is transmitted in real-time through VSAT communication to the Central Receiving Stations (CRS) at INCOIS, Hyderabad and IMD, New Delhi. In addition to this, ITEWC is also receiving real-time seismic data through internet from international seismic networks like IRIS, GEOFON and is able to detect all earthquakes occurring in the Indian Ocean in less than 10 minutes.

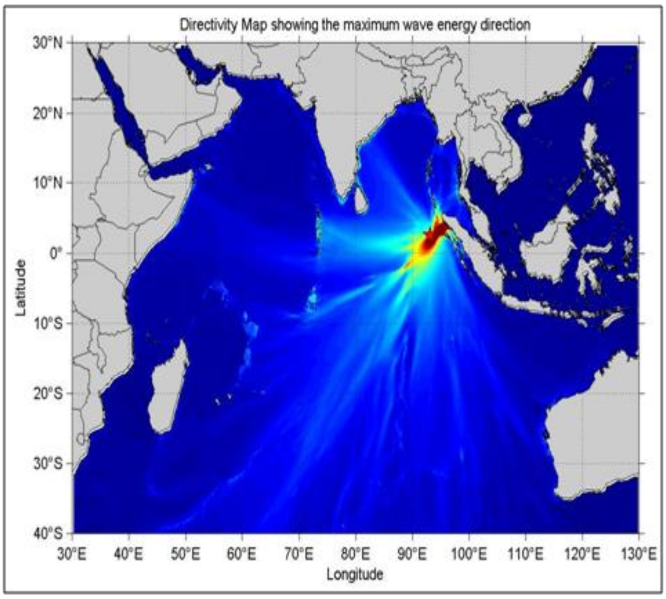
Sea level Network

The ITEWS comprises a network of 7 indigenously developed Tsunami Buoys (consisting of Bottom Pressure Recorders & Surface Buoy) and three SAIC tsunami buoys (Figure 1) in the Indian Ocean Region. The deployment and maintenance of these buoys are done in collaboration with National Institute of Ocean Technology (NIOT), Chennai. The data is transmitted in real-time through satellite communication simultaneously for processing and interpretation. Apart from these national buoys, data from 3 international buoys are also being received at INCOIS.

To monitor sea level changes, in addition to tsunami buoys, the ITEWS comprises a network of 26 state-of-the-art tide gauges that are installed at strategic locations along the Indian Coast (Figure 1) and maintained in collaboration with Survey of India (SOI). The continuous real time data is being received at the warning centre through various communication channles like VSAT, INSAT and GPRS. Real-time processing & analysis software is configured at INCOIS to receive, archive, process & analyze the real time data from the Tide gauge network as well as for alert generation and automatic notification for any significant water level changes/ communication delays. The centre also receives continuous data from 68 international tide gauges located along the coasts of the Indian Ocean in near real-time through internet.

QUANTITATIVE FORECASTING OF TSUNAMIS

The warning centre follows a quantitative approach to tsunami warning, as against the qualitative system adopted by several other warning centres. This eliminates generic threat categorization of areas under tsunami risk. The quantitative warnings are generated using numerical simulations which provide estimated wave amplitude and estimated travel times for a local or distant tsunami. Currently, TUNAMI-N2 model, customised for Indian Ocean region, is used to generate forecasts. A scenario database of pre-computed open-ocean propagation scenarios is generated for all possible earthquakes along both subduction zones. In addition, Coastal Inundation Modelling is also carried out to estimate and evaluate the risk and vulnerability of tsunami flooding in coastal areas. The results are aimed at assessing the geographical extent of the area to be affected by tsunami and generate maps for the use of disaster management offices in planning & warning the public.



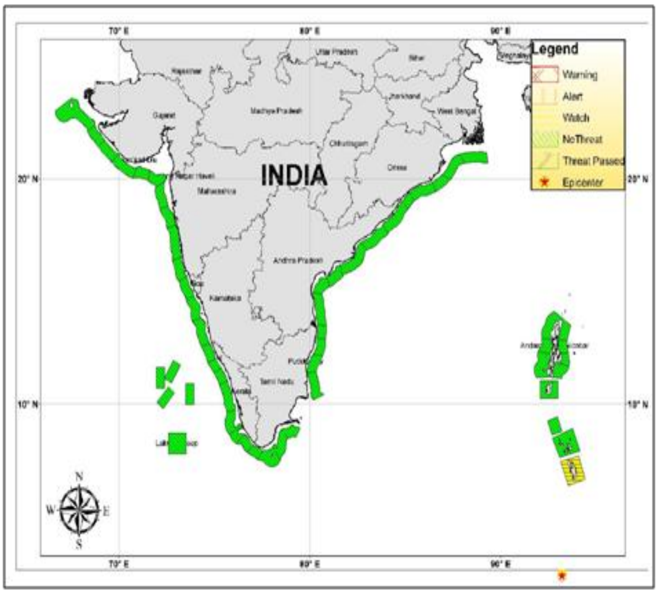


Figure 2: Directivity and threat Maps of Off West coast of Northern Sumatra

STANDARD OPERATING PROCEDURE & DECISION SUPPORT SYSTEM

The Warning Centre has a very uniquely designed Standard Operating Procedure (SOP) and Decision Support System (DSS) for generation of timely and accurate tsunami bulletins. From a tsunami a tsunami warning perspective, different Indian coastal area can be categorized as being near-source or far-source based on their proximity to the tsunamigenic earthquake source regions. For example, if an earthquake happens in the Sunda subduction zone, coastal areas in Andaman & Nicobar Islands with tsunami travel times of < 60 min are categorized as near-source and for those areas where water level exceeds > 2 m, Warning is issued. However, the areas in mainland are categorized as far-source and will be under Alert/Watch based on estimated water levels until confirmation from sea level observations. Accordingly the DSS generates and disseminates the tsunami bulletins to all stakeholders simultaneously through various communication modes viz. Email, Fax, SMS, GTS, Web etc.

WARNING CENTRE PERFORMANCE

Since its inception in October 2007 till August 2013, the warning centre successfully monitored 364 earthquakes of M > 6.5, out of which 64 are in the Indian Ocean region. Only on five occasions Warning/Alert/Watch were issued that too only for selected near-source areas in A&N Islands and east coast of India. The best example for performance of warning centre is great EQ of Mw 8.6 on April 11, 2012 that occurred off west coast of northern Sumatra, Indonesia wherein only three areas were under warning. Also, a comparison of earthquake parameters (elapsed time, magnitude, focal depth and location) estimated by warning centre has been made with other international agencies, like the US Geological Society (USGS).

ROLE OF 'ITEWS' IN INTERNATIONAL FRAMEWORK

The ITEWS serves not only as a national tsunami warning centre but also as a Regional Tsunami Advisory Service Provider (RTSP), which is responsible for providing Tsunami advisories to all Indian Ocean member countries. Formerly these advisories were provided by the Pacific Tsunami Warning Centre (PTWC) & Japan Meteorological Agency (JMA). On October 12, 2011 during mock Tsunami Drill (IOWave11 Exercise), this responsibility had been handed-over to Indian Tsunami Early Warning Centre along with other RTSPs (Australia and Indonesia). Since then warning centre monitored eight major events and issued appropriate tsunami bulletins to all stakeholders of India as well as Indian Ocean member countries.

CONCLUSIONS

Refinement of warning criteria is an ongoing process. Currently, the pre-computed scenarios are limited to tsunami generated by static sea floor displacement. To characterise the rupture direction and area, quick enough to estimate tsunamigenenic potential of an earthquake, a new approach based on near-field GPS measurements has been initiated. The establishment of GPS network would result in real-time processing of GPS data for the estimation of tsunami genesis at the earliest possible time. In addition to this, establishment of a national data centre for integrating near real time seismic and GPS data in India has been initiated.

The 2004 tsunami accelerated the pace of research and developments in tsunami science and forecasting. The world is now moving towards a multi-hazard approach, wherein the resources established for tsunami early warning systems could be fruitfully used to handle other oceanogenic hazards such as storm surges, sea-level rise, etc using the new geospatial technologies such as 3D GIS. It has transformed the way in which coasts can be mapped and managed, which in turn used for improving the accuracies of coastal inundation modelling. INCOIS has already initiated preliminary work on cutting edge research areas such as: (i) Multi-hazard Vulnerability Mapping, (iii) Real-time tsunami inundation modelling as well as (iii) 3-D GIS. The broad scientific methodologies have been established and pilot work has been successfully completed for a few areas.

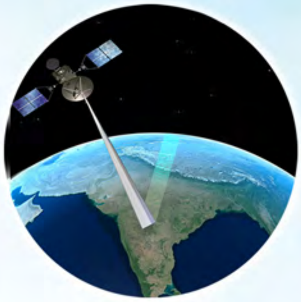
First Circular

NATIONAL SYMPOSIUM
ON
REMOTE SENSING AND GIS FOR ENVIRONMENT
With Special Emphasis on Marine and Coastal Dynamics

and

ANNUAL CONVENTIONS
OF
Indian Society of Geomatics & Indian Society of Remote Sensing

December 4-6, 2013
Visakhapatnam



Hosted by

Department of Geo-Engineering & Centre for Remote Sensing,
College of Engineering (A), Andhra University, Visakhapatnam
and
Indian Society of Geomatics - Visakhapatnam Chapter

Jointly Organized by

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Prof. Kakani Nageswara Rao

BACKGROUND

The modern Remote Sensing (RS) and GIS technologies have revolutionized monitoring, analysis and modeling of the environments, resources and dynamics of the lithosphere, hydrosphere, atmosphere and biosphere including anthropogenic issues and challenges that beset the present world. Significant research and development activities are being carried out in various scientific, academic and industrial establishments relentlessly improving these technologies and their applications in every sphere of human activity and for societal benefit. The Indian Society of Geomatics (ISG) and Indian Society of Remote Sensing (ISRS), the two premier professional societies dedicated to promotion and dissemination of RS & GIS in India, conduct annual conventions and joint national symposiums in tandem providing excellent opportunities to the scientists, teachers and students for presenting their research findings, updating their knowledge base and interacting with experts and peers. Continuing this rich tradition, a national symposium is being organized by ISG in association with ISRS in the beautiful coastal city of Visakhapatnam during ***December 4-6, 2013***. This mega event is jointly hosted by Department of Geo-Engineering & Centre for Remote Sensing, College of Engineering (A), Andhra University and ISG-Visakhapatnam Chapter.

The topic of this National Symposium is ***'Remote Sensing and GIS for Environment with Special Emphasis on Marine and Coastal Dynamics'***. Recent advances in the development of algorithms/techniques for accurate retrieval of atmospheric and oceanic parameters from various international as well as the Indian Earth observation satellite missions are aiding numerical modeling of the marine biogeochemical cycles, sea-ice dynamics, monsoon variability and climate change. Coastal zones at the interface between land and ocean are highly resourceful, densely populated and at the same time, being extremely low-lying, are vulnerable to natural hazards such as floods, storm surges and tsunamis. Human activities at global, regional and local levels, especially for the past several decades are exacerbating the problems and hazards that beleaguer the coastal zones. Therefore, mapping and monitoring of the characteristics and process dynamics of the coastal zones and the adjacent land and marine systems have become imperative for a proper management of their resources and environment. RS & GIS technologies being the mainstay of studies on coastal and marine environments and their dynamics, the Symposium will have a special focus on these most important regions that sustain more than two-thirds of the world population. In addition, with emerging trends in computation, processing speeds, visualisation techniques and web based services, the symposium shall address related issues in the field of Geomatics.

THEMES

Papers based on original unpublished research related to RS, GIS and allied tools and techniques are invited on the following themes:

- *Marine and Coastal Processes, Ecosystems and Hazards*
- *Monsoon Dynamics and Climate Change*
- *Geoinformatics Tools and Techniques*
- *Web and Location based Services*
- *Urban / Regional Planning and Spatial Data Infrastructure*
- *High Resolution Sensors, Processing Techniques and Large-scale Mapping*
- *Advancements in Sensor Technology and UAV based Remote Sensing*
- *Trends in Image Processing, Photogrammetry and Terrain Analysis*
- *Natural Resources Management (Water, Soil, Forest, Mineral and Energy Resources)*
- *Agricultural Applications*
- *Environmental Monitoring*
- *Geosciences and Planetary Exploration*
- *Disaster Management*
- *Industrial Applications and E-governance*

ABSTRACT SUBMISSION

Participants who intend to present their research need to submit abstracts of their papers within 300 words online through the symposium website *www.isgvizag.org/symp13/abs* or may be sent as email attachment to *isgsymp2013@gmail.com*. Follow the guidelines for abstract preparation available at *www.isgvizag.org/symp13/guidelines.pdf.*

Manuscripts of the full papers submitted in time as per the prescribed format of ***the Journal of Geomatics*** *(www.isgindia.org)* will be included in the soft copy proceedings. Selected papers will be peer reviewed and considered for publication in a special volume of the Journal.

Apart from paper presentations, a number of high-profile events are lined up for the Symposium including:

Two popular lectures - Millennium Lecture of ISG and Vikram Sarabhai Memorial Lecture of ISRS, Lead talks on all major themes, Presentation of various annual awards of ISG & ISRS, Annual General Body meetings of both ISG & ISRS, Pre-Symposium Tutorials and many other interesting programs, which make the event an enriching and memorable experience to all the participants.

PRE-SYMPOSIUM TUTORIALS

There will be two pre-symposium tutorials during ***December 2-3, 2013*** aimed at providing training on latest developments on the following topics:

1) Geoinformatics in Marine and Coastal Environments (GMCE)
Co-ordinator: Dr. A.S. Rajawat, Head, Geo Sciences Division, SAC, Ahmedabad.
Email ID : asrajawat@sac.isro.gov.in

2) Planetary Exploration (PE)
Co-ordinator: Dr. Prakash Chauhan, Head, Planetary Sciences & Marine Biology Division, SAC, Ahmedabad. Email ID: prakash@sac.isro.gov.in

Interested candidates may submit their applications and biodata online at the Symposium website www.isgvizag.org/symp2013/register or by email/post to the Organizing Secretary on or before **August 31, 2013**. Since only 30 candidates will be taken into each tutorial, the admission is based on merit.

REGISTRATION FEE

Participant category	Payment of Registration Fee	
	Up to Sept. 30, 2013	After Sept. 30, 2013
ISG/ISRS Members	₹ 3000	₹ 3500
Non-Members	₹ 3500	₹ 4000
Students, Senior Citizen Members of ISG/ISRS & Accompanying persons	₹ 1000	₹ 1500
Students, Senior Citizens & Accompanying persons (non-members)	₹ 1500	₹ 2000
Foreign Participants	US $ 150	US $ 200
Pre-Symposium Tutorial	₹ 2000	₹ 2500

Those who register for Pre-Symposium Tutorial and the Symposium are entitled for a discount of ₹ 500/- on the total registration amount payable for both events put together.

The registration fee may be remitted online to Account Number: 32991376320 of State Bank of India, Andhra University Campus Branch, Visakhapatnam (IFSC code: SBIN0000772 and MICR Code: 530002004), and a hard copy of the bank receipt of such online payments along with full details of the remitter should be sent to the Organizing Secretary. Registration Fee may also be sent by registered/speed post in the form of a bank draft drawn in favor of "ISG National Symposium - 2013" payable at Visakhapatnam.

Note: Registration Fee covers Symposium material (except for accompanying persons), local transport between guest houses / designated hotels and the Symposium venue, working lunches and social events on the Symposium days. Registration Fee does not cover the cost of accommodation. Those registering under student category need to submit a bona fied certificate from head of the institution.

COMMERCIAL PRESENTATIONS

A special joint session will be arranged exclusively for commercial presentations by various companies on their hardware, software, equipment, services and utilities related to RS & GIS technologies and applications. Those who wish to make use of this opportunity to explain their products and services to the participants need to register by paying ***Rs.20,000/-*** for a ***10-minute presentation*** which includes one complimentary registration as well.

INDUSTRIAL EXHIBITION

An industrial exhibition with well-designed stalls will be arranged at the Symposium venue which provides a unique opportunity to showcase various space & geomatics technology based products and services for fostering awareness and business interactions. Exhibition Stalls may be booked well in advance by paying an amount of ***Rs. 50,000/-*** for a single unit of 3m x 3m size, which also includes two-complimentary registrations.

ACCOMMODATION

Limited accommodation is available in Andhra University guest houses, which will be booked on first-come-first-served basis, latest before ***September 30, 2013.*** Accommodation in designated hotels at negotiated tariff shall be arranged. Participants seeking hotel accommodation are required to book directly to the designated hotels giving reference of the Symposium. Details of the designated hotels shall be provided in the Sympsium website www.isgvizag.org/symp2013/accom. Participants requiring guest house accommodations should make advance payments along with registration fee duly filling the relevant information in the Registration Form.

IMPORTANT DATES TO REMEMBER

Release of First Circular	*May 20, 2013*
Last date for Abstract submission	*August 20, 2013*
Abstract acceptance intimation	*August 31, 2013*
Last date for submission of Tutorial applications	*August 31, 2013*
Intimation of admission into Tutorials	*September 15, 2013*
Last date for Registration for Tutorials	*September 30, 2013*
Last Date for Guest House Booking	*September 30, 2013*
Registrations for Commercial Presentations	*October 15, 2013*
Registrations for Industrial Exhibition	*October 15, 2013*
Submission of full papers	*October 31, 2013*
Pre-Symposium Tutorials	*December 2-3, 2013*
National Symposium	*December 4-6, 2013*

INDIAN SOCIETY OF GEOMATICS

Indian Society of Geomatics (ISG), established in 1993, has been promoting interactions among professionals for advancement of RS & GIS technologies and applications through symposia and workshops that it frequently conducts, besides publishing the Journal of Geomatics and ISG Newsletters at regular intervals. With more than 1500 members and 16 Regional Chapters, ISG is growing from strength to strength. The ISG-Visakhapatnam Chapter started in 2012 with 37 life members and many student members is the 16th of such Chapters and latest addition to the ISG family actively conducting awareness and expert programmes in the field of Geomatics in the region. Every year, ISG confers several awards during the Society's annual conventions through nomination. Further details are available at ISG website (*www.isgindia.org*)

INDIAN SOCIETY OF REMOTE SENSING

Indian Society of Remote Sensing (ISRS), established in 1969 as 'Indian Society of Photo-interpretation', is the pioneering professional society dedicated to popularization and dissemination of RS technology and applications through seminars/symposia and a number of publications such as bulletins, proceedings and the internationally reputed Journal of Indian Society of Remote Sensing. With more than 4000 members and 23 regional chapters, ISRS is now a valued member of the International Society of Photogrammetry and Remote Sensing (ISPRS) and Asian Association of Remote Sensing (AARS). ISRS confers a number of awards during the Society's annual conventions, the details of which are available at *www.isrsindia.in*

ANDHRA UNIVERSITY

Andhra University (AU), established in 1926 in Visakhapatnam overlooking the Bay of Bengal, is one of the oldest and largest academic institutions imparting education in various branches of engineering, pharmacy, science, arts, commerce, and law to over two lakh students every year. **AU College of Engineering - AUCE (Autonomous)**, one of the six campus colleges of AU with 11 engineering and 4 basic sciences departments, is a highly rated academic institution in india, accredited with high grades by NAAC and NBA, adjudged as 'Best Performer' by TEQIP; as 'Best Government Engineering College' by Star News TV Channel; and also ISO 9001-2008 certified. The interdisciplinary **Department of Geo-Engineering & Centre for Remote Sensing** in the AUCE (A) is running a unique B.Tech. Geoinformatics course, besides M.Tech. Remote Sensing and Ph.D. programs. For details, visit *www.andhrauniversity.edu.in*

VISAKHAPATNAM

Visakhapatnam, a breathtakingly beautiful coastal city with green hills and beaches dotting the seafront, has many tourist attractions and holiday spots. The weather in December is pleasant with temperatures ranging between 19°C and 28°C. The city is well connected by air, rail and road with most of the cities in the country and with direct flights to Dubai and Singapore.

ADDRESS FOR CORRESPONDENCE

Prof. (Emeritus) Kakani Nageswara Rao
Organizing Secretary, ISG National Symposium-2013
Department of Geo-Engineering, College of Engineering (A),
Andhra University, Visakhapatnam – 530003
Telephone: (office) 0891-2712964; (Mobile) 09441019341

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P-23	Senior Manager, Larsen & Toubro Ltd., Library & Documentation Centre, ECC Constr. Gp., PB No. 979, Mt. Poonamalee Rd,, Chennai-600089
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P-25	Programme Coordinator, (C-DAC), Pune University Campus, , Pune-411007
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P-33	Director, Rolta India Limited, Rolta Tower "A", Rolta Technology Park, MIDC, Andheri (E), Mumbai-400093
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(Updated up to September 2013)

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INDIAN SOCIETY OF GEOMATICS (ISG)

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