Mapana J Sci, **13**, 1 (2014), 85-99
ISSN 0975-3303 | doi:10.12723/mjs.28.6

Applications of IRS and INSAT Data with Specific Case Studies

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Abstract

Indian satellite programme has over the past three decades achieved operational capability in the area of remote sensing. The Indian Remote Sensing (IRS) satellites are developed towards providing data for natural resources survey and management. Techniques have been developed to retrieve several parameters related to land, ocean and atmosphere. Since the launch of IRS 1A in early 80's, the technology has improved to achieve satellite imagery with resolution of 1 meter. The Indian National satellite (INSAT) system is made up of geostationary satellites towards monitoring and study of weather over the Indian region. The INSAT data is operationally used for study of monsoon onset, cyclone prediction and forecast of severe weather conditions. The paper portrays a few unique case studies using IRS and INSAT data. The satellite data is proving to be very useful in study of the global changes and possible impacts.

Keywords: Remote Sensing, Resource Surveys, Satellite data, IRS and INSAT, Satellite Applications.

1. Introduction

Remote Sensing (RS) refers to the science of identification of earth surface features and estimation of their geo-biophysical properties using electromagnetic radiation as a medium of interaction.

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Spectral, spatial, temporal and polarization signatures are major characteristics of the sensor/target, which facilitate target discrimination. Earth surface data as seen by the sensors in different wavelengths (reflected, scattered and/or emitted) is radiometrically and geometrically corrected before extraction of spectral information. RS data, with its ability for a synoptic view, repetitive coverage with calibrated sensors to detect changes, observations at different resolutions, provides a better alternative for natural resources management as compared to traditional methods.

2. Scientific rationale

Remote sensing usually refers to the technology of acquiring information about the earth's surface (land and ocean) and atmosphere, using sensors on-board airborne (aircraft, balloons) or space-borne (satellites, space shuttles) platforms. The electromagnetic radiation is normally used as an information carrier in RS. Remote sensing employs passive and/or active sensors. Passive sensors are those which sense natural radiations, either reflected or emitted from the earth. On the other hand, the sensors which produce their own electromagnetic radiation, are called active sensors (e.g. LIDAR, RADAR). Remote sensing can also be broadly classified as optical and microwave. In optical remote sensing, sensors detect solar radiation in the visible, near-,middleand thermalinfrared wavelength regions, reflected/scattered or emitted from the earth, forming images resembling photographs taken by a camera/sensor located high up in space.

3. Concept of spectral signature

Signature of any object and/or its condition comprises a set of observable characteristics, which directly or indirectly lead to the identification of an object and/or its condition. The principle characteristic is the variation of response to different spectral regions. For example, vegetation has a high response to green and near infrared regions. Each object on earth has a unique signature as shown in Figure 1. For example, dry soil gives typically increasing trend of response with wavelength while when in the case of wet soil, the same curve will have lesser reflectance values but similar shape as dry soil. The satellite sensing is based on this principle and operates in multi wavelengths to identify various objects.

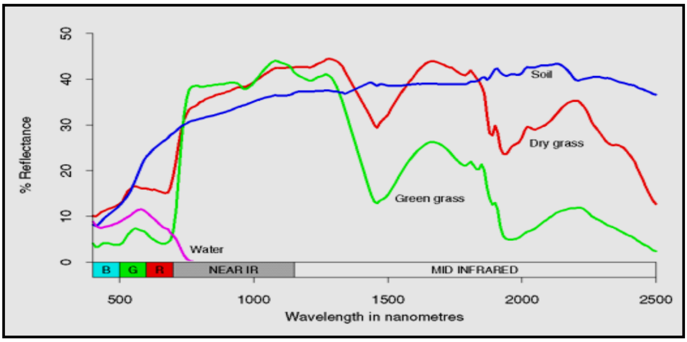

Fig. 1.Spectral signatures of objects

4. IRS Satellite System

Following the successful demonstration flights of Bhaskara-1 and Bhaskara-2 satellites launched in 1979 and 1981, respectively, India began to develop the indigenous Indian Remote Sensing (IRS) satellite program. The IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world, with 12 operational satellites. All these are placed in polar sun-synchronous orbit and provide data in a variety of spatial, spectral and temporal resolutions. Indian Remote Sensing Programme[1-3] completed its 25 years of successful operations on March 17th, 2013.

Remote sensing observations provide data on earth's natural resources in a spatial format. The remote sensing (RS) data has the advantage of synoptic view and large area coverage. The information required in the field of civil engineering is derived mainly from analysis of image patterns present in the data. These patterns reflect the influence of the type of parent material, geological processes undergone, the climatic, biotic and physiographic environment and man's activity. Thus applications of remote sensing to engineering involve the recognition of basic landforms as indicated by the pattern elements on the image.

5. INSAT Satellite System

Accurate and reliable weather and climate prediction holds the key for socio-economic development and is essential for food security and several human activities. In India, we experience in general four major seasons of winter, summer, monsoon and post monsoon. The monsoon is a global flow of moist air mass across the equator to the Indian sub-continent bringing copious rainfall. During the post monsoon season, cyclonic storms form over the Bay of Bengal and rarely over Arabian sea and move into the coastal areas. One of the major concerns is the variability of monsoon rainfall. It is interesting to note that while the all India rainfall remains within ± 10% of Long Term Average of 900 mm, there is large variability in rainfall at district and local scales.

India entered the satellite meteorology era with the launch of INSAT 1A in 1983 to the geostationary orbit (Figure 2). Since then series of satellites have been launched to provide continuous monitoring of weather over the country [4]. The INSAT satellites carry meteorology payload called Very High Resolution Radiometer (VHRR) with sensors operating in visible, infrared and water vapour channels viz., spectral bands – visible [0.55-0.75 μm] and thermal infrared [10.5-12.5 μm] and water vapour [6.3 μm] [5]. The major advantage of INSAT data is that it covers entire region and provides valuable data over the data sparse oceanic regions.The INSAT capability to provide half hourly weather imageries and scan specific regions every 5 minutes in case of cyclonic systems [6].

The quantitative product available from INSAT data computes the following numerical products:

1. Cloud Motion Vectors (CMVs)
2. Quantitative Precipitation Estimates (QPEs)
3. Outgoing Long-wave Radiation (OLR)
4. Vertical Temperature Profiles (VTPRs)

5. Sea Surface Temperatures (SSTs)

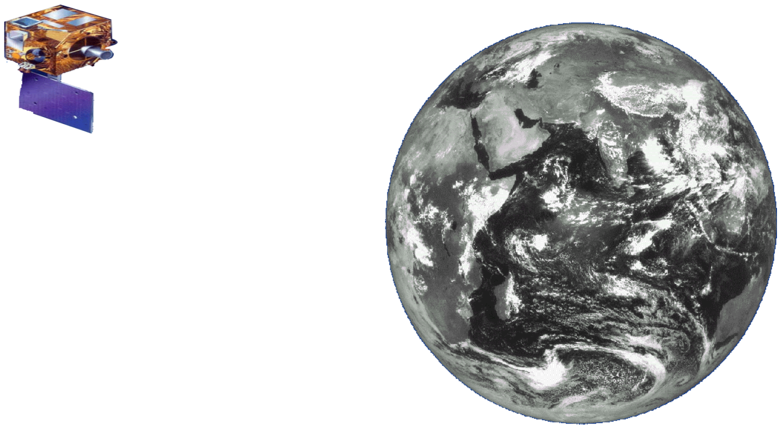

Fig. 2. INSAT 3A Satellite in Orbit around Earth

An important application of meteorological satellite data is for monitoring and forecasting of cyclones. INSAT/VHRR images are being used to identify cloud systems over the oceans and their development into cyclone. India Meteorological Department has achieved great success in developing a tropical cyclone model using satellite and ground observations to give accurate forecasts of intensity and landfall.

Table 1 gives a summary of the Potential applications of IRS and INSAT satellites.

Table 1. Key applications using satellite data

Sl. No	Satellite	Sensors/ Resolution (m)	Frequency (days)	Applications
1	IRS– 1A	LISS-1: 72.5/148	22	Earth resources, survey and mgt. of resources in areas like agriculture, geology and hydrology
2	IRS -1B	LISS-II: 36.25/148	22	--do--
3	IRS – 1C	LISS-III : 23.6/141 PAN : 5.8	24	Agriculture, Forestry, Urban, Land use, Soil, Geology, Terrain, Water

		/70.5 WiFS: 188/774		resources, DEMs, Environment , disasters damage assessment
4	IRS P 3	WiFS : 188/ 810 MOS-A: 1570/195 MOS-B : 525/200 MOS -C : 645/192	5	X-ray astronomy, periodic calibration of PSLV radar located at tracking stations
5	IRS– 1D	PAN : 5.8/70.5 LISS-III: 23.6/141:70.8/ 148 WiFS: 188/ 774	24	Agriculture, Forestry, Urban, Land use, Soil,Geology, Terrain, Water resources DEMs, Environment, Natural disasters (damage assess/relief)
6	IRS P 4	OCM : 360/1420 40/1360 ;: 120, 80,10,6MHzPA N<2.5/13	2	Oceanography data, Coastal, Atmospheric applications, Marine resources
7	INSAT-1	Visible & TIR 5 KM	Continuous	Clouds, CMVs (2 level), SST, QPE OLR,
8	INSAT - 2	Visible, TIR, WV & CCD	Continuous	Clouds, CMVs (3 levels), SST , WV image, QPE, OLR
9	INSAT-3	Visible, TIR, WV & Sounder, CCD	Continuous	Clouds, WV image, SST, OLR, vertical profiles
10	METSAT	Visible/thermal, water vapour	Continuous	Clouds, CMV, SST, Rainfall, OLR
11	INSAT3D	VHRR Sounder 18 channels	continuous	Weather systems, cyclones, temp./humidity profiles, SST

1. Case studies using IRS data

The followingsection highlights a few case studies carried out by our team using IRS satellite data.

a. Flood monitoring of Brahmaputra Valley

Satellite remote sensing permits monitoring of disaster events and assist in damage assessment, providing a quantitative base for relief operations. Following sections briefly summarize the Indian experiences in operational use of satellite data for disaster management. Mapping of flood-affected areas is one of the most successful applications of satellite remote sensing in flood management. Because of the unique spectral signature, it is possible to map areas under standing water, areas from where flood water has receded, submerged standing crop areas, sand casting of agricultural lands, breaches in the embankments, marooned villages and towns, etc.Based on the assessment of user requirements, the critical information for flood management viz., information on weather, infrastructure (roads, hospital, administrative boundaries), demography, conditions terrain have been included in the GIS database [7]. Currently such information are generated by multiple users and stored in multiple formats and media making it difficult to bring the data together to support disaster management activities. In addition there is a need to assess the disaster in terms of location, extent and likely impact so as to plan relief and recovery actions. An integrated system adequately equipped with necessary infrastructure and expertise to constantly monitor the risk profiles on all possible disasters and maintain a national database will become relevant [8].

In this context, the GIS techniqueoffers a tool to analyze multiple layers. In the current study we have brought together the flood maps generated from IRS data and all ancillary information from other sources.Using multi-date satellite imageries, the extent of damage due to crop loss, destruction of infrastructure facilities etc., can be assessed. Space technology for flood monitoring and management has been successfully operationalized in India. Near real time monitoring and damage assessment of all major flood events are being carried out operationally. Satellite remote sensing and GIS techniques have been integrated [8] in Brahmaputra river basin to provide information on flooded area and damage to croplands, roads and rail tracks (Figure 3).

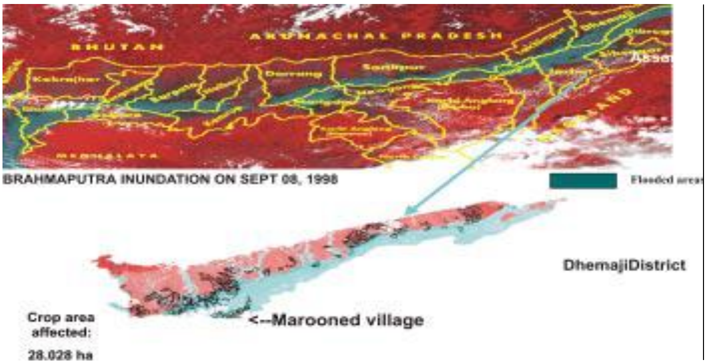

Fig. 3. Flood map derived from IRS 1C data for Brahmaputra

Global Positioning System (GPS) is being used to aid in the development of a Digital Elevation Model (DEM) for a flood prone area in Andhra Pradesh, to enable assessment of spatial inundation at different water levels in the river. When satellite derived land use/cover and ancillary ground based socio-economic data is draped over the DEM, flood vulnerability can be assessed to provide location specific flood warnings. Remote sensing data are evaluated for integration with existing forecasting models. Also microwave data from RADARSAT is used in conjunction with optical data to overcome the limitation of cloud cover.

b. Study of sediment dynamics using satellite remote sensing

Variations of optical properties of sea water are due to the presence of dissolved and suspended materials with different absorption and scattering characteristics. Satellite based observations have been found to provide valuable inferences about the sediment levels of oceanic waters. The IRS LISS sensor is sensitive to sediment load in the coastal waters. The West coast of India is highly prone to erosion especially during the monsoon season due to the wave action associated with the south westerly currents. The heavy run-off from west flowing rivers in the peninsular region also contribute to the high level sedimentation in the offshore regions. In the present study, the multidate data from Indian Remote Sensing Satellite, IRS-1A has been utilized to analyze the sedimentation levels and dispersal patterns for the coastal region of Mangalore in Southern India [9].

Digital techniques have been employed to bring out the variations in the sedimentation patterns (upto 14 levels) for the pre and post-monsoon seasons. The available *insitu* observations on wind, waves and tides have been used to understand the seasonal dispersal characteristics. The study has indicated high level of sedimentation in the post-monsoon period, revealing highly erosion prone nature of the coast. A semi- quantification of the sedimentation has also been attempted through correlation with sea truth data.The multidate data have indicated that the coast has not undergone major seasonal changes except a few modifications in the configuration and location of spits, shoals, bars mouths, etc.

However, long term changes have occurred along estuarine mouths, spits, beaches and pocket beaches. Such changes are linked to the variations in the outflow from the rivers, nature, type and composition of landforms and their interaction with coastal processes operating in the study area. The study has revealed that the coast has not undergone any significant progradation or retrogradation during the past two decades under study

c. Multidate satellite data for study of dynamics of coastal landforms Uttara Kannada, South India

The Uttara Kannada coast in the State of Karnataka lying on the west coast of India, characterized by diverse terrains with widely differing structures, is an important region for many developmental activities. In order to understand its coastal landforms, and their seasonal and long term dynamics, multidate satellite data of SPOT and IRS have been studied along with the Survey of India toposheet from 1976-77 as the baseline. In the present study approximately 100 km of the coast of the Uttara Kannada district has been covered [10]. Coastal landforms were mapped and the dynamics were assessed using satellite, collateral data and field observations. The SOI maps and satellite derived maps for multi dates were co-registered with one pixel accuracy to assess the changes in the coastal landforms. The study revealed that the coast is studded with several estuaries and creeks that support extensive mudflats, which are being used for salt production and aquaculture activities. The coast is also marked by spectacular cliffs/headlands, bays, beaches, sand dunes, spits, offshore islands, bars/shoals and river.

d. Vegetation dynamics and Inter-linkages of NDVI to seasonal precipitation in dryland NOAA/AVHRR derived.

Normalized Difference Vegetation Index (NDVI) offers immense potential to study dry land ecosystems. Amongst the different spectral vegetation indices derived from remotely sensed imagery the Normalized Difference Vegetation Index has been the most widely used. NDVI is calculated by the follow equation: NDVI $=R_{nir}–R_r / R_{nir} + R_r$,where R_r and R_{nir} are the spectral reflectance in the red and near-infrared channels, respectively. NDVI has been found to be related to several biophysical variables such as Leaf Area Index), photosynthetically active radiation (PAR), biomass and productivity. NDVI's relation with rainfall in semi-arid regions is both sensitive and complex.

The physical basis of this relation is vegetation, mainly grown due to soil moisture availability as the result of the seasonal rainfall, which intercepts photo-synthetically active radiation (PAR) and hence directly influences the aggregate of NDVI. While the major part of rainfall is lost through direct evaporation from the soil surface, run-off and drainage, a small fraction of rain water which is used by crops for their growth and yield, is a key parameter linking rainfall with NDVI, especially in dry land tropics. The extent of non-utilized rain water depends not only on the local weather parameters but also on optimal land and water management practices along with the cropping pattern having efficient radiation use efficiencies. Although there have been several studies reporting the relation between AVHRR NDVI and rainfall in semi-arid regions the sensitivity of this relation in varying dry [11] land conditions has rarely been analyzed quantitatively. The present study aims to interpret seasonal

AVHRR NDVI variations with the seasonal aggregate of rainfall and fraction of soil moisture used by vegetation in the six drought prone districts of Karnataka State, India representing very severe, severe and moderate drought conditions. Area averaged seasonal transpiration which has been theoretically linked to integrated NDVI (INDVI), has been realized up to a certain extent in the study areas. The study reveals a closer AVHRR NDVI relation with the water used by vegetation for its growth and yield than the precipitation in dry land ecosystems.

Meteorological Studies using INSAT data

a. Cyclone monitoring and warning

Meteorological satellites are valuable for monitoring and forecasting cyclones. INSAT/VHRR images are being used to identify cloud systems over the oceans, where no observational data is available, as well as for cyclone tracking, intensity assessment and prediction of storm surges, etc. They need to be supplemented by ground meteorological observations and radar data for accurate assessment of rainfall intensity. Several cyclones that occurred in the Bay of Bengal were studied using satellite data (Figure 4). The study of pre and post satellite period showed [12-15] a statistical increase in number of cyclones per year. This is due to the fact that prior to the satellites, several cyclones have gone unreported.

Fig. 4. INSAT imagery of cyclone crossing Orissa coast in Oct. 2013

The intensity of cyclones derived from satellite data can be used to determine the maximum winds in the cyclone field. The wind maxima is related to the cyclonecentral pressure by the formula

$V_{max} = K \sqrt{P - P_c}$

where P_c is the central pressure, and V_{max} is the maximum wind. The constant K has been calibrated for the Indian Ocean region using a number of cyclones studied using satellite data.

b. Stability index using radio occultation refractivity profiles

The data from GPS satellites are used to derive atmospheric conditions, based on the principle that the time delay in arrival of signals from GPS satellite is directly linked to the moisture content and temperature profile of the atmosphere. A new stability index based on atmospheric refractivity at ~500hPa level and surface measurements of temperature, pressure and humidity is formulated. The new index named here as refractivity based lifted index (RLI) is designed to give similar results as traditionally used lifted index derived from radiosonde profiles of temperature, pressure and humidity [16].

The formulation of the stability index and its comparison with the traditional temperature profile based lifted index (LI) is discussed. The index is tested on COSMIC radio occultation derived refractivity profiles over Indian region. The forecast potential of the new index for rainfall on 2°×2° latitude–longitude spatial scale with lead time of 3–24 hours indicate that the refractivity based lifted index works better than the traditional temperature based lifted index for the Indian monsoon region. Decreasing values of RLI tend to give increasing rainfall probabilities.

c. Study of break and active rainfall cycles over Nepal linked to Indian Monsoon

Using INSAT and ground truth data for the four years (1994-1997) of 12 stations of Nepal and 18 subdivisions of India, an attempt has been made to establish a relationship between Nepal and three different regions selected of India on break and active monsoon over Nepal. The three different meteorologically homogeneous regions of India west central, peninsular and north east India have been selected for the present study [17]. Generally these three regions of India are more related to Nepal's monsoon especially during break monsoon conditions. Weekly rainfalldata of the area have been analyzed statistically. Similarly satellite imageries and synoptic charts have also been used to study the movement of cloud and trough line. The nature of the weekly variations of rainfall over the different regions for the monsoon season is discussed.

d. Rain-rate classification using INSAT-VHRR data

This study covering a large number of rain guages describes a procedure to determine rain rates using INSAT visible and infrared data by means of statistical methods. Satellite rain estimation techniques are more sensitive to spatial degradation than to temporal degradation. In the present study, visible and infrared samples selected from the VHRR images are used in the training process to achieve good spatial correspondence between satellite and ground estimates [18] Brightness features which are providing the best separability among the selected rain rate categories are extracted from the images.

By locating all the 560 rain gauge stations maintained by the India Meteorological Department (IMD), the maximum likelihood decision rule was employed to classify the 8 km × 8 km window centered at a rain gauge station into one of the four selected rainfall rate categories. The training process used the rainfall data obtained from IMD daily weather reports for verification. The INSAT data for sample dates, representing different seasons has been used for the study. Classification accuracy, defined as the percentage of samples correctly classified out of all the samples in the selected class, was found to be above 80%.

2. Conclusions

With several satellite missions in the past two decades, India has emerged as a strong operational user of satellite data for applications of direct relevance to the society. The data is being used for natural resources surveys, environment assessment, disaster mitigation and weather forecasting. Recent launches of INSAT -3D with vertical sounders and MeghaTropiques with advanced payloads for study oftropics has led to formulation of national projects on Monsoon, Disaster management and Climate change. The future planning needs to take cognizance of climate change scenarios. A suitable mix of satellite and ground observations with high resolution weather modelling holds the key for future.

Acknowledgments

The author wishes to acknowledge the support provided by ISRO and Bangalore University in terms of materials and logistics. Author also thanks Dr. Kamsali Nagaraja, Department of Physics, Bangalore University and Dr. Shivappa B. Gudennavar, Department of Physics, Christ University, Bangalore for constant encouragement and inspiration.

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