APPLICATIONS OF REMOTE SENSING FOR CLIMATE STUDIES

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Abstract
The potential climate changes and possible adverse impacts on the economy and society at large are causing concern. In India, one of the major factors is the variability of monsoon rainfall and its impact on agriculture and water management. The effects of global warming on the Indian subcontinent vary from the submergence of low-lying islands, frequent flooding, coastal degradation and melting of glaciers in the Indian Himalayas. Climate-related natural disasters cause massive losses of Indian life and property. Droughts, flash floods, cyclones, avalanches, landslides brought on by torrential rains, and snowstorms pose the greatest threats. Other dangers include frequent summer dust storms with north westerly track causing extensive damage in North India. INSAT and IRS satellites in early 1980s heralded the era of Space observations. The IRS satellites are providing observations of parameters such as land use/cover, forest, water bodies, crops etc. while INSAT provides quantitative products. It may be necessary to adopt improved agriculture practices with resistant seeds, efficient water management. The satellite data is operationally used for climate change studies and long term database on vegetation, soil condition, rainfall, groundwater, land use, ocean temperature, ocean productivity etc. is being generated. Some of the unique studies include Mapping of Himalayan Glaciers, Biodiversity Mapping, Early Warning of Drought and Severe Weather Events. The paper presents details of the critical role played by satellite systems in climate change studies and modeling.

Keywords: remote sensing, climate change, reflectance, vegetation,

Introduction

Remote Sensing 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. Spectral, spatial, temporal and polarization signatures are major characteristics of the sensors, which facilitate target discrimination. Earth surface data as seen by the sensors in different wavelengths as reflected, scattered and/or emitted is corrected both radiometrically and geometrically before extraction of spectral information. Remote sensing 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.

Scientific rationale

Science of remote sensing gathers information through the electromagnetic radiation reaching the sensor. In remote sensing, a variety of devices are used for gathering information on a given object or area. The radiation coming from the Sun consists of electromagnetic spectrum of visible, thermal, radio and microwave frequencies, with very wide coverage. A maximum intensity of 49% is in the visible region that covers 0.4 to 0.7 μm. The radiation fall on to the atmosphere and interacts with the gases and molecules present. The main processes that occur are reflection, scattering and absorption. Due to these processes, the radiation reaching earth's surface is reduces. The ratio of radiation transmitted through the atmosphere reaching the earth to the incoming radiation from the Sun is called as transmittance. This varies for different frequency regions due to the selective absorption and scattering by gases in the atmosphere. The era of Earth observing and Weather monitoring satellites such as Landsat, IRS, Nimbus, SPOT, ERS, INSAT, GOES, GMS and more recent missions such as Megha Tropiques, RISAT, RADARSAT and UARS started with high quality observations from space. This provides the strong basis for global and regional studies of natural resources, natural disasters, environmental assessment and climate change.

Concept of signature

The satellite imageries are interpreted based on signature of various objects. Each object on Earth such as water bodies, crops, forest, building, soil have specific spectral signature as shown in Fig. 1. The 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. There are four principal characteristics of signatures to identify objects and features on Earth's surface and atmosphere. The satellite sensors operate in different bands which are sensitive to various features over the Earth. The details of various bands and mapping of features are depicted in Table 1.

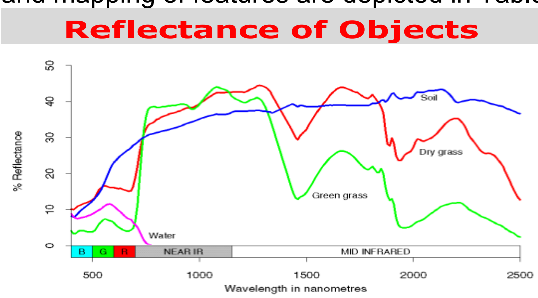

Figure 1. Spectral signature of objects

Table 1. Spectral bands giving land and ocean parameters

Band	**Spectral band (μm)**	**Sensitivity to features**
1	0.45-0.52	sedimentation, deciduous/coniferous forest cover discrimination, soil vegetation differentiation
2	0.52-0.59	Green reflectance by healthy vegetation, vegetation vigour, rock-soil discrimination, turbidity and bathymetry in shallow waters
3	0.62-0.68	Sensitive to chlorophyll absorption: plant species discrimination, differentiation of soil and geological boundary
4	0.77-0.86	Sensitive to green biomass and moisture in vegetation, land and water contrast, landform/geomorphic studies.

IRS Satellite System

On 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 completed its 25-years of successful operations on 17 March 2013.

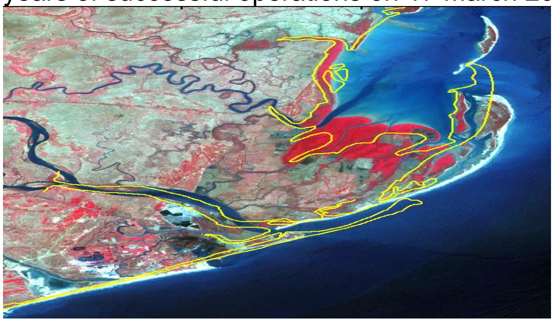

Figure 2. Coastal ecosystem off Orissa Coast from IRS Satellite

Remote sensing application to climate and weather

In India, we experience in general four major seasons of winter, summer, monsoon and post monsoon. The monsoon season extends from June to September. During the post monsoon season, cyclonic storms form over the Bay of Bengal and rarely over Arabian Sea and move into the coastal areas. The launch of the first meteorological satellite TIROS-1 in April 1960 heralded the era of space observations and gave the first glimpses of the dynamic cloud systems surrounding the Earth. The advantages of Space observations emanate from several factors such as a) Synoptic view of large areas b) Frequent observations c) High level of uniformity of space observations d) Filling of gaps in observations, especially over Oceans and inaccessible and remote land areas. The climate of an area is affected by several land surface processes such as land cover, vegetation, soil moisture, ocean surface winds and temperature. The potential of satellites includes mapping and monitoring of dynamic features of land surface such as Coastal ecosystem, vegetation, water resources etc. as shown in Figs. 2 and 3.

Indian Meteorological Satellites

The INSAT (Indian National Satellite) is a geostationary satellite providing continuous view of Indian sub continent. It carries meteorology payload called Very High Resolution Radiometer (VHRR) with sensors operating in visible, infrared and water vapour channels [1-3]. The INSAT satellites give every hour weather imageries of the country [2] showing the cloud systems, their movement and potential severe weather events. INSAT series of geostationary satellites was conceived to meet the operational needs of meteorology and weather services. The INSAT 1 series launched through the 80's carried a Very High resolution Radiometer (VHRR) payload that operates in 2-spectral bands such as visible (0.55-0.75 μm) and thermal infrared (10.5-12.5 μm).

Currently several operational meteorological satellites are providing global and regional observations. Six different types of satellite systems currently in use are:

Visible/Infrared/Water Vapour Imagers., Infrared Sounders., Microwave Imagers., Microwave Sounders., Scatterometers and Radar altimeters

Though the water vapour imaging capability is available only on the geostationary satellite, the visible and infrared imagers are available on geostationary as well as polar orbiting satellites. The last four are currently available only on polar orbiting systems. The INSAT system, which is the primary satellite for weather surveillance in the Globe is a multipurpose geostationary satellite that caters to the requirements of Meteorology and Communication. It carries a met payload VHRR that enables us to have visible, infrared and now even water vapour images [3].

The quantitative products available from INSAT data compute the following numerical products: Cloud Motion Vectors (CMVs., Quantitative Precipitation Estimates (QPEs)., Outgoing Long-wave Radiation (OLR)., Vertical Temperature Profiles (VTPRs) ., Sea Surface Temperatures (SSTs) .

Meteorological data along with satellites are valuable for monitoring and forecasting of 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. Current research around the globe is concentrating on use of mesoscale models with satellite data inputs to improve the cyclone intensity and track prediction [4-6].

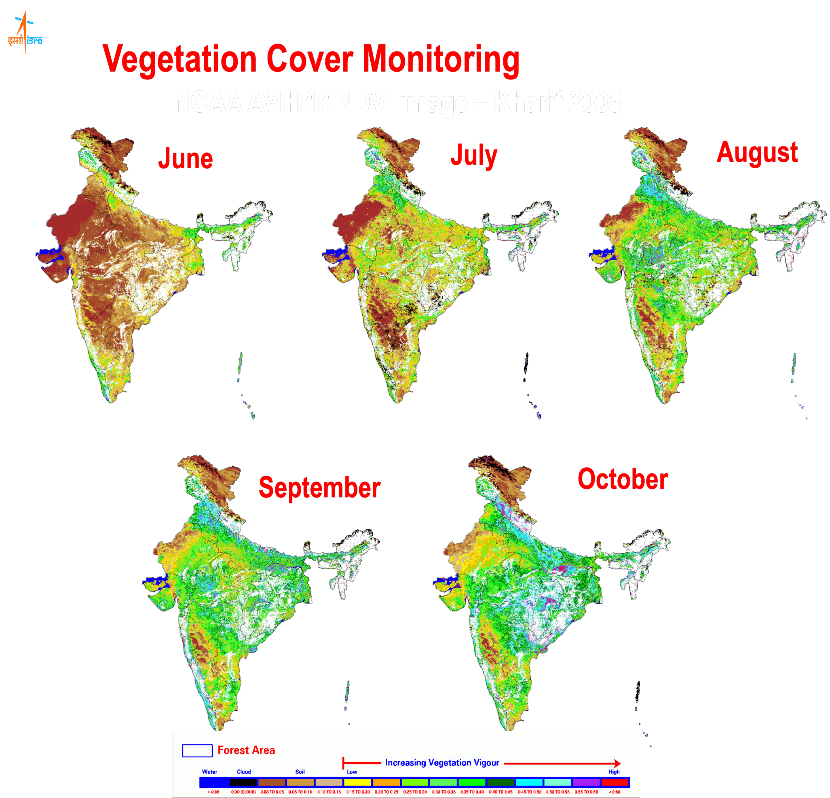

Figure 3. Vegetation dynamics of Indian continent

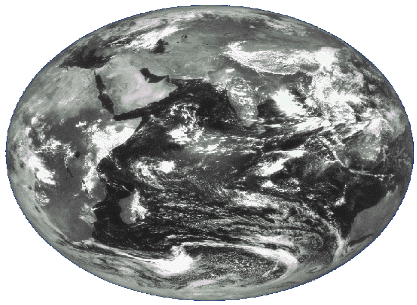

Figure 4. Monitoring of weather with INSAT

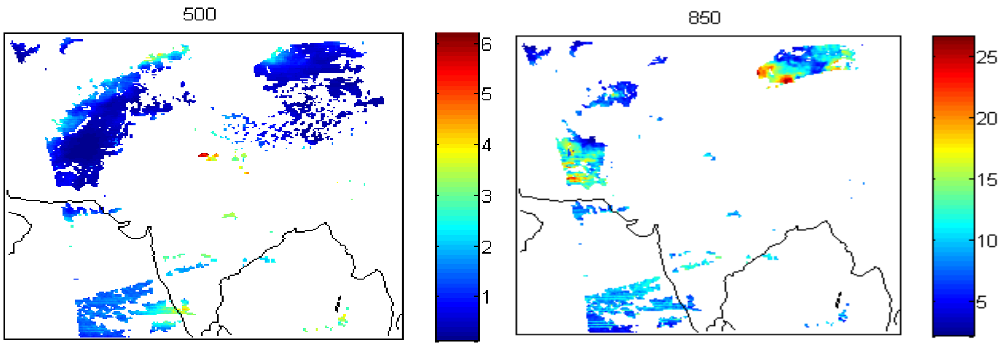

Figure 5. Humidity profile (g/kg) from INSAT 3D (10 August 2013 of 0331 UTC)

Fig. 6: Satellite Image of Tropical Cyclone

Agromet Advisories

Based on the weather forecast for next few days, agromet advisories are generated for helping the farmers. The forecasts relating to heavy rain or deficient rain help in recommending suitable actions to save crops. Currently, the India Meteorological Department (IMD) is providing agromet advisories at district level. With the use of mesoscale models, it is possible to extend this service to Taluk levels benefiting farmers to a great extent.

Satellite Based Weather Forecasting

The recent advances in satellite technology in terms of high resolution, multi-spectral bands covering visible, infrared and microwave regions have made space data an inevitable component in weather monitoring and dynamic modelling. The impact of satellite data is phenomenal in certain areas of meteorological applications such as short-range forecasts, Tropical Cyclone (TC) monitoring, aviation forecasts etc. With improving trend in accuracy of satellite retrievals, improvements could be carried out in models leading to improved forecasts, especially in the tropics [7-9]. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve. The chaotic nature of the atmosphere, the massive computational power required to solve the equations that describe the atmosphere, error involved in measuring the initial conditions, and an incomplete understanding of atmospheric processes mean that forecasts become less accurate as the difference in current time and the time for which the forecast is being made (ex. *range* of forecast) increases. Numerical weather prediction models are computer simulations of the atmosphere. The large amount of weather parameter observations are provided by satellites and ground based stations such as Automatic Weather Stations (AWS), Mini Boundary Layer Mast (MBLM), GPS Sonde, RADAR, LIDAR and so-on.

Observations from satellite remote sensing for climate change assessment

The climate change studies require accurate observations on a long term basis on parameters related to Atmosphere, Oceans, Land surface and weather related extreme events. The approach is to acquire satellite observations and validating with ground/sea truth data and build a long term series on above parameters. Currently such database is available on land use, land cover, water resources, sea surface temperature, cyclones, droughts, rainfall.

Conclusions

The global warming effects on the Indian subcontinent vary from the submergence of low-lying islands and coastal lands to the melting of glaciers in the Indian Himalayas. The future direction of research is to analyze the space data and quantify the impacts. While studying such scenarios, it is essential to build up necessary strategies at local level to reduce the adverse impacts especially on agriculture and water management. It may be necessary to adopt improved agriculture practices with resistant seeds, efficient water management etc. It will be a challenging task to counter the effect of climate change through scientific means.

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