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SATELLITE APPLICATIONS FOR CLIMATE CHANGE STUDIES WITH SPECIAL REFERENCE TO AGRICULTURE

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ABSTRACT

Recent times have witnessed large concern regarding the global climate change and its impacts on society. The process is complex and needs to be understood well so that appropriate combative measures can be taken up. The satellites, with their capability to provide global uniform data on a repetitive basis are proving to be an invaluable tool in the study of weather and climate changes in a quantitative manner. The weather data available with many countries for past several decades is being reanalyzed and a long term series data with satellite observations is being created. Several unique observations from satellites such as sea surface temperature, cloud water content, energy budget of earth-atmosphere system will contribute to our study of weather processes and likely changes.

The satellites play a key role in providing valuable observations for assessing the impact of climate change. India has a series of remote sensing satellites namely INSAT and IRS satellites operating in geostationary and polar orbits. These satellites carry CCD based imaging sensors and provide imageries of the Earth in different spectral bands. The advantage of satellites is its capability to provide data over large areas thus providing a synoptic view of the region. The climate change studies require observations at high frequency and over large areas which is provided by satellites.

The INSAT satellite is capable of monitoring various weather parameters such as temperature, humidity, winds, rainfall etc. and using computer models it is possible to assess the weather over large areas. With long term series of data over an area, the climate change is analyzed and potential changes in temperature and rainfall are assessed.

The IRS series of satellites provide observations over the Earth features such as water resources, agriculture, forests, and soil conditions that are directly affected by climate change. Over the past 4 decades, India has developed databases on all important natural resources in the country and these databases will be very useful to assess the potential impacts of climate change. The paper highlights the role of satellites and describes case studies related to agriculture.

Key Words: Remote Sensing, Natural Resources, Satellites, Agriculture, Climate Change

INTRODUCTION

The beginning of ISROs Space programme was in a humble way by launching of rockets for study of middle atmosphere under a United Nations programme. The site selected for rocket launching was Thumba near Tiruvananthapuram in Kerala, which lies near to Equator. Based on the rocket chaff movement, the wind conditions were studied and this led to very interesting aspects of equatorial electro jet, wind reversal during monsoon, temperature inversion etc.

OPERATIONAL INDIAN SATELLITE PROGRAMME

The Indian Space Programme was designed to meet country's priorities such as weather monitoring, communication, natural resource mapping and ultimately provide valuable inputs to planning of country's resources. This led to a series of satellite systems – IRS (Indian remote Sensing Satellites) and INSAT (Indian National Satellites). The IRS is a polar orbiting system moving across the poles. A typical IRS at an altitude of 800 kms will revisit the same area once in 22 days which is adequate to study the crop growth, forest changes, flow of water etc. The first IRS satellite was launched in 1982 and since then a series of satellites has been designed and launched (Fig. 1).

Fig. 1. Indian Operational satellites

Remote sensing usually refers to the technology of acquiring information about the earth's surface (land and ocean) and atmosphere, using sensors onboard airborne (aircraft, balloons) or space-borne (satellites, space shuttles) platforms. The electromagnetic radiation is normally used as an information carrier in Remote sensing. 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 infrared wavelength regions, reflected/scattered or emitted from the earth, forming images resembling photographs taken by a camera/sensor located high up in space.

APPLICATION TO WEATHER & CLIMATE STUDIES

Accurate and reliable weather and climate prediction holds the key for socio-economic development and is essential for food security of the human society. The day-to-day changes in weather are another factor that has direct impact of human society. The agricultural operations of ground preparation, tilling, sowing, weeding, fertilizer/pesticide applications, irrigation, harvesting etc. are decided based on weather situation and trends. The crop selection to a large extend is based on arrival of monsoon and its expected performance. Further, the post-harvest operations such as drying, transportation etc. also critically depend on fair weather. Availability of weather information to the rural community through forecasts in short and medium range can significantly reduce the risk involved in agriculture operations and lead to improved productivity.

Recent times have witnessed increasing concern over the climate changes and possible adverse impacts on the economy and society at large. Though it is difficult to clearly identify the natural variability of atmosphere versus anthropogenic impacts, the recent report of the International Panel on Climate Change has attempted to quantify the impacts. Accurate weather forecast will need observations from global to regional to local scales.

INDIAN WEATHER: VARIABILITY

In India, we experience in general four major seasons of winter, summer, monsoon and post monsoon. The severe winter conditions are experienced by northern India while summer heat occurs across the country. The monsoon is a global flow of moist air mass across the equator to the Indian sub continent bringing copious rainfall. The monsoon dynamics is very systematic and year and year shows consistency with respect to its onset, movement of rainfall belt across the country and withdrawal. 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. avalanches, landslides brought on by torrential rains, and snowstorms pose the greatest threats. Other dangers include frequent summer dust storms, which usually track from north to south; they cause extensive property damage in North India and deposit large amounts of dust from arid regions.

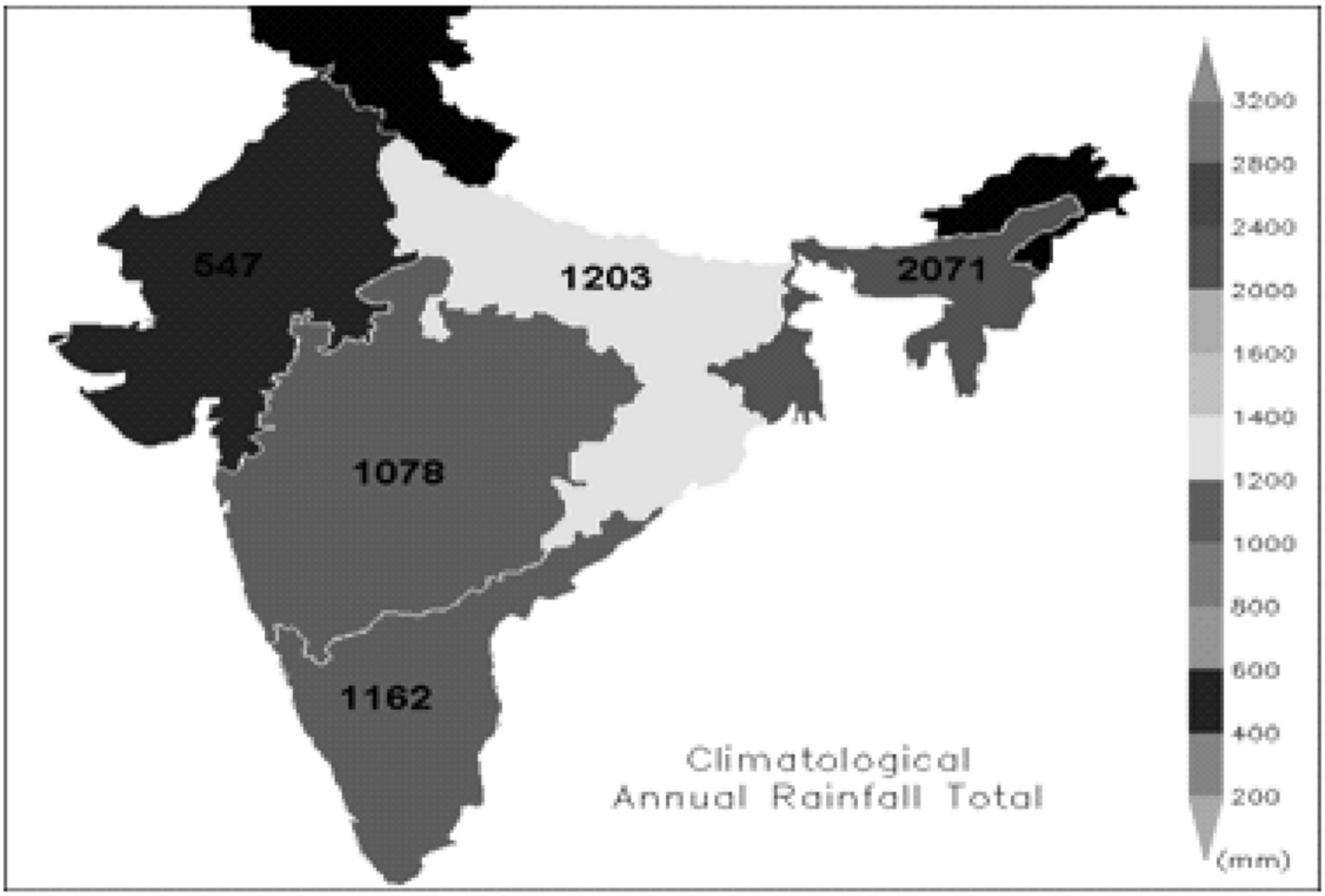

Fig. 2. Agro climatic zones based on rainfall

One of the concerns is with respect to the variability of monsoon rainfall. Every monsoon is distinct and shows changes from the expected normal. It is interesting to note that while the overall rainfall remains within ± 10% of Long Term Average of 900 mm, there is large variability in rainfall at district and local scales. The impact of such variability is different in different regions of the country and the country is divided into various agro climatic zones (Fig. 2) based on the rainfall, temperature and agricultural practices.

Climate-related natural disasters cause massive losses of Indian life and property. Droughts, flash floods, cyclones, Hail is also common in parts of India, causing severe damage to standing crops such as rice and wheat.

Indian agriculture is heavily dependent on the monsoon as a source of water. In some parts of India, the failure of the monsoons result in water shortages, resulting in below-average crop yields. This is particularly true of major drought-prone regions such as southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Orissa, Gujarat, and Rajasthan. In the past, droughts have periodically led to major Indian famines.

CONTRIBUTION OF SATELLITE OBSERVATIONS

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. Since then the technology has developed by leaps and bounds in observation capabilities in terms of spatial, spectral and temporal resolutions. A global system of Space observations with both geostationary and polar orbiting satellites has evolved. The advantages of Space observations emanate from several factors such as:

- Synoptic view of large areas, bringing out the inter-relations of processes of different spatial scales.
- Frequent observations from geostationary satellites provide continuous monitoring while polar orbiting satellites give typical twice daily coverage; such data is relevant for study of weather system dynamics.
- The inherent spatial averaging is more representative than the point in-situ observations and readily usable for weather prediction models.
- High level of uniformity of space observations overcomes the problem of inter-calibration needed for ground based instruments.
- Filling of gaps in observations; Space data covers large oceanic areas and inaccessible and remote land areas, thus giving global coverage.
- New types of data and observations; parameters such as sea surface (skin) temperature, sea surface wind stress, sea level, cloud liquid water content, radiation balance, aerosol are some of the unique parameters provided only by satellites.

Meteorological Satellites/ Payloads

Currently several operational meteorological satellites are providing global and regional observations. Six different types of satellite systems currently in use are – (1) Visible/ Infrared/ Water Vapour Imagers, (2) Infrared Sounders, (3) Microwave Imagers, (4) Microwave Sounders, (5) Scatterometers and (6) 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. We first describe in detail below the INSAT system which is the primary satellite for weather surveillance in this part of the globe. It is a multipurpose geostationary satellite that caters to the requirements of Meteorology and Communication. It carries a met payload called Very High Resolution Radiometer (VHRR) that enables us to have visible, infrared and now even water vapour images.

Monitoring weather with INSAT

The Indian Meteorological Department is the primary agency to monitor weather and give predictions. A network of weather observatories is providing round the clock weather data both surface and upper air. The Indian Space programme since inception gave great thrust to meteorology and weather forecasting. 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 which operated in two spectral bands – visible [0.55-0.75 μm] and thermal infrared [10.5-12.5 μm]. The INSAT satellites give every hour weather imageries of the country showing the cloud systems, their movement and potential severe weather events.

All these data are input into weather models which generate forecast of weather for 24 hrs to 72 hours. These models require good quality weather data at regular intervals. Some of the scientific results are:

- One of the earliest studies using satellite data showed the 30-40 day oscillatory nature of monsoon flow. The critical role played by the sea surface temperature in the Indian and Pacific ocean regions was clearly brought out by several studies.
- Based on the weather forecast for next few days, agro met 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 IMD is providing agro met advisories at district level. With the use of mesoscale models, it is possible to extend this service to taluk level benefiting farmers.
- Meteorological data along with satellites are valuable for monitoring and forecasting of cyclones. INSAT/VHRR

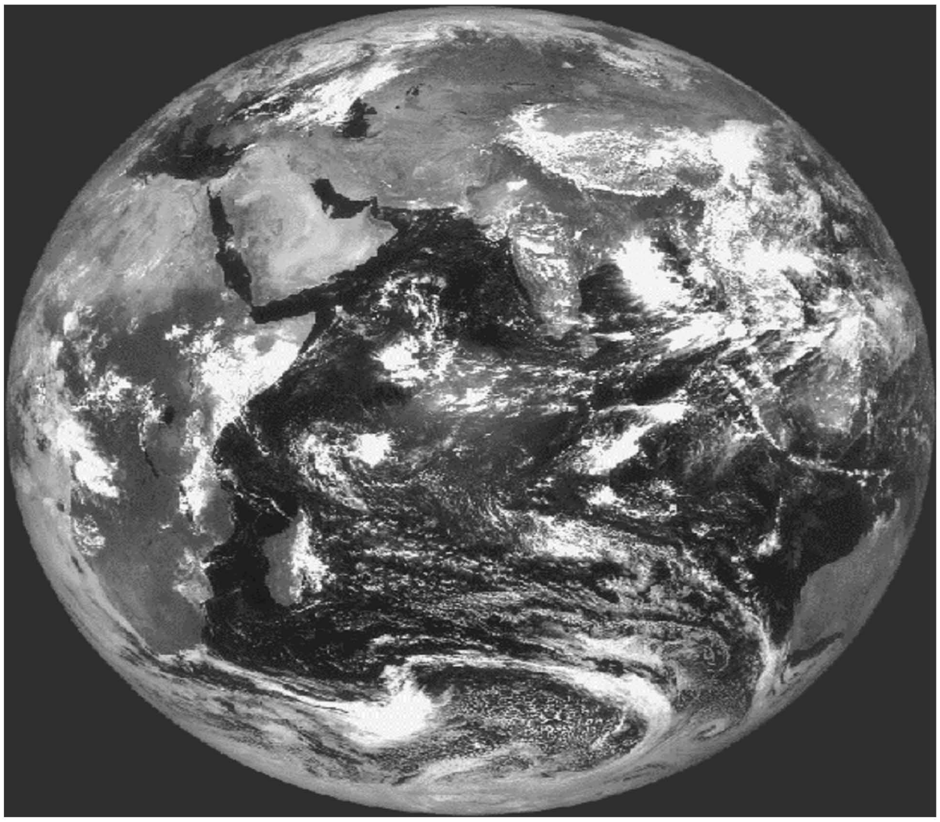

Fig. 3. INSAT Satellite Cloud Image

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. (Fig. 4). Current research around the globe is concentrating on use of meso-scale models with satellite data inputs to improve the cyclone intensity and track prediction.

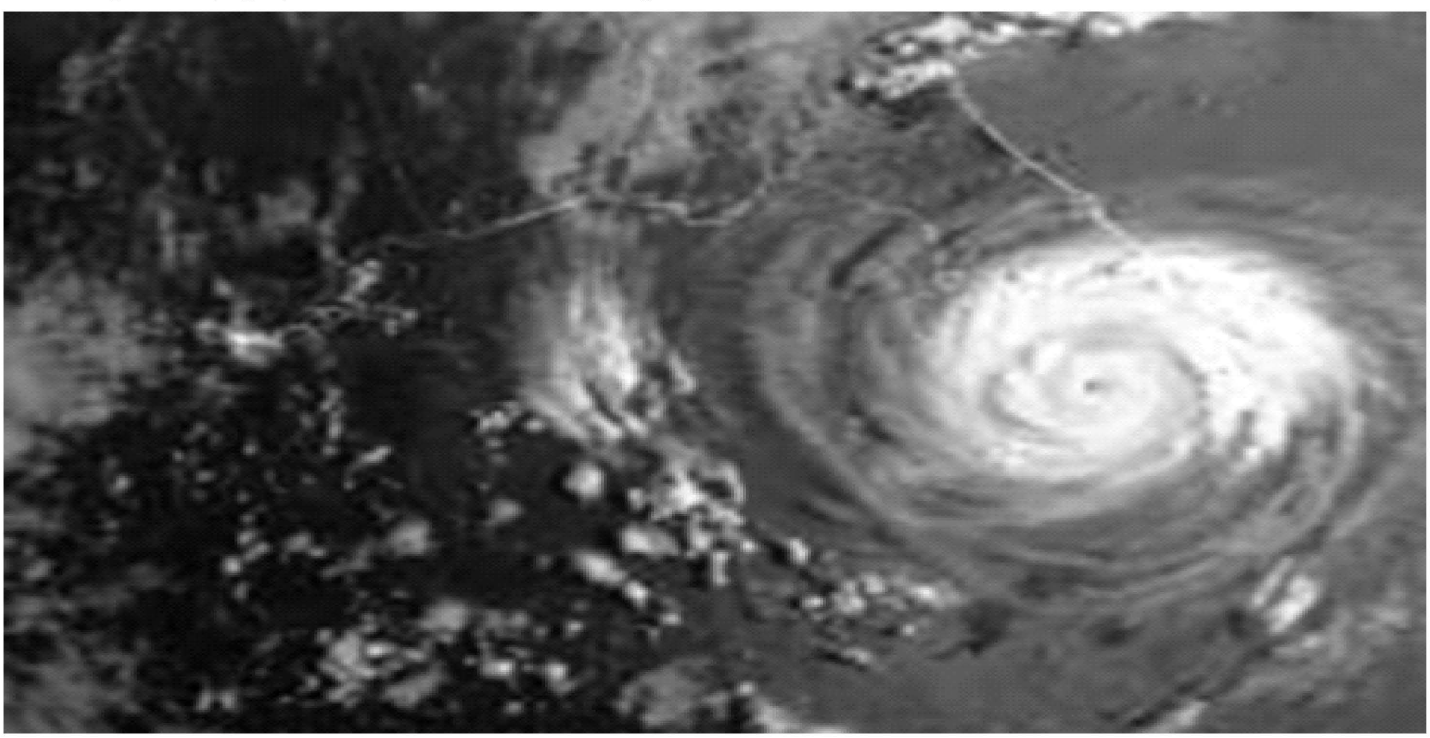

Fig. 4. INSAT Satellite Image of Tropical Cyclone

Early warning of drought is useful for on-farm operations and to arrive at an optimal local water utilization pattern. Rainfall anomalies as observed from geo-stationary/ meteorological satellites are being used for early warning of drought, which is yet to be fully operationalized. Satellite derived vegetation index (VI) which is sensitive to moisture stress (Fig. 5) is now being used continuously to monitor drought conditions on a real time basis often helping the decision makers initiate strategies for recovery by changing cropping patters and practices.

The quantitative is used to products available from INSAT data compute the following parameters, which are unique and not directly observable:

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)

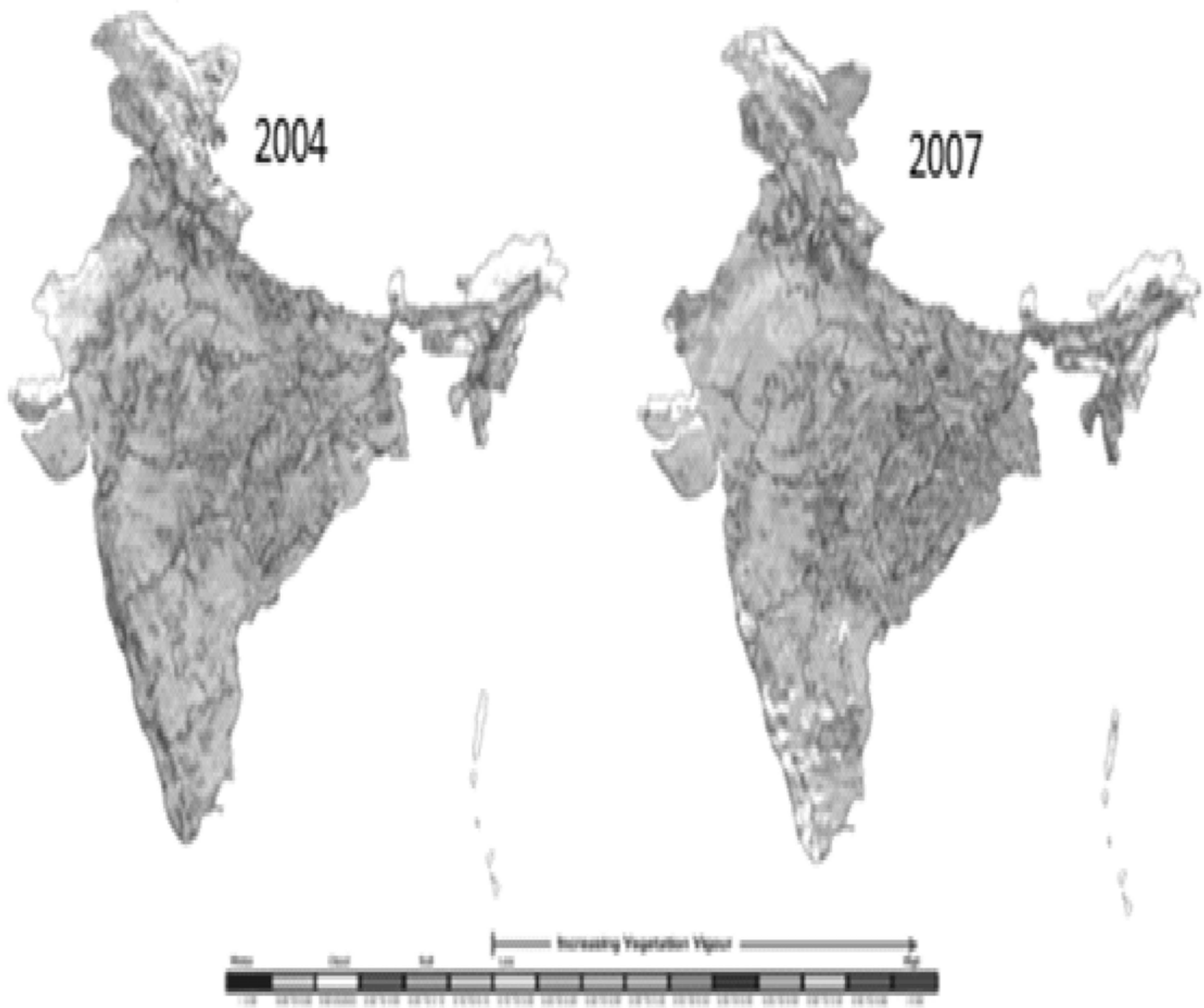

Fig. 5. Monitoring of year to year Agricultural Drought

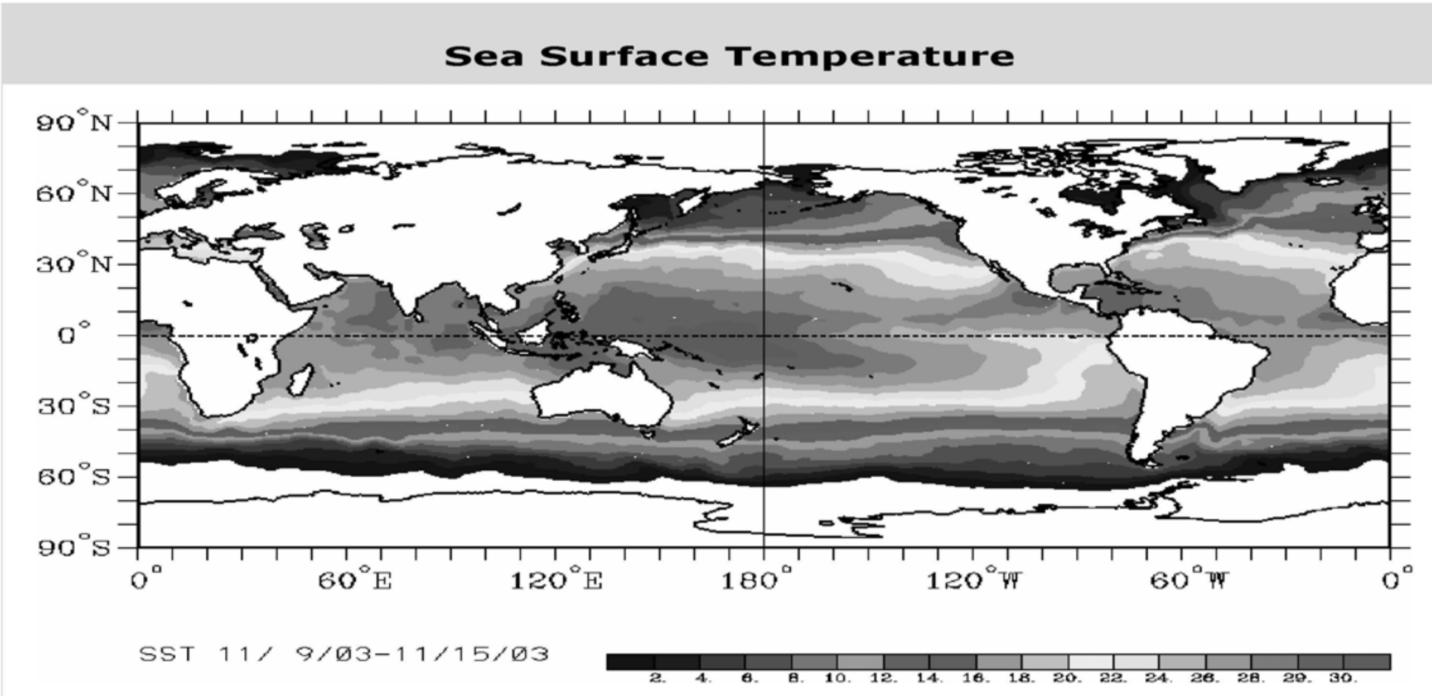

Fig. 6. Sea Surface Temperature Map

FUTURE SATELLITE MISSIONS

Several satellite missions have been planned to support the operational data needs and ongoing research efforts. The future Metsat missions will carry improved VHRR and vertical sounders for temperature/humidity profiles. The Megha -Tropiques Mission scheduled for 2004 launch will be a joint project by ISRO and CNES, France with the objective of studying the water cycle and energy exchanges in the tropics. With an equatorial inclined orbit, the satellite will have high repetitively over tropical regions. The forthcoming advanced satellites for weather & climate studies are:

INSAT-3D, an exclusive meteorological satellite, is configured with advanced meteorological payloads - a 6 Channel Imager, 19 Channel Sounder along with Data Relay Transponder and Satellite Aided Search & Rescue payloads. The spacecraft platform is adopted from the standard I-2K bus with a power handling capability of around 1100 W with a lift off mass of 2090 kg.

The Satellite for ARGOS and ALTIKA (SARAL) is a joint ISRO - CNES mission, and was launched during 2012. The Ka band altimeter, ALTIKA, provided by CNES consists of a Ka-band radar altimeter, operating at 35.75 GHz. A dual frequency total power type microwave radiometer (23.8 and 37 GHz) is embedded in the altimeter to correct tropospheric effects on the altimeter measurement. Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) on board enables precise determination of the orbit. A Laser Retro-reflector Array (LRA) helps to calibrate the precise orbit determination system and the altimeter system several times throughout the mission.

The future appears bright for our space-based observing system. Advanced, multispectral (visible, IR, and passive microwave) imagers, sounders (infrared and microwave) and scatterometers are planned for launch in the near future. Hyperspectral measurements from newly developed interferometers are expected to be flown experimentally by 2006. The information content will vastly exceed that of the current measuring devices. Instead of a few dozen viewing channels, these instruments will have more than a thousand channels over a wide spectral range.

EFFECTS OF GLOBAL WARMING

The effects of global warming on the Indian subcontinent vary from the submergence of low-lying islands and coastal lands to the melting of glaciers in the Indian Himalayas, threatening the volumetric flow rate of many of the most important rivers of India and South Asia. In India, such effects are projected to impact millions of lives. As a result of ongoing climate change, the climate of India has become increasingly volatile over the past several decades; this trend is expected to continue.

Several global climate models run by leading meteorological agencies have indicated possible increase in rainfall over Indian region. This could mean large intensity rain events leading to floods etc. The intensity of cyclones is also expected to increase.

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.

The effects of emission of gases to atmosphere, deforestation, high density built up areas are considered to be the initiators of climate change. The important indicators are sea level change, change in rainfall, recurrent floods/extreme events, warming of atmosphere, melting of snow cover in Himalayas, Antarctic & Arctic regions. With the advent of satellite observation with global coverage, each of the above factors has been extensively studied. While there are indications of an ongoing climate change, there are still questions to be answered such as whether the signals are above the natural variability of earth system.

SATELLITE OBSERVATIONS FOR CLIMATE CHANGE STUDIES

The critical parameters related to climate change were listed as under three main themes of land, ocean and atmosphere. The land related parameters are landuse changes, biodiversity, coast line change, deforestation. Ocean contributes in terms of sea surface temperature, productivity, sea level change. The atmosphere expresses climate change in terms of circulation patterns, jet streams, near surface temperature, weather systems and intensity.

There are classes of satellites such as IRS, SPOT, IKONOS, RISAT, RESORCESAT, and CARTOSAT that give land surface parameters with high resolution. Oceansat 2, ERS 2 are giving ocean parameters with sensors such as OCM, Scatterometer, Altimeter. The missions such as TRMM, Megha Tropiques, SSM/I, DMSP, INSAT, METSAT are giving wealth of information on weather systems, cloud cover, rainfall, atmospheric conditions etc.

CONCLUSIONS

This is a highly debated topic globally with several teams working on various aspects of climate change. The effects of emission of gases to atmosphere, deforestation, high density built up areas are considered to be the initiators of climate change. The important indicators are sea level change, change in rainfall, recurrent floods/extreme events, warming of atmosphere, melting of snow cover in Himalayas, Antarctic & Arctic regions. With the advent of satellite observation with global coverage, each of the above factors has been extensively studied. While there are indications of an ongoing climate change, there are still questions to be answered such as whether the signals are above the natural variability of earth system.

The scenario indicates major effect on coastal population due to raise in sea level, increased frequency of storms and rainfall. The urban population has to face extreme weather events such as cloud bursts and high intensity rainfall. One of the serious impacts is on the agricultural systems which depend on weather and any change in rainfall will adversely affect agriculture. The melting of ice/snow will have long term effect of reduction in river flow and ecosystems.

What is needed is a synergy of all these data and analyzes the land-ocean-atmosphere interactions and derives information on changes happening. A long term data base is essential for climate change studies and satellites with about a decade or more of observations are a good starting point.

Suggested Readings

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