

Space Technology and Observation in Climate Change: Indian Perspective

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Abstract:

Climate change is associated with earth radiation budget that depends upon in-coming solar radiation, surface albedo and radiative forcing by green house gases. Human activities are contributing to climate change by causing changes in Earth's atmosphere (greenhouse gases, aerosols) and biosphere (deforestation, urbanization, irrigation). Long term and precise measurements from calibrated global observation constellation is a vital component in climate system modelling. Space based records of biosphere, cryosphere, hydrosphere and atmosphere over more than three decades are providing important information on climate change. Space observations are an important source of climate variables due to multi scale simultaneous observation (local, regional, global) capability with temporal revisit in tune with requirements of land, ocean and atmospheric processes. Essential climatic variables that can be measured from space include atmosphere (upper air temperature, water vapour, precipitation, clouds, aerosols & GHGs etc.), ocean (sea ice, sea level, salinity, ocean colour etc.) and land (snow, glacier, albedo, biomass, soil moisture etc.). The paper reviews observational needs, space observation systems and studies that have been carried out at ISRO towards mapping/ detecting the indicators of climate change, monitoring the agents of climate change and understanding the impact of climate change, in national perspectives

Key Words: Remote Sensing, Climate Variables, Land Surface Parameters, Green House Gases, Monitoring

Introduction

Climate change is one of the complex problems facing mankind today. The overriding complexity of the problem is attributed to its deeper global ramifications on a vast range of issues impacting the very survival of life on Earth. Understanding such a complex issue with vast and varied dimensions and implications, assumes greater significance for all stakeholders, especially for our policy makers. There are varieties of perceptions regarding the exact size and consequences of climate change. Yet, it is no secret that risks emanating from climate change are indeed profound, which call for urgent mitigation. There is now strong evidence that climate change is a reality. Therefore, there is an imperative need to take urgent and strong measures in the interest of calibrating an appropriate response to meet the emerging challenges of climate change. In fact, the scientific community has already perceived the early warning signs, which are now being noticed even by a lay man. Vulnerability to climate has a strong linkage with poverty. Across developing countries, millions of the world's poorest people are already being forced to cope with the impacts of climate change. Increased exposure to severe droughts, intense storms, devastating floods and lasting livelihood insecurity is proving to be a major roadblock, holding back the efforts of the India's poor to build a better life for themselves and their children.

The earth's climate system has demonstrably changed on both global and regional scales since the preindustrial era. Further evidence shows that most of the warming (of 0.1°C per decade) observed over the last 50 years, is attributable to human activities¹. The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius (C) by 2100. This unprecedented increase is expected to have severe impacts on the global hydrological system, ecosystems, sea level, crop production and related processes. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, like India.

Geographical Location and climate variability of India

India is spread across the warmer regions of the planet as compared to the developed countries in North America or Europe, which are in relatively cooler regions. If we look at data from Indian Institute of Tropical Meteorology, it shows that much of India is warming. The mean annual surface-air temperature has risen by an average of 0.4°C in the last 50 years. India is a large country which extends from 8° to 33°N. The variety in terrain, from the high mountains of the Himalayas in the north to tropical coastlands in the south, makes for a wide range of climatic conditions. In the northern mountain regions, winters are cool at lower levels, and increasingly cold at higher altitudes. In the summer, intermediate levels around 2000 m above sea level are pleasantly cool, but it can get quite hot at lower levels. The Himalayas act as a barrier to the cold winds flowing down from Central Asia. Northern inland areas have a continental climate with a high seasonal and diurnal temperature

range. For example, New Delhi on the Northern Plains has a mean annual temperature of 25°C, but this varies from 14°C in January to 34°C in June. Further south, it is hot throughout the year, with annual mean temperatures of 27°C at Mumbai on the mid-west coast, and 29°C at Chennai on the south-east coast.

Besides being in the hotter region, India heavily depends on summer monsoon rains which are an important climatic feature on the Indian subcontinent.

As much as 70% of the annual aggregate precipitation is received in a short period from June to September during the southwest monsoon. Fragments of the southeastern states receive rainfall during the winter months. The vulnerability increases because of variable rainfall patterns. Meteorological records confirm that the monsoon exhibits considerable random and unexplained variation, but nevertheless has a relatively stable core. Most parts of the country are subject to marked seasonal rainfall and are heavily dependent on an uncertain monsoon. India, the seventh largest country in the world and the second largest in Asia, has a total geographical area of 329 million hectares, of which only 305 million hectares is the reporting area (the area as per the land records of villages and towns). The mainland stretches from 8°4' N to 37°6' N and 68°7' E to 97° 25'E. It has a land frontier of 15,200 km and a coastline of 7,516 km.

Space Technology in India

A geographic information system (GIS) captures, stores, analyses, manages, and presents data, which is linked to locations or having spatial distribution. It is a computer-based system that provides four sets of capabilities to handle geo-reference data. GIS is run on all spectrums of computer systems ranging from personal computers (PCs) to multi-user supercomputers, and are available in a wide variety of software languages. A number of tools are essential for effective GIS establishment such as computer, digitizer, GPS (Global Positioning System), plotter, network, CD-ROM drive, printer and software which links all of the equipment to run properly. GIS provides a valuable tool for information analysis, automated mapping and data integration. The powerful GIS software, tools in problem-oriented systems, provides direct and easy access to large volumes of data. It supports their interactive analysis and helps to display and interpret results in a format directly understandable and useful for decision-making processes.

Remote sensing (RS) technology has been developed well ahead of GIS technology. Remote sensing acquires information about material objects from measurements made at a distance, without coming into physical contact with the object. Usually an aircraft or satellite does the process. A remote sensing system using electromagnetic radiation has four components - a source, interactions with the earth's surface, interaction with the atmosphere and a sensor. The source of electromagnetic radiation may be natural, like the sun's reflected light or the earth's emitted heat, or man-made microwave radar. Earth's surface interaction, that is the amount and characteristics of radiation emitted or reflected from the earth's surface, is dependent upon the characteristics of the objects. Electromagnetic energy passing through the atmosphere is distorted and scattered, treated as atmospheric interaction, and the electromagnetic radiation that has interacted with the atmosphere and the surface of the earth is recorded by a sensor, such as a radiometer or camera.

Aerial photography is the earliest method of remote sensing and even in today's age of satellites and electronic scanners it remains the most widely used remote sensing method. Aerial photo means sensing the image of earth's surface through cameras fitted in an aeroplane or balloon. These photographs are very much useful for preparing large scale maps. The most commonly used earth's resource satellites are - Landsat series of USA, SPOT satellite series of France, and IRS series of India. These bear different types of scanners, viz, Multispectral Scanner (MSS), Thematic Mapper (TM), Panchromatic (PAN) scanner, High- Resolution Visible (HRV) scanner, Linear Imaging and Self Scanning (LISS) system, Wide Field Scanner (WiFS), etc. NOAA, NIMBUS, GOES Meteos and Himawari are the most commonly used meteorological satellites. Remote sensing data can be digitized and analyzed by GIS tools to give precise outputs in different formats.

Space Based Climate Observation in India

It has been fairly established that climate change happenings are real and these are further evident from recent increase in extreme events. With a view to understand the underlying science aspects, ISRO on its part, through its focused ISRO Geosphere Biosphere Programme (ISRO GBP), has been pursuing a climate research programme over the past two decades with specific focus on studying atmospheric aerosols, trace gases, GHGs, paleoclimate, land cover change, atmospheric boundary layer dynamics, energy and mass exchange in the vegetative systems, National Carbon Project (NCP) and Regional Climate Modeling (RCM). ISRO has also carried out extensive campaigns with integrated satellite, aircraft, balloon and ground-based measurements, jointly with many sister institutions in the country, to study quantitatively the above aspects, and has brought out many scientific findings in many reputed international peer reviewed journals. Many studies have been carried out towards mapping and monitoring of climate change indicators, which include glacier retreat (Kulkarni et al. 2005, 2006, 2007), changes in polar ice cover (Vyas et al. 2003, 2004), timberline change (Panigrahy et al. 2007) and coral bleaching (Bahuguna (2008), Bahuguna et al. 2008). There have been some pioneering efforts to map the

global change forcing agents. Spatial methane inventories from paddy rice (Manjunath et al. 2009), livestock (Chhabra et al. 2009) and wetlands (Garg et al. 2005) have been prepared. Seasonal pattern of CO₂ (Singh et al. 2008), CO, CH₄ and NO₂ have been analysed. All these, information along with land surface parameters may help in improving the accuracy of regional climate models and their projections for India.

Long-term impact assessment requires simulation models for forecasting. Studies are being carried out towards calibrating and validating these simulation models for Indian condition under Programme on Climate Change Research in Terrestrial Environment (PRACRITI) Programme (Pracriti, 2008). Presently these studies is being carried out in the fields of agriculture, hydrology, snow and glacier, impact on coastal zone due to sea level rise and green house gases. The experience and knowledge gained from these studies would be useful in forecasting the climate change impacts and suggesting adaptation measures.

Glaciers are normally described as mass of ice slowly moving down a gradient. A glacier consists of ice crystal, water and rock debris. Out of these, ice is an essential part of the glacier. Climate change is expected to change the ice cover and glacier extent. Satellite remote sensing data has been used to map and monitor the Himalayan glaciers. Glacier inventory of Indian Himalaya was completed at 1:250,000 scale using IRS-1A LISS-II data. 1702 glaciers covering an area 23,300 sq km were mapped. Glacier inventory at 1:50,000 scale was carried out in the Satluj, Tista, Dhauliganga and Chenab basins. Initial studies on monitoring of glacial retreat and estimation of loss in glacial area was carried out for two glaciers viz. Samudra Tapu (Kulkarni et al. 2006) and Parbati glaciers (Kulkarni et al. 2005) in Himachal Pradesh. Satellite images and data showed that these glaciers are presently retreating at the rate of 26 m and 38 m per year, respectively (from base year 1962). Similarly, change in snow cover is also expected as an indicator of climate change. Snow cover monitoring algorithm was used to monitor seasonal snow cover in 28 sub-basins in the Indus.

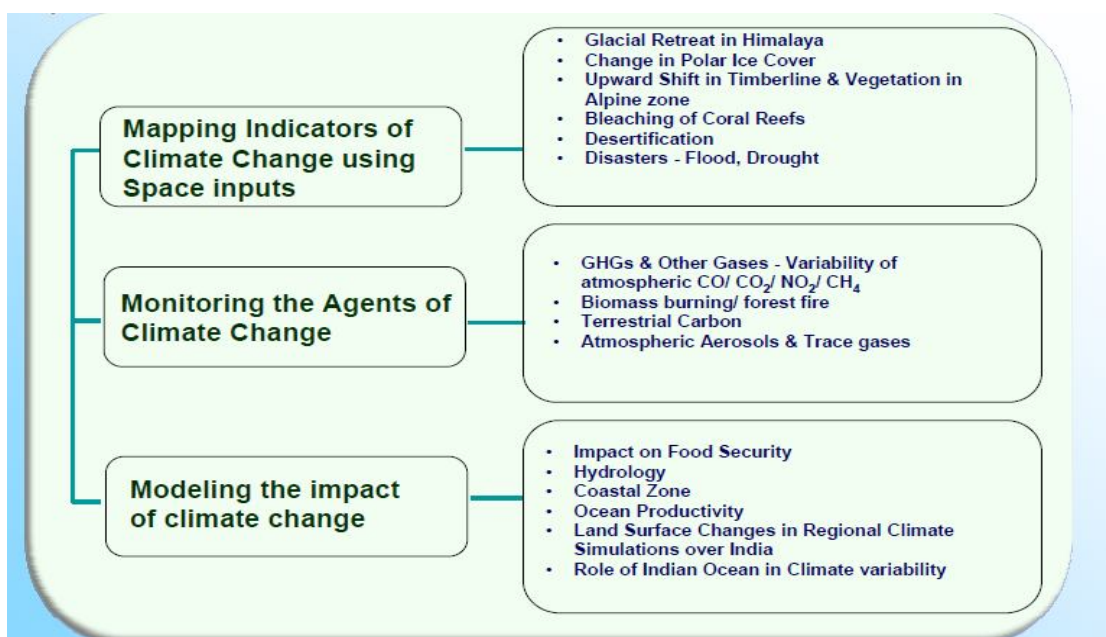


Figure 1: Research Themes and Activities of Climate Change in ISRO

High altitude/ mountain ecosystems defined by low temperatures are considered sensitive to climate warming. Simulation studies show that climate change impact will result in invasion of vegetation to higher altitudes. Study has been carried out in high altitude Central Himalayan ranges in a part of the World Heritage site (the Nanda Devi Biosphere reserve) using temporal satellite remote sensing data (Panigrahy et al. 2007). Data of March 1986 (Landsat TM), March 1999 (Indian Remote Sensing satellite – IRS LISS III) and March 2004 (IRS LISS III and LISS IV) were used in conjunction with the topographic map of Survey of India at 1:50,000 scales (based on 1960 aerial photographs).

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