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Key Note Paper

Space Technology Application for Climate Change Studies with Special Emphasis to Hydrological Regime

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Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by change in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. (IPCC Climate Change 2007: Synthesis Report).

The climate system is very complex as there are multiple interaction between atmosphere, land, cryosphere and ocean. To understand the climate variability and climate change, it is necessary to have a continuous monitoring, synoptic coverage, 3-dimensional atmospheric measurements on long term basis. In recent past lot many studies has been taken place to understand the various components of climate system as well as their interaction. However, few questions are yet to be answered viz. coupling between climate and biogeochemical cycle as well as hydrological cycle, LULC change and its impact on climate change, Cryosphere vs. climate change etc. There is still an incomplete physical understanding of many components of the climate system and their role in climate change. Key uncertainties include aspects of the roles played by clouds, the cryosphere, the oceans, land use and couplings between climate and biogeochemical cycles (IPCC fourth assessment report: climate change 2007).

There is a utmost need to monitor the process influencing the climate change on continuous basis with certain accuracy. Space based sensors provide not only continuous monitoring but also provide synoptic as well as 3-dimensional measurements. The information collected from space based sensors can also integrate with physical based simulation models to predict the climate change scenario as well as impact of climate change on earth system. Remote sensing data is utilized to study the hotspots. The observational needs consist of retrieval of atmospheric composition, Bio-physical changes in biosphere and ocean related physical, biological and chemical parameters.

CLIMATE CHANGES SCENARIO AND ITS MONITORING USING SPACE TECHNOLOGY

Carbon dioxide and methane are two most important green house gases which are responsible for global warming. These gases are affecting climate by altering the energy balance of earth by changing incoming solar radiation as well as outgoing long wave radiation. CFC (Chloroflourocarbons) and HCFC (hydrochloroflourocarbons) and Aerosols are another important anthropogenic factors which affect the surface energy balance significantly.

Climate change directly impact the snow cover area and glacier mass balance. This change alters the albedo as snow mainly reflected back the solar radiation. Due to decrease in snow cover, albedo will be reduced significantly which will result into more heating of land surface. Due to this chain reaction the snow cover area will decrease exponentially. Monitoring of snow cover area and glacier mass balance in Himalayas, polar region etc. is important to see the impact of climate change.

An important human influence on atmospheric temperature trends is extensive land use/land cover change (LULCC) and its climate forcing. Studies using both modeled and observed data have documented these impacts (e.g., Chase et al. 2000; Kalnay and Cai 2003; Cai and Kalnay 2004; Trenberth 2004; Vose et al. 2004; Feddema et al. 2005; Ezber et al. 2007). Thus, it is essential that we detect LULCCs accurately, at appropriate scales, and in a timely manner so as to better understand their impacts on climate and provide improved prediction of future climate.

Ocean salinity and Sea surface temperature are two most important parameters which influences the energy balance of earth. Climate change will not only increase the ocean water level but also influence the salinity by more evaporation. Coral reefs are the ifeline for living creatures of sea. Due to change in ocean temperature these coral reefs will also be affected.

Space based technology provides continuous monitoring at Local to global scale of above impacts. Some of the current and future space based systems are explained below

Orbiting Carbon Observatory (OCO)

The Orbiting Carbon Observatory (OCO) is a NASA Earth System Science Pathfinder Project (ESSP) mission designed to make precise, time-dependent global measurements of atmospheric carbon dioxide (CO_2) from an Earth orbiting satellite. The launch is scheduled to be no later than February 2013. It will be used for the dynamics of ocean carbon exchange, the seasonal dynamics of northern hemisphere terrestrial ecosystems in Eurasia and North America , the exchange of carbon between the atmosphere and tropical ecosystems due to plant growth, respiration, and fires , the movement of fossil fuel plumes across North America, Europe, and Asia,the effect of weather fronts, storms, and hurricanes on the exchange of CO_2 between different geographic and ecological regions , the mixing of atmospheric gases across hemispheres

CALIPSO and CLOUDSAT

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite provides new insight into the role that clouds and atmospheric aerosols (airborne particles) play in regulating Earth's weather, climate, and air quality. CALIPSO combines an active lidar instrument with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols over the globe. CALIPSO was launched on April 28, 2006 with the cloud profiling radar system on the CloudSat satellite. CALIPSO and CloudSat are highly complementary and together provide new, never-before-seen 3-D perspectives of how clouds and aerosols form, evolve, and affect weather and climate. CALIPSO and CloudSat fly in formation with three other satellites in the A-train constellation to enable an even greater understanding of our climate system from the broad array of sensors on these other spacecraft.

SCIAMACHY-ENVISAT

SCIAMACHY is an imaging spectrometer whose primary mission objective is to perform global measurements of trace gases in the troposphere and in the stratosphere. The solar radiation transmitted, backscattered and reflected from the atmosphere is recorded at relatively high resolution (0.2 nm to 0.5 nm) over the range 240 nm to 1700 nm, and in selected regions between 2000 nm and 2400 nm. The high resolution and the wide wavelength range make it possible to detect many different trace gases despite low concentrations (The mixing ratios of most constituents are of the order of 10-6 or less). The large wavelength range is also ideally suited for the detection of clouds and aerosols. SCIAMACHY has three different viewing geometries: nadir, limb, and sun/moon occultations which yield total column values as well as distribution profiles in the stratosphere and (in some cases) the troposphere for trace gases and aerosols.

ICESat and Cryosat

ICESat (Ice, Cloud,and land Elevation Satellite) is the Earth Observing System mission for measuring ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics. From 2003 onwards the ICESat mission provided multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds common over polar areas. It also provided topography and vegetation data around the globe, in addition to the polar-specific coverage over the Greenland and Antarctic ice sheets. CryoSat-2's primary payload is the Synthetic Aperture Interferometric Radar Altimeter (SIRAL), designed to meet the measurement requirements for ice-sheet elevation and sea-ice 'freeboard', which is the height protruding from the water.

SMOS

The Soil Moisture and Ocean Salinity (SMOS) mission will be ESA's second Earth Explorer in orbit. It follows on from the Gravity field and steady-state Ocean Circulation Explorer (GOCE), which was launched in March 2009. SMOS will make global observations of soil moisture over land and sea-surface salinity over the oceans to improve our understanding of the water cycle. Data from SMOS will be important for weather and climate modelling, water resource management, agriculture and also contribute to the forecasting of hazardous events such as floods.

MODIS

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data is utilized extensively for understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

Indian Earth observation system for Climate change impact studies

In the recent past ISRO has launched several polar orbiting as well as geostationary satellites which can be utilized for impact of climate change on ecosystem. These are IRS 1 C, IRS 1D, Resourcesat-1, Resourcesat-2, Oceansat-1, Oceansat-2, Cartosat-1, Cartosat-2 and INSAT 1,2,3 and Kalpana-1. These satellites provides the multispectral, temporal, multi-resolution data with revisit capability from 5 days to 22 days and spatial resolution from 0.8 metere to 55 meter and swath from 9.6 Km to 2000 km. This is an unique earth observation system for mapping and monitoring of impact of climate change as well as input to circulation models. The INSAT series satellites consist of VHRR (Very High Resolution Radiometer) with imaging capability in visible band (0.55-0.75 micron), thermal infrared (10.5-12.5 micron)and water vapour channel (5.71-7.1 micron) having spatial resolution from 2km to 8 km.

Some of ISROs present and future mission are dedicated to climate change studies. The details are as follows

Megha Tropiques

Recently launched Meghatropiques is a joint venture of ISRO, India and CNES, france is a state of art satellite consist of 4 payloads namely MADRAS(Microwave Analysis and Detection of Rain and Atmospheric Structures), SAPHIRE (Sounder for atmospheric profiling of Humidity in the intertropics by radiometry) , SCARAB(Scanner for radiation budget) and ROSA(Radio Occultation Sensor for Vertical Profiling of Temperature and Humidity) . The main objective of this mission is to understand the life cycle of convective systems that influence the tropical weather and climate and their role in associated energy and moisture budget of the atmosphere in tropical regions. A microwave imager (MADRAS) aimed mainly to study precipitation and cloud properties, including ice at the top of clouds. SAPHIR is a microwave sounding instrument for the atmospheric water vapor and ScaRaB is devoted to the measurement of outgoing radiative fluxes at the top of the atmosphere. With its circular orbit inclined 20 deg to the equator, the Megha-Tropiques is a unique satellite for climate research that will also aid scientists seeking to refine prediction models.

OCEANSAT-2

Oceansat-2 satellite mainframe systems derive their heritage from previous IRS missions and launched by PSLV-C14 from Satish Dhawan Space Centre, Sriharikota on Sept. 23, 2009. It carries three payloads namely Ocean Colour Monitor (OCM), Ku-band Pencil Beam scatterometer (SCAT) developed by ISRO and Radio Occultation Sounder for Atmosphere (ROSA) developed by the Italian Space Agency. Oceansat-2 is envisaged to provide continuity of operational services of Oceansat-1(IRS-P4) with enhanced application to climate change impact studies on ocean state.

SARAL

The SARAL/AltiKa project is a collaboration between France and India in the environment monitoring domain. AltiKa is an innovating Ka-band altimeter system, dedicated to accurate measurement of ocean surface topography. It will also have ARGOS-3 payload.

INSAT 3D

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.

IMPACT OF LULC AND CLIMATE CHANGE ON HYDROLOGICAL REGIME

Human-induced alteration in land-cover characteristics and climate change together can result in substantial change in hydrological and watershed processes (Bosch and Hewlett, 1982; Stednick, 1996, Matheussen et. al., 2000; Foley *et al.*, 2004; Gosain et al., 2006; Gao *et al.*, 2009; Petchprayoon *et al.*, 2010; Schilling *et al.*, 2010). Previous studies have shown that removal of forest cover alone is the major cause of changes in hydrological processes, including evapotranspiration, streamflows, accumulation and snowmelt processes (Bosch and Hewlett, 1982; Gao *et al.*, 2009). Hence, there is a need to understand the impacts of such changes on water resources availability so as to evolve suitable adaptation strategies. Many river basins of India have been repetitively facing adverse hydro-meteorological conditions, such as floods, droughts and cyclones in the recent times. Frequent occurrence of these events indicates a shift in the hydrological response of the river basins. The reason for such changes in the hydrological regime could be attributed to the long-term climate and land-cover changes in the region.

The impacts of LULC and climate changes on hydrology can be best handled through a physical-based, distributed hydrological model capable of simulating hydrological processes. Such a treatment is essential since the hydrological response of river basin is a highly complex process which is governed by a large number of biophysical variables of the land surface and climatic forcing.

In order to understand and quantify the effect of LULC and climate change on hydrological regime, basin-scale hydrological modeling is envisaged within the framework of ISRO-GBP LULC and NAPCC (National Action Plan for Climate Change) projects. A broad framework of the methodology to be adopted is shown in Fig. 1. Hydrological simulation, including calibration and validation of the model, will be carried out based on LULC datasets for the years 1985, 1995 and 2005. Various bio-physical parameters, *viz.* leaf area index, albedo, fractional vegetation cover, etc. will be determined using remote sensing data. Soil parameters will be determined using field observations and existing soil maps of NBSSLUP (National Bureau of Soil Survey & Land Use Planning). Terrain parameters, *viz.* elevation, slope, flow direction, flow accumulation will be derived using SRTM or ASTER DEM (digital elevation model). Hydro-meteorological parameters will be forced in the model for different years which includes projected IPCC scenarios. Then, hydrological simulation in selected river basins for past, current and future (years 2020 and 2070) LULC scenarios will be carried out and finally impact of LULC and climate change on hydrologic regime (evapotranspiration, surface runoff and base flow) will be analysed. The results will help in formulating strategies for sustainable water resources management and food security.

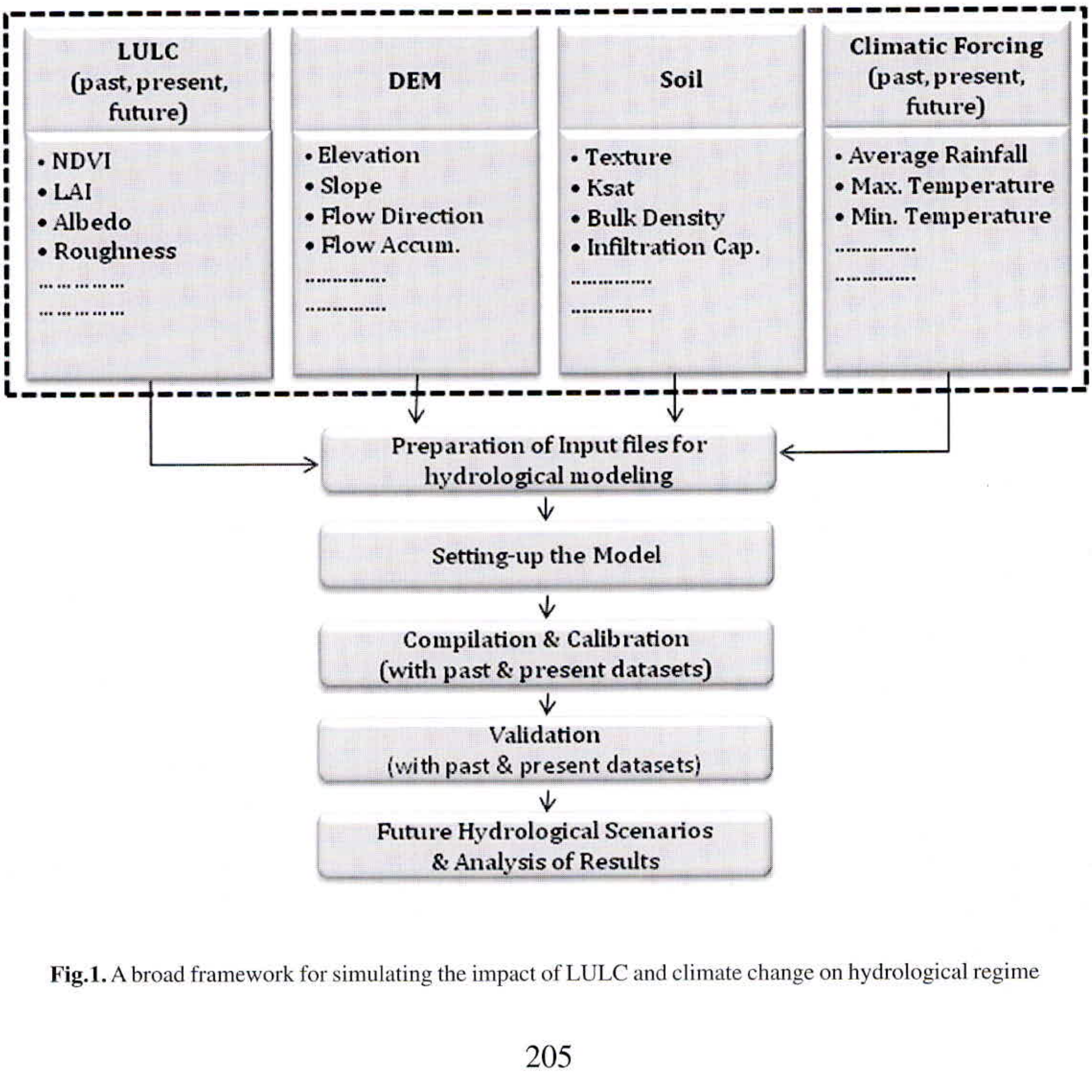

Fig.1. A broad framework for simulating the impact of LULC and climate change on hydrological regime

IMPACT OF CLIMATE CHANGE ON HYDROLOGICAL REGIME OF A RIVER BASIN

The important parameters that affect hydrologic process are climatic variables such as maximum and minimum temperature, precipitation. Impact of these variables on hydrology at basin scale is important for efficient management of water resources. In order to study the impact of climatic change on hydrological regime, Ganga basin has been considered . The Ganga basin falls in four countries, namely India, Nepal, Tibet (China), and Bangladesh. The Ganga basin extends over an area of 1,086,000 km^2. The major part of the geographical area of the Ganga basin lies in India. Basin experiences periodic droughts in contrast with the regular flood events. Frequent occurrence of these events indicate a shift in the hydrological response of the basin attributed to climatic variability. Trend analysis of climatic variables has been carried out by performing several statistical tests namely Pettitt's test, von-Neuman test, Standard Normal Homogenity test and modified Mann-Kendle's test. A physically based distributed Variable Infiltration Capacity hydrological model was used to simulate the hydrology of Ganga river basin and analysis were carried out of the impact of climatic variability on hydrological regime. The meteorological forcing, vegetation parameters and soil parameters were derived using remote sensing based products and other ancillary information. Water balance scenario for different time periods namely baseline (1961-1990), early century (2011-2040), mid century (2041-2070) and end century (2071-2098) has been generated using GCM downscaled dataset. Only the meteorological forcing was changed during simulation, vegetation and soil parameter were kept same to remove the effects of land use change. It was observed that there is a increasing trend for Runoff as well as Evapotranspiration. While there is no trend observed for base flow.

Similar study was also carried out at IIRS for Mahanadi basin. It was found that Runoff and ET will increase due to predicted high rainfall and Temperature. It was also found that there will be a decrease in baseflow.

CONCLUSION

Space based technology provides most of the climate change parameters and indicators. The advantage lies with their synoptic coverage with continuous monitoring at spatial domain. Indian earth observing system alongwith foreign satellites provides a wide range application for climate change impact studies. Retrieval of hydrological parameter from space and its input to hydrological model coupled with output from RCM will help in future water resource management strategies.

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Web Resources

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