

## Geomatics and impact of climate change with specific reference to mountain ecosystem\*

Natural climate changes have occurred throughout the history of the earth. Climate affects natural vegetation and agriculture, the source of food for all human beings and animals. During the past few decades, the scale, intensity and permanence of human impacts on the environment have been recognized and understood. Human activities are profoundly affecting the world climate, and mountains are sensitive indicators of that effect. Mountains are an important source of water, energy, biological diversity and areas of recreation and are a major ecosystem representing the complex and interrelated ecology of our planet and are essential for the survival of the global ecosystem.

Understanding the effects of climate change in tropical and mountain ecosystem needs multiple sources of data. Geospatial technologies comprising tools like high resolution satellite remote sensing data, geographic information system (GIS), global positioning system (GPS), digital cartography, etc. have immense capability to understand the intricacies including prospects and problems of the Himalayan mountain system and to plan their sustainable development and management.

The focal theme of the conference was climate change and subsequent implications on snow and glaciers, water resources, forest, land use, agriculture, wildlife and humans. The special theme was geospatial information for Uttarakhand State. Detailed deliberations revolved around eight technical sessions.

The glacial events in the western Himalaya are being monitored with the help of latest technologies, for e.g. Cartosat-1 stereo data. Techniques have

been evolved using IRS-IC and ID, PAN, stereo data to estimate loss of ice. A glacier index map of Bhagirathi basin has been prepared and continuous monitoring of changes in glacier area from 1962 onwards is being done for the Gangotri glacier. Glaciers are shrinking and they are geological signatures or footprints of climate change in the Alpine region.

There were discussions on monitoring of trace gases and their spatial distribution in India. The various agents that were discussed are dust storms, methane emission from wetlands using remote sensing, fitting of ARIMA (autoregressive integrated moving average) model, GIS and census data. Emission of carbon monoxide from biomass burning was measured from space using MOPITT (measurements of pollution in the troposphere). Apart from the natural forcings, demography is directly responsible for perturbances to mountain climate in particular. Forest and climate interact and a disturbance in any one can adversely affect the other. The Indian satellite for aerosol and trace gases (ISTAG) is monitoring the chemical weather and chemical climate over India. Environmental observatories across India are being set up by ISRO-GBP. Method of recording dust storm events and principles and sources of global dust storm were discussed. Spatial patterns of livestock methane emission at district and state levels are being recorded.

Loss of glaciers is leading to subnormal snowfall, higher temperatures in summer, less severe winter and a combination of all. The disaster looming large over us due to loss of ice resources is the depletion of freshwater reserves. Initially there will be more water but ultimately it will decrease. Silt load and debris production will increase, tree line will rise however execution of engineering structures in snow bound glaciated areas is still beset with problems and need urgent consideration. The alarming rate at which sea level is rising along the east coast of India, particularly in Chennai and Andhra coast, were highlighted. This rise is also threatening our heritage monuments and calls for immediate attention. The fre-

quency of cyclonic events and their impact on productivity of the phytoplanktons in the Indian Ocean region reflected climate change. Using the ocean colour data, a study was conducted on the anomaly in phytoplankton production and their effect on the carbon dynamics in the ocean and the impact of climate change was assessed.

It was observed that there is need for a GREEN technology, i.e. Growth with Resource Enhancement in Environment and Nature. M. Arora spoke on the emerging trends in digital image interpretation of remote sensing data and enlightened all with the image classification and the neural network classification. Geospatial technology can be used for better management of soil carbon particularly in the mountains. GIS and GPS techniques can be effectively used for development of district resource information as well as monitoring and visualizing of vector-borne diseases. Pathan described the Natural Resource Database (NRDB) project under the Natural Resources Reporting (NRR) programme which is primarily concerned with systematic digital archival storage, management need based retrieval and supply of these datasets in standard and open format, to users in order to promote/encourage its use for government business and societal needs. There were several discussions on various geospatial technology and application, for e.g. geospatial approach for route analysis, utilization of Cartosat-2 data for cadastral level applications, satellite image compression using 'ridgelet transform' automated change detection system using IDL, web-based urban information system, GIS-based 3D surface area computation, cartographic potential of Cartosat-1, band selection algorithm using hyperspectral data, kriging interpolation technique for DEM (digital elevation model) generation using ALOS Prism Stereo Data and application of ARIMA model for stream flow.

The seismic vulnerability of the Himalayas and how geo-informatics can help in flood disaster management were discussed at length. LIP or landslide

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initiation point was used with certain quantitative multiparametric modelling to pinpoint the locales of future landslide using satellite data and computer-based multiparametric analysis. Flood disaster management systems in Bihar and Jharkhand were discussed with case studies. Storm surge risk and tsunami risk were assessed along the Andhra coast and Tamil Nadu coast. An in-house tsunami simulation model 'TUNA' has been developed to simulate tsunamis along the impacted beaches. Various aspects of landslide hazards were presented by different speakers with reference to the Himalayas.

S. P. Singh cautioned that the tropical tree species are not adaptable like temperate species and alpine region species and have no space to migrate upwards as a consequence of global warming. Climate change is leading to failure of trees to regenerate and warming is affecting seed maturation due to water stress. It has been observed that spring time warming has not advanced leafing mainly due to water stress. Global warming has resulted in phenological disturbances, biophysical impact on forests, expansion of agricultural areas, spread of disease, precipitation changes and turbulence in the ocean. The importance of forest maps, their utility, working plan and their role in biodiversity studies were highlighted. The maps of Champion and Seth have been digitalized and physically verified. The biological system is responding fast to climate change which was demonstrated with several examples of high altitude species phenology. Faunal migrations as a result of climate change were discussed. It was highlighted that the most protected areas lack adequate conservation and management plans to

counter the effect of climate change on fauna. Snow cover monitoring in Alaknanda basin and the hindrances faced for detection of snow under forest canopy were discussed. The spectral profile approach for wheat yield modelling has been successfully demonstrated using multivariate MODIS data. Geoinformatics is also being used for assessing historical forest cover changes and predicting soil erosion.

Climate change will have a major effect on our socio-economic status the world over. Anthropogenic activities are being monitored along the coast, in the hills and in the water bodies. Climate change evidences in watersheds, vegetation and soil and how it is being monitored were discussed.

A session was dedicated to the state of Uttarakhand which lies in the Himalayas and plays an important role in shaping the climate of India. Uttarakhand is blessed with a vast repository of geothermal energy resources and it can be an ecofriendly alternative energy source. The geothermal hotspots have been identified at Tapovan and Uttarkashi. Arora informed that a centre for glaciology has been established at the Wadia Institute to address the problems related to glaciers. It will be the flagship station for glacier monitoring. Thermistors will be used for monitoring heat changes at the base of glaciers. The first Indian Multiparametric Geophysical Observatory has been established at Ghuttu for understanding seismic movements. It was suggested that Uttarakhand Space Application Centre may become the nodal agency for synchronization of data generated by various institutes and make it available in a simple manner in one platform for nonspecific users. A digital avalanche atlas has

been developed using GIS and remote sensing by the snow and avalanche study centre. Web enabled GIS technology has led to the creation of BIS (Biodiversity Information System) and Indian Bio-resource Information Network (IBIN). It is an innovative mechanism to conserve biological diversity at local, regional and national levels. Forest fire information system for Uttarakhand has been modernized using real time satellite monitoring and GIS dataset, and several major forest fires have been prevented with this advanced technology. Traditional crops are on the verge of extinction as farmers have changed their cropping pattern due to climate change and switched over to more economically profitable crops for sustainable existence.

It was concluded that technology has advanced and we have a wide range of applications to study various aspects of climate change. However there is no room for complacency and we need to work harder and faster to catch up with the anomaly and solve the problems, especially with respect to the mountains. It was observed that the Himalayas are a very special ecosystem and need more attention in terms of R&D, administration and coordination of both. A set of recommendations made at the conference to provide a basis for initiation of a national debate may be obtained from the authors.

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