**Melting Glaciers in the Himalaya**

Samjwal Ratna Bajracharya and Pradeep Kumar Mool

Global climate change in the history of earth is a natural phenomenon due to continental drift, earth axis and orbital variations, variants in solar energy output and frequent volcanic activity. With the end of Little Ice Age ($15^{th}$ to $18^{th}$ centuries), the behaviour of average surface temperature on earth depicts an increasing trend. Over the past few decades, since industrialization human activities have resulted in steady increased concentrations of greenhouse gases in the atmosphere, which lead to the enhanced greenhouse effects, and thereby cause global warming. Over the past hundred years, the world's average surface temperature has increased between 0.3° C and 0.6° C. Ten warm years have already has been recorded in this century. The 1990s were likely to be the warmest decade of the millennium in the Northern Hemisphere, and the year 1998 was the warmest year, followed by the second warmest year 2005. According to the Intergovernmental Panel on Climate Change (IPCC 2001), and its assessments based on climate models, the increase in global temperature will continue to rise during the 21st century. The mean global temperature is the average from 1961 – 1990, assumed as normal period. The increase in the global mean temperatures from 1990 to 2100 could amount to anything from 1.4° C to 5.8° C, depending on the climate model and greenhouse gases emission scenario. On the Indian sub-continent temperatures are predicted to rise above an average between 3.5° C and 5.5° C by 2100.

Glaciers are one of the key indicators for exploring quaternary climate changes; as they remain sensitive to global temperature conditions; this is indicated by the continuous retreating and shrinkage of glaciers. For example, with temperatures rising by 1° C, Alpine glaciers have shrunk by 40 percent in area and by more than 50 percent in volume. One forecast suggests that up to a quarter of the global mountain glacier mass could disappear by 2050, and up to half could be lost by 2100.

This is anticipated from a study of glaciers in the Himalaya by the satellite images, which are complemented by field verifications and historical data. Nearly all of the glaciers are shrinking and retreating at different rates in different basins. A long-term study entitled, 'The Chinese Glacier Inventory', by the Chinese Academy of Sciences reported that during the last 24 years there has been a 5.5 percent shrinkage in volume of China's 46,928 glaciers; equivalent to the loss of more than 3,000 km² of ice. The study predicts that if the climate continues to change at the present rate, two-thirds of China's Glaciers will disappear by 2050, and almost all will be gone by 2100. A study by the International Centre for Integrated Mountain Development (ICIMOD) carried out in the Poiqu basin of Tibet Autonomous Region (TAR) of the Peoples Republic (PR) of China revealed that the glaciers area had decreased by over 5 percent within 12 years from 1988 to 2000 and some valley glaciers have retreated by up to 68 m per year.

Similarly, the position of the Gangotri Glacier snout in Indian Himalaya has shifted about 2 km upwards from 1780 to 2001. Whereas its retreat is continuing at an alarming rate. In Bhutan, glacier retreat was approximately eight percent in 66 glaciers that were studied in a topographic map from 1963 and a satellite image taken in 1993. Some small glaciers from 0.1 to 0.2 km² in area have disappeared completely in Bhutan. In some cases, glacier retreated areas are replaced by glacial lakes. A study of such lakes in Nepal reveals

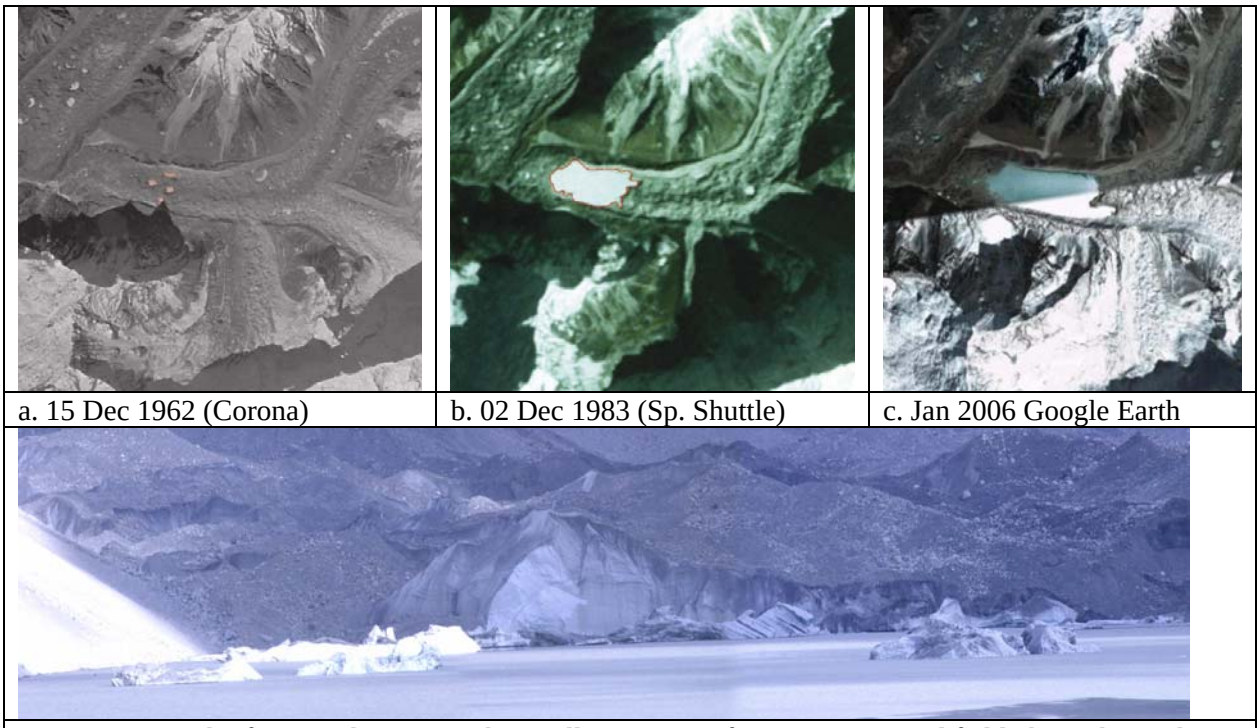
stratling results. From 1962 to 2000, the retreat of the Imja glacier is by about 41 m per year and this increased drastically to 74 m per year from 2000 to 2006. The Imja glacier's retreat is found to be one of the highest in the Himalaya amongst those studied as shown in the Figure 1. Observations of individual glaciers indicate that annual retreat rates vary from basin to basin and in some instances, with a doubling of the rate in recent years compared to the early seventies.

Some of the retreating glaciers result in the formation of glacial lakes at the toe of glaciers dammed by the loose moraine. Consequently, increased rate of glacier retreat results in rapid accumulation of water in lakes, which may lead to sudden breaches of their unstable moraine dams. The resultant discharges of huge amounts of water and debris – glacial lake outburst flood (GLOF) – often have catastrophic effects downstream. A number of GLOF events have been reported in the region in the last few decades, particularly from the eastern sector of the region. These changes in climate will inevitably interact with changes in glaciers and glacial lakes and, due to GLOFs, will pose increasing threats. Such changes in climate will have effects ultimately on life and property of mountain people living in the remote area.

A study conducted by ICIMOD in partnership with the United Nations Environment Programme (UNEP), Asia-Pacific Network for Global Change Research (APN) and in close collaboration with national partner organisations generated an important baseline information of approximately 15,000 glaciers, which cover a total area of 33,400 km² and include 9,000 glacial lakes, of which 200 are potentially dangerous glacial lakes in Pakistan, Nepal and Bhutan and some selected basins from India and TAR PR China (Figure 2). The study also revealed 21 GLOF events from the Hindu Kush-Himalayan region. Records of past GLOF events illustrate that once in every three to ten years a GLOF has occurred in the region of Nepal, Bhutan and China causing varying degrees of socio-economic impacts.

The baseline information of glacial lakes prepared by ICIMOD formed an important basis to monitor accelerating global warming. Most of the lakes mapped at the toe of the glacier moraine are growing and new lakes have appeared in recent decades. If lake growth continues, then it has to breach out ultimately. This will create devastating effects to downstream environments, livelihoods and property. The unprecedented global warming, melting and retreating of glaciers give rise to the formation and growth of moraine dammed lakes and increase threats of GLOF. Monitoring these lakes, by means of remote sensing, and verifications in the field are important to identify mitigation work in order to install early warning systems to reduce the GLOF risks.

Glaciers and freshwater reserves of the Himalaya are an inherent part of the life support system; since half of world's population depend upon these vital resources. In the face of accelerating global warming, retreating and shrinking glaciers in the Himalaya are clear indicators of climate change. There are several predictions of glaciers melting that are accompanied by impacts to millions of people whose survival depends directly or indirectly on these fresh water reservoirs. In addition, the increase of lakes dammed by the moraine will augment the frequency of GLOF in near future. It is difficult to speculate or to predict just how glaciers will retreat in the Himalaya, but now is the time for rigorous attempt to monitor glaciers environment and to initiate mitigation measures of GLOFs.



| a. 15 Dec 1962 (Corona) | b. 02 Dec 1983 (Sp. Shuttle) | c. Jan 2006 Google Earth |
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Figure 1: Growth of Imja Tsho seen in the satellite images of 1962 to 2006 and field photo shows the active calving on the Imja glacier snout (15 Oct 2006).

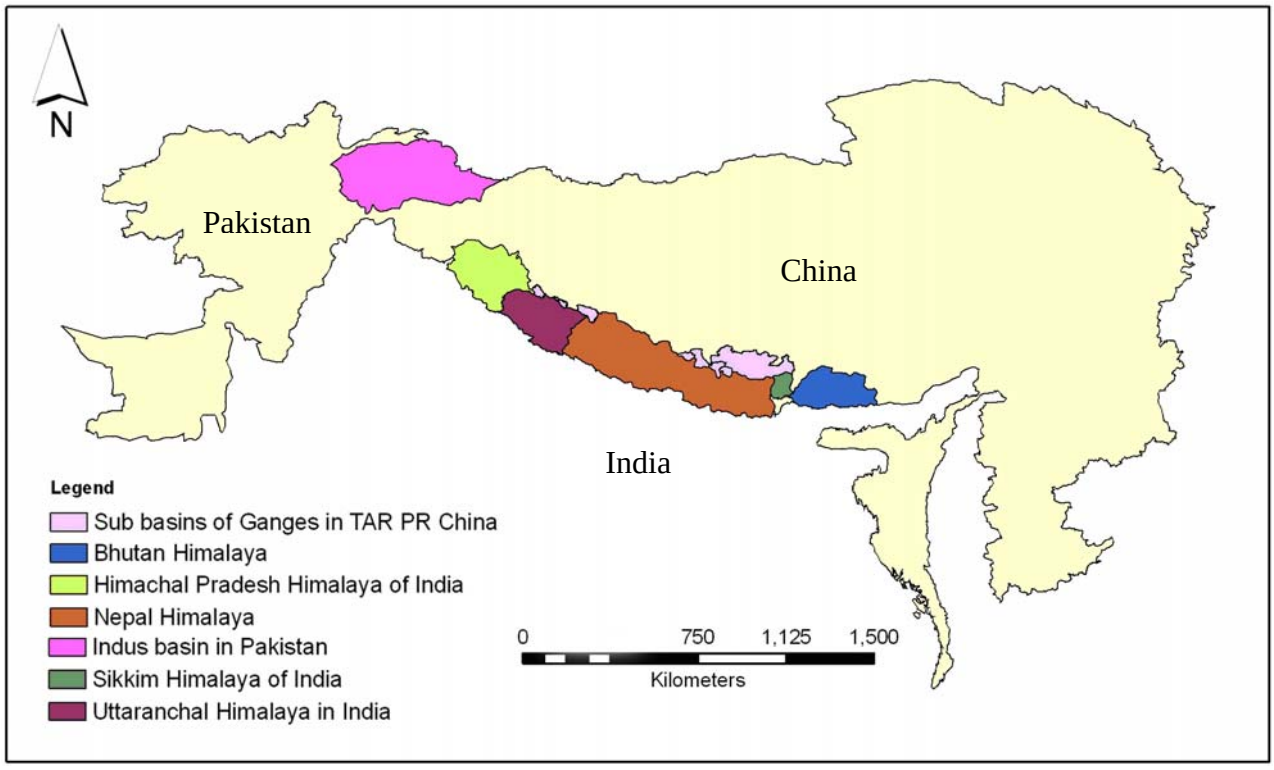


Figure 2: Map of Hindu Kush-Himalayan region showing the study area of glaciers and glacial lakes covered by ICIMOD

Samjwal Ratna Bajracharya is a Geomorphologist and GIS Analyst and Pradeep Kumar Mool is a Remote Sensing Specialist with the Mountain Environment and Natural Resources Information Systems (MENRIS) programme of the International Centre for Integrated Mountain Development (ICIMOD). To learn more about their work at http://www.icimod.org or write to sabajracharya@icimod.org and/or pmool@icimod.org