Retreat of Himalayan Glaciers – Indicator of Climate Change

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Abstract: Glaciers are the coolers of the planet earth and the lifeline of many of the world's major rivers. They contain about 75% of the Earth's fresh water and are a source of major rivers. The interaction between glaciers and climate represents a particularly sensitive approach. On the global scale, air temperature is considered to be the most important factor reflecting glacier retreat, but this has not been demonstrated for tropical glaciers. Mass balance studies of glaciers indicate that the contributions of all mountain glaciers to rising sea level during the last century to be 0.2 to 0.4 mm/yr. Global mean temperature has risen by just over 0.6^0 C over the last century with accelerated warming in the last 10-15 years. The major impact will be on the world's water resources. Many climatologists believe that the decline in mountain glaciers is one of the first observable signs of the human induced global warming. [Nature and Science. 2006;4(4):53-59]

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Mountain regions covering about one-fifth of the Earth's land surface are an important source of water, energy, minerals, forest and agricultural products as well as area of recreation. Geographers have produced numerous definitions aiming to distinguish mountain environments from non-mountains ones; many of them have build on common perceptions of what constitutes a mountain, and none of them is fully quantitative. The global mountain area defined is almost 40 million km^2, or some 27 per cent of the total Earth's surface area. Mountain ecosystems support vibrant livelihoods, and include significant watershed resources, biological diversity of unique flora and fauna. They act as a barometer of global climate change. These fragile ecosystems are vulnerable particularly towards the adverse effects of climate change at global level and need specific protection and conservation strategies against the problem. Many climatologists believe that mountains provide an early glimpse of what may come to pass in lowland environments.

Ice sheets, ice streams, floating ice shelves and mountain glaciers together constitute the cryosphere, an integral and dynamical part of Earth's land-ocean-atmosphere system. The cryosphere is very sensitive to changes in temperature and its various components are sensitive monitors of climate change. Polar ice sheets respond very slowly to climate change with response time of 100-1000yrs whereas mountain glaciers respond rapidly on the order of seasons to decades.

The Himalaya encompasses the world's third largest glacier systems after Antarctica and Greenland occupying about 15% of the mountain terrene, increasing to about double this size with the winter ice core. The glacier systems are being classified as mountain or ice caps. As the Himalayan glaciers are mountain glaciers, therefore they exhibit a typical differentiation with the Antarctica and Greenland. Mountain glaciers constitute only about 3% of the glacierized area of earth. The importance of these glaciers system is because they may be melting rapidly under present climatic conditions and therefore makes large contribution to rising sea level. They are estimated to store freshwater stocks of approximately, 12 billion m^3, but have been observed to be shrinking rather fast, faster than the average global rate. In India, there are more than 5,000 glaciers on the southern slope of Himalayas covering an area of nearly 38,000 Km^2. The distributions of these glaciers are higher in North-West than in the North-Eastern part of the Indian Himalayas due to the criss-cross mountains, altitude variations and different climatic environment.

We live in a time of significant climate change, with almost all regions of the world experiencing accelerated and ongoing continuous and permanent warming of the environment in the recent decades. Few natural environments are able to testify this long term warming trend as tangibly as the world's mountains glacier systems. In India, the work on the recession of Himalayan glaciers started during the period of 1970 onwards. Studies have revealed that most glaciers in Himalaya and Karakoram region are in receding mode. The ongoing glacier studies have revealed that glaciers are retreating with an average rate of 18m - 20 m $year^{-1}$. Glacier snout is the best indicator of the glaciers advance and retreat over a period of few years and decades (Table 1) (GSI, 1999, Srivastva et al., 2001, Naithani et. al., 2001, D.P. Dobhal, 2004). It has also been observed that the rate of recession for both the small glaciers (<5 km) and large glaciers (>10 km) are more or less the same, which indicates that the future of small glaciers is not very encouraging. This can be alarming as the number of small glaciers far exceeds the number of large glaciers. Alpine glaciers are in retreat in almost all mountain belts of the world. Many of the smallest alpine glacier complexes are likely to disappear in the forthcoming two decades. Large glacier systems particularly those at high altitudes, such as massive tidewater glacier systems in Alaska, are also thinning and retreating. Their future in the current century will depend on the condition, whether climate stabilizes or continues to warm in the near future.

Weather and climate shape the physical environment. As a result, changes in climate should be clearly reflected in the ongoing changes to the seas, lakes, rivers and land of the world. Changes in climate also affect plants and animals. Glaciers are a source of continuous water supply to perennial river systems and two of the world's largest rivers, the Indus and Brahmaputra originate from these glacial lake systems and thereby ensure round the year irrigation facility to agriculture, which is the main string of economy of the developing nations like of India. The average annual run-off of Indus, Ganges and Brahmaputra rivers is 208, 494 and 510 km^3 $year^{-1}$, respectively. Varying estimates of water resources in the Himalayan region have been made. Murthy (1978) estimated Himalayan water resources around 245 km^3 $year^{-1}$, Gupta (1983) and Kawosa (1988) estimated the total amount of water flowing from the Himalayas to the plains to be around 8643 km^3 $year^{-1}$. Bahadur (1998a) re-evaluated his earlier estimates of 200–500 km^3 $year^{-1}$as 400-800 km^3 $year^{-1}$as melt water contributions from the snow and glacier fields in the high mountain region. Despite these widely differing estimates of the water resource of the Himalayan region, the water output could be the highest from any single mountain range in the world (Stone, 1992). They are powerful tourist attractions and bear a great influence on stream flow and the strategic enterprise dependent on it, such as power generation, irrigation, municipal water supplies, fish and other forms of aquatic life and recreation.

Fluctuations in the physical environments of glaciers and ice caps in cold mountain areas have been systematically observed for more than a century in various parts of the world and therefore they are considered to be highly reliable indicators of worldwide warming trends of the environment. The interaction between glaciers and climate represents a particularly sensitive approach (Kaser, 2001; Wagnon et al., 2001). The tropical glaciers provide important proxy data in climate change research (IPCC, 2001; Oerleman, 2001). It is now being an item of great interest. Mountain glaciers and ice caps are, therefore, key variables for early-detection strategies in global climate-related observations (Forel, 1895). The global retreat of mountain glaciers during the 20th century is striking. Trends in long time series of cumulative glacier-length and volume changes represent convincing evidence for fast and sudden climatic change at a global level. Since 1990, the Intergovernmental Panel on Climate Change (IPCC) has documented such changes as an evidence for the existence of global warming, independent of the various surface temperature data sets.

The 20th century was a period of dramatic glacier retreat in almost all alpine regions of the globe, with accelerated glacier and icefield melt in the past two decades. According to the World Resource Institute, the total size of the world's glaciers has declined by about 12% in the twentieth century. The first phase of this glacier retreat was associated with emergence from the Little Ice Age that ended in the 19th century. Twentieth century warming was amplified over the continents, with a temperature rise of close to about 1ºC. Observations from alpine elevations are inadequate to assess whether this surface warming has been amplified at altitude, but the punishing impact on mountain glaciers and icefields is unequivocal. Small glacier systems have rapid response times to climate perturbations, and these systems exhibit the most visible changes. In Montana's Glacier National Park, ice-covered area decreased by 73% (99 km^2 to 27 km^2) from 1850 to 1993. Glacierized area in the Alps has decreased by 40% since 1850, with an estimated volume loss of 50%. Spain has 13 glaciers remaining, a decline from 27 glaciers in 1980. Tropical ice caps in the Andes and Africa are disappearing at a similar rate; Mt. Kilimanjaro's icefields have diminished by 82% by area since 1912, from 12 km^2 to just over 2 km^2 in 2000.Approximately 33% of this retreat has come in the last 20 years. On the global scale, air temperature is considered to be the most important factor reflecting glacier retreat, but this has not been demonstrated for tropical glaciers (IPCC, 2001). However work carried out in Kilimanjaro concludes that increased air temperature governs the glacier retreat in a direct manner (Kaser, 2004).It is more difficult to assess the impacts of climate change on large glacier systems, as their dynamical response time can be many decades, and these systems are found in colder regions (higher latitudes and altitudes), where ice fields are comparatively less sensitive to climate change. The effect of global warming on the cryosphere in mountain areas are most visibly manifested in the shrinkage of mountain glaciers and in reduced snow cover duration (Barry, 2002).

Glaciers are a relative newcomer to the mountain scene, despite their immense impact on the landscape. The first buildup of ice covered approximately 240,000 years ago and ended 128,000 BP. Mountain glaciers are melting at unprecedented rates. Over the last century, glaciers in the European Alps and Caucasus mountains have shrunk to half their size while in Africa 8% of Mount Kenya's largest glacier remains. If the current trend continues many of the world's mountain glaciers including all those in the Glacier National park will vanish entirely. The major impact will be on the world's water resources. Many climatologists believe that the decline in mountain glaciers is one of the first observable signs of the human induced global warming.

Over the past 30 years majority of the Himalayan glaciers have been retreating and thinning. In Bhutan, glaciers are retreating at an average rate of 30-40 m per year[2]. In Central Asia, glaciers are wasting at exceptionally high rates. In the northern Tien Shan (Kazakhstan), glaciers have been collectively losing 2 sq km of ice (0.7% of their total mass) per year since 1955, and Tuyuksu glacier has receded nearly a kilometer since 1923. Glaciers in the Ak-shirak Range (Kyrgyzstan) have lost 23% of their area since 1977, similar to area losses in the northern Tien Shan (29% from 1955-1990) and the Pamirs (16% from 1957-1980). In the Chinese Tien Shan, Urumqihe Glacier lost the equivalent of 4 m ice thickness from 1979-199524, and the Chinese Meteorological Administration predicts that China's northwestern mountains will lose over a quarter of their current glacier coverage by 2050.

Mountain glaciers are sensitive indicators of climate change, although which parameter is playing an important role and quantitative relationship between climate change and glacier fluctuations is still ambiguous, but it corresponded to a warming of ~0.3ºC in the first half of the 20th century in the northern hemisphere. On the global scale, air temperature is considered to be the most important factor reflecting glacier retreat, but this has not been demonstrated for tropical glaciers (IPCC, 2001). However work carried out in Kilimanjaro concludes that increased air temperature governs the glacier retreat in a direct manner (Kaser, 2004). In the last 25 years a second 0.3ºC warming pulse caused northern hemisphere temperatures to rise to unprecedented levels in the last 1,000 years, with the 1990s representing the warmest decade and 1998 the hottest year of the millennium. Glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 is very high Thus, climate change is shrinking the mountain glacier and directly affecting the landscape and threatening water supplies all over the globe. The above explanation of facts clearly revealed that the Himalayan glaciers can be considered as a reliable indicator of climate change and are a major cause of concern worldwide.

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Table 1. Snout Recession rates of some glaciers in Himalaya

S. No	Glacier	Period of Measuring	Period (years)	Recession (metres)	Average rate (myr^{-1})
1	Milam glacier	1849- 1957	108	1350	12.50
2	Pindari glacier	1845-1966	121	2840	23.40
3	Gangotri glacier	1935-1996	61	1147	18.80
		1962-1991	29	580	20.0
		1996- 1999	3	76	25.33
4	Tipra bamak glacier	1960-1986	26	325	12.50
5	Dokriani Glacier	1962-1991	29	480	16.5
		1991-2000	09	161.15	18.00
6	Chorabari glacier	1962-2003	41	196	4.8
7	Shankulpa glacier	1881-1957	76	518	6.8
8	Poting glacier	1906-1957	51	262	5.13
9	Bara Shigri glacier	1956-1963	07	219	31.28
		1977- 1995	18	650	36.11
10	Chotta Shigri Glacier	1987-1989	03	54	18.5
		1986-1995	09	60	6.7
11	Sonapani glacier	1909-1961	52	899	17.2
12	Kolai glacier	1912-1961	49	80	16.3
13	Zemu glacier	1977-1984	07	193	27.5
14	Arwa valley	1932-1956	24	198	8.25
15	Trilokinath	1969-1995	26	400	15.4
16	Dunagiri	1992-1997	5	15	3.00
17	Chiba	1961-2000	39	1050	26.9
18	Meola	1961-2000	39	1350	34.6
19	Jhulang	1962-2000	38	400	10.5

Source: GSI (1999), Srivastva et al. (2001), Naithani et. al. (2001), D.P. Dobhal (2004), Oberoi et al. (2001)

Plate 1- Origin of Ganges from Gangotri Glacier

Plate 2-View of Dokriani Glacier

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