GLOBAL WARMING AND MELTING GLACIERS ALONG SOUTHERN SLOPES OF HKH RANGES

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Abstract:

Glaciers are the most sensitive precursors of climate change due to natural and anthropogenic reasons. Using meteorological and hydrological data in combination with remote sensing data from various sources, the isothermic dynamics of heat in upslope direction was evaluated on pentad basis. It revealed that 30ºC isotherm has creeped upward by 725m higher elevation than 28 years before. Frequency and duration of heat waves both have increased by two fold. The rate of increase since 1990 has also been doubled resulting into frequent occurrence of severe thunderstorms and lightening events. As an example of anthropogenic change in climate, ever fastest rate of glacial depletion is presented on Siachen glacier which has lost about 2km of its length and 17% of ice mass since 1989. Surface velocity of the glacier has also increased considerably due to the interacting warmer atmosphere with frozen water reserves in the presence of large human concentration. Projected future temperatures would further exaggerate the ice depletion and drift related dynamic processes making the situation more and more complex for the planners and dependants.

Key words: *Global Warming, Melting Glaciers, Siachen Glacier, Heat Waves, Anthropogenic Climate Change*

Introduction:

Himalaya-Karakorum-Hindukush together makes the largest mountain chain over the earth and they are custodian of the third largest ice reserves after the Polar Regions. Located side by side north-south makes difficult to distinguish where one ends and other starts. They are elongated almost east-west drawing a border between China and south Asian nations including Pakistan, India, Nepal and Bhutan. Existence of these ranges is a blessing for South Asia. They protect the inhabitants from the cold surges in winter associated with northerly winds. They confine the monsoon precipitation to this region which is the great resource of water. In addition to that they possessed a treasure of solid water which melts with high temperature in summer and makes this precious resource available in rivers during needy times. Several famous rivers such as the Indus, the Ganges, and the Yangtze are fed by the runoff from the glaciers of these ranges which serve as the lifeline for more than a billion people in Asia.

Almost all the glaciers over the globe are subjected to depletion with a few exceptions to Andes and Alps in Europe (IPCC 4AR). Among them polar ice sheets and Greenland glaciers are on the top followed by the Himalayan glaciated reserves. Shroder et al., 2007 found that the loss of significant glaciers between Afghanistan and Pakistan may

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be becoming more serious progressively unless global warming ultimately generates greater marine evaporation that augments precipitation. Concerns over worldwide loss of ice have prompted several research groups to address the global warming issues related to the depletion of glaciers with a special focus on interaction of atmosphere and cryosphere. Both the systems have a complex exchange mechanism and its understanding is utmost important to answer the issue related questions.

Global glacier depletion is the roar of the last two decades which would consequently result into sea level rise and water scarcity over the plains and changes into mountain landscape. The question is not only if the ice is melting, but also how fast it is melting; how much melt water be produced and for how long. To answer these questions, the denser network of direct field measurements along the glaciers and snowlines is required. For this purpose remote sensing science may play an important role along with installation of Automatic Weather Stations (AWSs). Presently this set up is insufficient to draw authentic inference.

Lack of data collection points and their reasonable distribution over this complex terrain is a great hurdle for predicting future trends accurately. Most of the studies made use of satellite remote sensing data except a few in situ datasets generated by some scientific groups during small temporal and spatial scale experiments. Chinese side of Himalaya has, however, denser network of 40 automatic and satellite-linked weather stations across Tibet. China has recently established the world's highest climate station at an altitude of 5200m above mean sea level on the Tibetan side of Mount Everest (Qomolangma in Chinese; Sagarmata in Nepali). But due to Pakistan and Indian tensions on the south of the Himalayan chain, researching efforts are capped in the name of classified strategic assets.

The HKH frozen water reserves are the water tank over the roof whose operation is regulated with temperature. Unfortunately its thermostat has been tempered with global warming and it has started changing much of solid mass into liquid flowing downstream. Accelerated depletion of solid mass has been exposing threat to future generations by a paucity of this precious commodity essential for all the living creatures. Several studies on hydrological, meteorological and glaciological aspects of the third largest ice reserves of the globe are underway from around this pyramid by international, governmental, non-governmental research and welfare organizations.

Indian peninsula is platform of four Asian nations namely India, Pakistan and Nepal. Pakistan makes the western border of the peninsula bound by the Arabian Sea on its south and covered on the north by Himalaya, Karakoram and Hindukush. These mountains are the water tanks over the roof which provides supply of water when required. The environment has given the operational control of this tank in the hands of temperature after the strong buildup of greenhouse gases. Temperature is surpassing its normal limits not only due to natural processes but mainly because of non-environment friendly anthropogenic activities. Growing population caused accelerated deforestation which believed to be the main cause of environmental heating among others. Snow and ice extent is shrinking must faster than ever now, as a whole, on the HKH mountainous terrain (Rasul et al., 2006). Many of the atmospheric and environmental processes directly or indirectly interact with, control, or are controlled by landforms of the high mountains. These linkages are exemplified by the great snow and ice reserves of HKH region. They are the sources of the downstream snow- and ice-melt water which is the lifeline for millions of people who depend upon such water for food production.

Anthropogenic and natural aspects of global change, including climatic warming due to increased proportion of greenhouse gases and global dimming from aerosol emissions, are opposite climate forcings that complicate interpretations. The changes occurring in the portion of atmosphere immediately above the earth surface have direct effect on the frozen water reserves over mountain tops. Study of changes taking place can be perfectly understood until the interaction of atmosphere and cryosphere is properly addressed. Simply, climate warming alone could lead to melting away of small glaciers, with drastic decrease in vital melt water downstream. But increased heating over oceans could lead similarly to greater evaporation and increased monsoonal precipitation. Similarly certain aerosol absorb solar radiation and results in warming, while others reflect them back cooling earth's surface. Due to increased evaporation enhanced cloud cover can increase precipitation, but aerosol-induced clouds have smaller droplets that reduce precipitation. Thus, very serious questions about direction of future change exist to be answered by robust research and innovative observations.

The frequency and intensity of extreme precipitation events has increased along the foothills of Himalayan southern slopes where landslides and lightening have taken several lives and incurred huge damage to the infrastructure (Chaudhry et al., 2007). This paper presents the behaviour of thermal regime, the way it is stepping upward from the foothills of southern slopes of HKH ranges impacting the melting rate of perennial snow and ablating the centuries old glaciated ice. The heat has advanced to southern slopes in a fluctuating way composed of heat waves with some examples of severe snowmelt floods and occurrence of extreme precipitation events. Impact of natural and anthropogenic climate change on some important glaciers has also been discussed with the help of remote sensing tools.

Materials and Methods:

Due to the lack of regular data collecting points in the most difficult mountainous terrain of HKH, various sources of data are employed to draw representative inferences linking the past to the present state of cryosphere and its future potential of production of fresh water to feed the rivers. However, the maximum reliance remained on meteorological data collected at PMD stations located at the elevation ranging from 1250m to 2700m asl. Samiraglia et al., 2007 made use of maps and photographs, and satellite images to quantify the recent and ongoing fluctuatuations of the ice mass in the HKH region. Bishop et al., 2007 emphasized the integration of traditional data sets with Remote Sensing and GIS for glacier mapping, parameter estimation, and numerical modeling to produce reliable results. The detail about various sets of data used in this study is placed below:

Meteorological Data:

National Meteorological Service of Pakistan has been maintaining its 13 meteorological stations along the southern slopes of HKH ranges at various heights as shown in Table 1.

Table 1: **Geographical coordinates of meteorological stations maintained by Pakistan Meteorological Department along southern slopes of HKH ranges.**

S. No.	Station	Latitude(°N)	Longitude(°E)	Altitude(m asl)
1	Astore	35.34	74.90	2167
2	Bunji	35.67	74.63	1372
3	Skardu	35.30	75.68	2317
4	Gilgit	35.92	74.33	1459
5	Gupis	36.17	73.40	2155
6	Chitral	35.85	71.83	1500
7	Chilas	35.67	74.10	1250
8	Dir	3520	71.85	1369
9	Drosh	35.57	71.78	1464
10	Kakul	34.18	73.25	1308
11	Parachinar	33.87	70.08	1725
12	Murree	33.85	73.41	2167
13	Rawalakot	35.85	73.80	1676

The daily maximum temperature records from 1981 to 2005 have been incorporated in isothermal analysis on pentad basis. The daytime maxima were also used to carry out frequency of severe stress days and their continuous stretch on temporal scale for heat waves.

Hydrological Data:

Water and Power Development Authority (WAPDA) of Pakistan have installed 10 hydrological stations in HKH southern slopes at heights even more than PMD. Basic geographical information is presented in Table 2.

Table 2: **Hydomet Stations maintained by WAPDA in Northern parts of Pakistan.**

S. No.	DCP Stations	Basin	Latitude	Longitude	Elevation(m.a.s.l.)
1	Naltar	Hunza	36° 07′ 40″	73° 11′ 05″	2810
2	Yasin	Gilgit	34° 22′ 00″	73° 18′ 00″	3353
3	Hushey	Shyok	35° 22′ 00″	76° 21′ 30″	3010
4	Burzil	Astore	34° 54′ 20″	75° 05′ 30″	4030
5	Shogran	Kunhar	34° 38′ 00″	73° 29′ 15″	2895
6	Saif ul Muluk	Kunhar	34° 54′ 15″	73° 38′ 40″	3240
7	Kelash	Chitral	35° 39′ 00″	71° 37′ 00″	2810
8	Shangla	Swat	34° 52′ 30″	72° 35′ 45″	2134
9	Besham	Indus	34° 55′ 27″	72° 52′ 55″	480
10	Rehman Bridge	Poonch	33° 29′ 20″	73° 53′ 05″	530

Data from above stations were used to assess stream flow and river discharge at rim stations.

Reanalysis Data:

National Center for Environmental Prediction (NCEP) provided long records of reanalysis data although at 2.5° x 2.5° interval but proved to be a good input for filling up the gaps. The NCEP reanalysis data was able to capture much of the synoptic scale variabilities in the pressure and temperature fields and the differences between the observational and the reanalysis data decreased rapidly as the time scale went from synoptic to monthly (Xie Aihong et al, 2007). Some JMA (Japan Meteorological Agency) reanalysis data set of resolution 1^o x 1^o spanned over a period 1988-1998 was also incorporated over this complex terrain. It was combined with meteorological observed data and interpolation was carried out to generate uniform grided data for further analysis.

Satellite Data:

LANDSAT Satellite imageries of Northern Hemisphere fall (cloud free) are used at irregular intervals to draw inference on changes in Siachen glacier which draws the highest frontier between Pakistan and India.

ASTER images are used for Batura glacier which was studied in detail by Chinese scientists in 1974-75 and its past characteristic data are also derived from Chinese publications.

In Situ Data:

Italian scientists from Ev-K**Error! Objects cannot be created from editing field codes.**-CNR committee have extensively studies Baltoro glacier from different research aspects. Data from two Automatic Weather Stations (AWSs) at Askole and Urdukas located in Baltoro valley were also used to assess the interaction of atmosphere and cryosphere. Their secondary data from the ablation experiment has been utilized to identify the characteristics of atmosphere and cryosphere interaction

Stereo photographic Data:

Photographs taken during different expeditions by various mountaineers on glaciers, glacial lakes and their allied features have also been incorporated to overcome the lack of scientific data with the courtesy of photographer.

Results and Discussion:

Global warming is an inevitable fact and effects are very clear in most parts of the world. According to IPCC 4^{th} Assessment Report, all the 12 warmest years ever recorded over the globe occurred in 1990s and the recent ongoing decade (1990, 2005, 2003, 2002, 2004, 2006, 2001, 1997, 1995, 1999, 1990 and 2000). The strongest ENSO event of the meteorological history was also recorded during the same period (1997-98) which triggered 5 year long severest drought in Pakistan history. Global data show a sharp increase in temperature from 1980s.

Global trend is also reflected by the changing thermal regime in many parts of Pakistan and the most pronounced in northern high elevation stations located on the southern slopes of HKH. It was an interesting investigation on how the heat is creeping upward from lower elevations to higher elevation. It not only clarified the invasion of warmer thermal regime to the glaciated reserves responsible for sustainable supply of fresh water but also disclosed the characteristic features of atmospheric and cryospheric interaction. The results include higher elevation heat dynamics, heat waves, hydrodynamics and cryodynamics. They are discussed one by one as under:

Isothermic Dynamics:

Daily maximum temperatures from 1981-2008 for generally dry summer period from April to June were analyzed on pentad basis except last one which is two years less yet. Movement of isotherms with time along the elevation revealed the fact that heat is rushing towards the peaks of this elevated complex and highly irregular terrain. To know how fast it is moving upward, the dynamics of 30°C was considered the reference indicator. Figure 1 shows that in 1980s the changes in isothermic pattern were very slow and hardly a 35m upward shift of reference isotherm was seen from 1981 to 1990. Warming trend increased in 1990s. By the end of this decade, the 30°C isoline existed at about 300m higher than its position in 1981-85. The ever hottest year recorded over the globe was1998 which co-occurred with the strongest El~Nino event 1997-98 of the recorded history. The ENSO event associated with severe hygrothermal stress conditions contributed a lot to carry the heat to new heights. Overall the decade of 1990s was believed to be the warmest one.

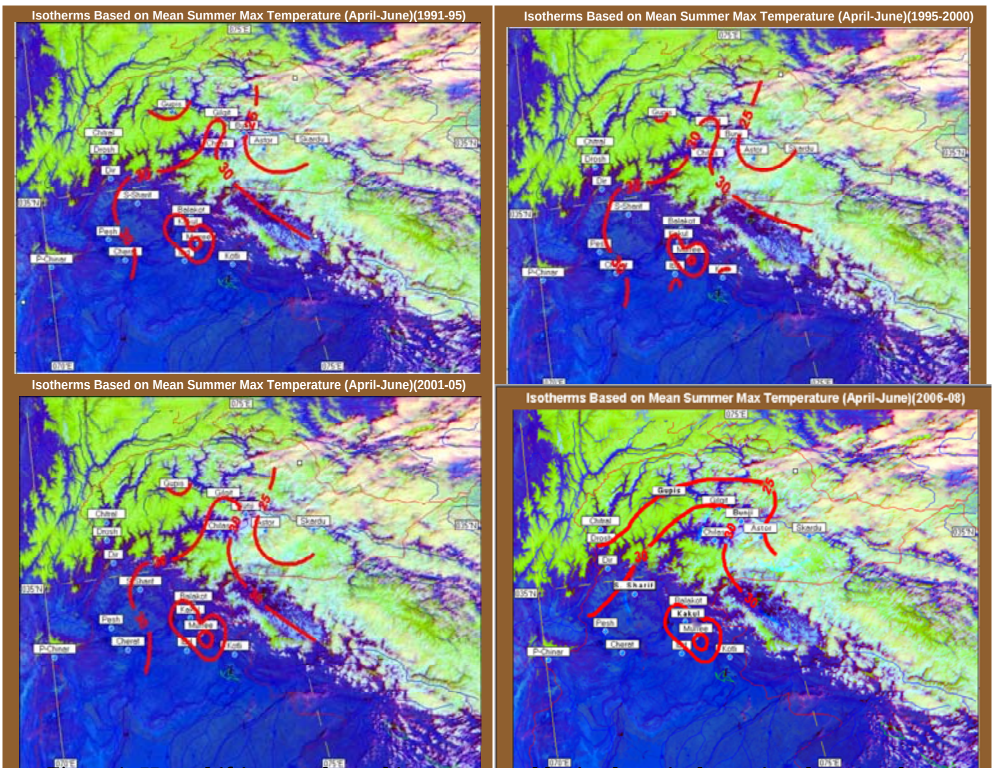

Figure 1: **Heat shifting northward is represented by isothermic dynamics along southern slopes of HKH ranges**

The first eight years of 21st century are seen surpassing all trends in the past among them 2005 believed to be the hottest for Pakistan when a historic snowmelt flood in June created a havoc downstream Indus. Last pentad has completed 3 years so far (i.e. 2006, 2007, 2008 April-June period) and is showing moderate advance of warmth in the upward direction. The dynamics of 30°C isotherm along southern slopes of HKH ranges is shown in Fig 1. Temporal isotherm's spread show that flux of upward creeping heat is more over the eastern part (Himalaya and Karakorum) of the southern slopes than western part comprising Hindukush range. Isothermic advance is not uniform rather skewed due to the complexities of terrain and environmental degradation. On the average, the 30°C isotherm has now moved at 580m above its location in early 1980s.

Heat Waves:

Heat waves are a continuous stretch of persisting maximum temperatures above certain threshold for a specified time period. Rising temperatures are embedded with thermal extremes which were rare occurrence in the past but now becoming more common year by year. They are grouped into three categories as defined below:

Severe Heat Wave=Five consecutive Days with Daily Maximum Temperature ≥ 40°C

Moderate Heat Wave= Five consecutive Days with Daily Maximum Temperature ≥ 35°C and <40°C

Mild Heat Wave= Five consecutive Days with Daily Maximum Temperature ≥ 30°C and <35°C

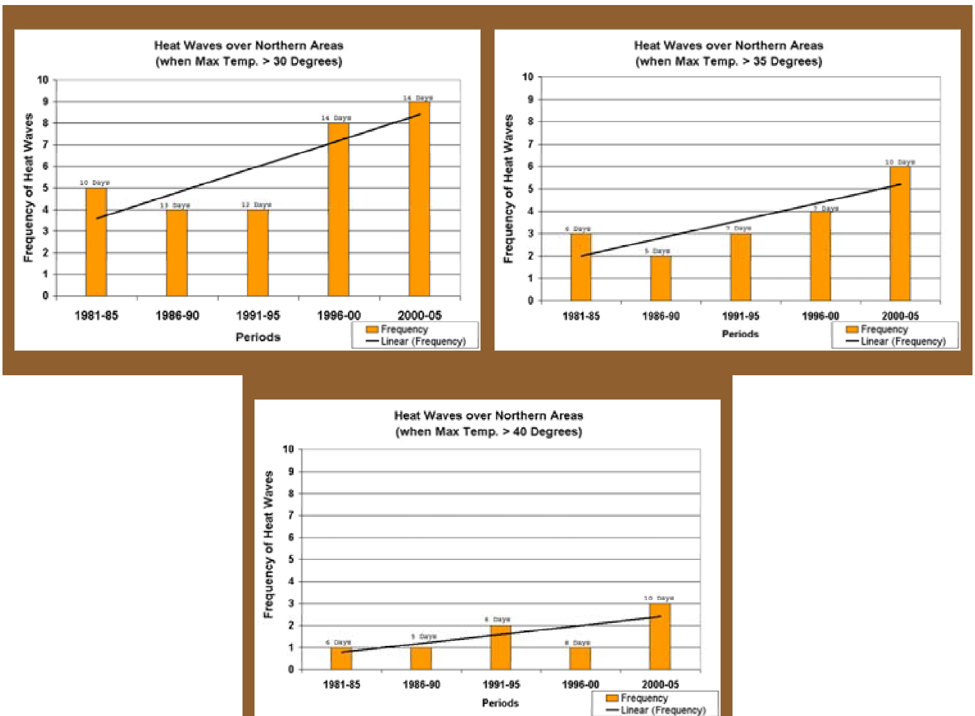

Figure 2: **Frequency of moderate, mild and severe heat waves of 5-days duration (bars) and their linear trend. The numbers on the top of the bars indicate the longest duration of heat wave recorded during that pentad.**

Frequency analysis carried out over all the above thresholds is presented in figure 2 from 1981 to 2008 using combined data set from all sources. The height of the bar represents the number of events when temperatures reached the mild, moderate and severe stress level in a particular pentad. Frequency of mild stress was quite common even in 1980s during May and June but moderate and severe stress conditions rarely occurred. Not only a significant increase had been noticed in occurrence of mild stress days but a sharp rise in moderate and severe stress events was also registered during the recent decade. The longest heat wave occurred during respective pentad is shown in Figure 2d. It can be observed that the persistence of heat waves has become longer over the temporal scale on one hand while their intensity has increased on the other hand during the recent years. Similarly their areal extent has also increased significantly. The valley areas or shadow zones appearing unaffected by increasing heat in the earlier period are dominated by the heat sweep. However, they are following certain lag period than the exposed elevations.

Snowmelt Flood:

Snow and ice are the most sensitive entities of the natural ecosystem to any change in thermodynamic regime directly or indirectly taking place. Due to a general trend of increasing warming, these frozen water reserves have also started melting at an accelerated rate giving rise to the formation of new glacial lakes and producing local flooding due to their outburst phenomenon. In addition to Glacial Lake Outburst Floods (GLOFs), ice and snowmelt water runs through the streams and converge into the major rivers. The convergence of stream flow peaks, sometimes, generates high river floods downstream.

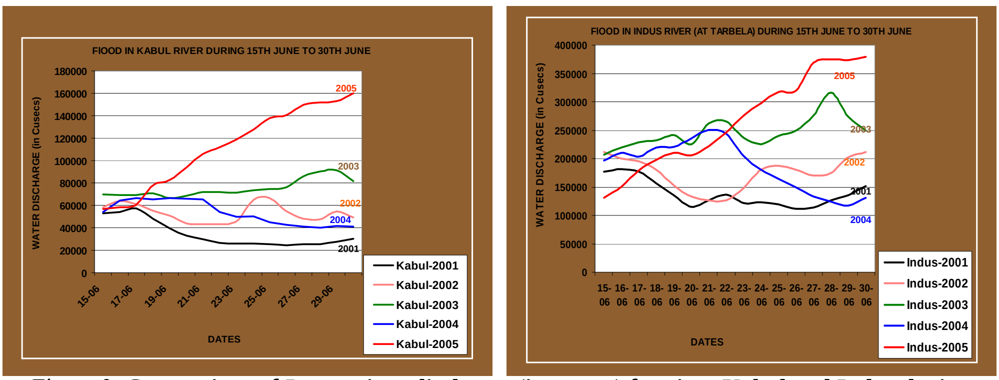

Figure 3: **Comparison of 5-year river discharge (in cusecs) for river Kabul and Indus during the last half of June.**

The most devastating flood of pre-monsoon season in the rivers Indus and Kabul during 2005 was the worst example in recent era. During the last fortnight of June, the high pressure ridge of westerly waves prevailed over the northern mountainous regions of Pakistan and Afghanistan. Temperatures plunged quickly above 40°C at most of the meteorological stations up to 2500m as and such conditions persisted until the end of June. Not only this stretch of hot spell was recorded as the longest heat wave ever occurred in these areas but also established new records of the maximum temperatures reaching 43.6 °C at Gilgit.

The large amounts of melt water rushed through the streams and flooded the main rivers. The river discharge of the Indus at Tarbela and the Kabul at Naushera are compared for the last 5-years during the last fortnight of June (Figure 3). The curves show an increasing trend of river discharge reflecting warming trend but an abrupt increase in flow of both the rivers during 2005 represent the extreme heat wave conditions discussed above. The river Indus and the Kabul join together off Naushera and known as the Indus. This historic and untimely flood took hundreds of lives, damaged thounsands of hectares of standing crops and incurred huge loss to infrastructure downstream from NWFP to Sindh. The main flooding season generally coincides with the monsoon season which extends from July to September.

Melting Glaciers:

Increasing concentration of GHGs due to uncontrolled emissions has made the situation very complex for projection of future climates. It does allow the change to be linear rather changes in pattern on every bit of increase makes the things complicated. The whole climate system is although nicely integrated but response to any change differs from entity to entity. Emissions taking places in one part of the world are not limited to that region rather immediately distributed over the globe as earth's climate system is dynamic machine like a centrifuge. However, the differential distribution pattern of climate system does not allow uniform distribution of the effects of added constituents in the solid, liquid or gaseous forms.

The global retreat of glaciers during 20th century is striking as shown in fig 5. The interaction between cryosphere and atmosphere approach is quite appropriate to study the dynamic behaviour of glacial fluctuations (Kaser, 2001; Wagnon et al., 2001). Trends in long time series of cumulative glacier-length and volume changes indicate convincing evidence for fast climate change or sudden variability at global scale. Since 1990, the IPCC has documented such changes as an evidence (Fig 5) of global warming. Mountain Glaciers are the most sensitive precursors of global warming and climate change, although which parameter is playing important role and quantitative relationship between climate change and glacier fluctuations is still ambiguous. However it corresponds 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 Kalimanjaro concludes that increased air temperature governs the glacier retreat in a direct manner (Kaser, 2004).

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). There is some disagreement among the scientists that all glaciers of Himalaya-Karakorum-Hindukush region are retreating. Most of the world's mountain glaciers have been shrining for at least the last 30 years (World Glacier Monitoring Service 2002), including the neighbouring Greater Himalaya (Hasnain 1999; Mastny 2000; Shrestha and Sherestha 2004). However, Hewitt

(1998) reports the widespread expansion of larger glaciers in the centeral Karakoram, accompanied by an exceptional number of glacier surges. This contrast raises many questions about the standard of instruments, methods of data collection and accuracy of collected data used in these studies.

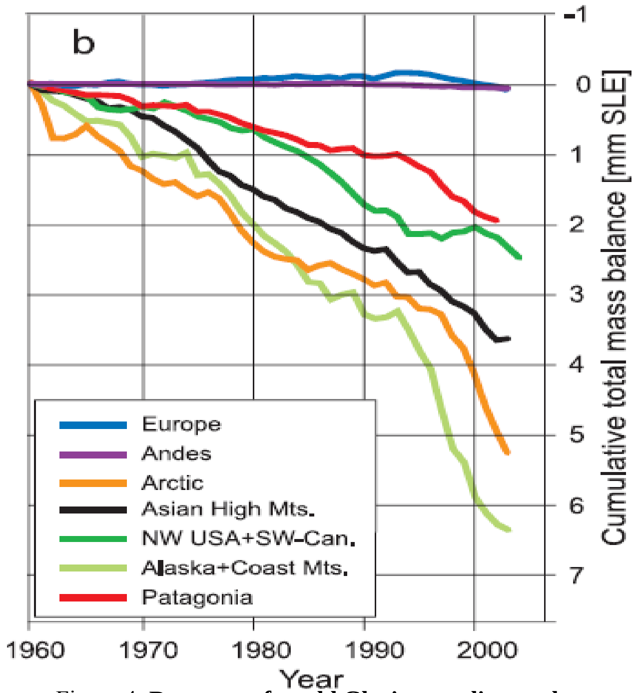

Figure 4: **Response of world Glaciers to climate change**

It is, however, clear that visible changes in mass and extent of glaciers can not be hidden from the eye of the satellite when present is related to the past. A similar evidence of decay is presented in Fig. 6 about Siachen glacier which had been a warfront between Pakistan and India since decades. The Siachen Glacier is located in the eastern Karakoram Range in the Himalaya Mountains in Ladakh at about 35.5ºN and 77.0ºE. Englishman W. Moorcroft was the first outsider to reach the region in 1820 while another traveler Henry Starchy was the first to explore the glacier in 1848. Major F. N. Workman and his wife stayed in the area for a long time in 1910s and named the glacier as Siachen. It ranges from an altitude of 18,875 ft. a.s.l. at its source Indira Col Pass near China Border to its snout at 11,680 ft. a.s.l. Melting water of Siachen Glacier is the main source of Nubra River flow and it drains into Shyok River which in turn joins the Indus River.

The visible decay of Siachen Glacier presented in satellite imageries (Fig. 5) is the proof of anthropogenic contribution to the warming of glaciated climate. Due to the presence of army on both sides, there is a large vehicular movement and allied activities such as building infrastructure. Temperature data collected at Hushey over the period 1991-2004 shows 4ºC rise in maximum temperature. Since temperature maxima have been increasing at a greater rate in the presence of large human concentration, the thinning of ice and retreat of glacial extent has taken place simultaneously at an alarming rate. The decay estimates calculated by remote sensing techniques show that Siachen Glacier has reduced by 1.9km in longitudinal extent from 1989 to 2006. Thinning of ice mass is evaluated 17% during the same period. It is also speculated that human presence at Siachen Glacier has also been affecting the neighbouring glaciers such as Gangotri, Miyar, Milan and Janapa which feed Ganges (first two glaciers), Chenab and Sutlej Rivers respectively.

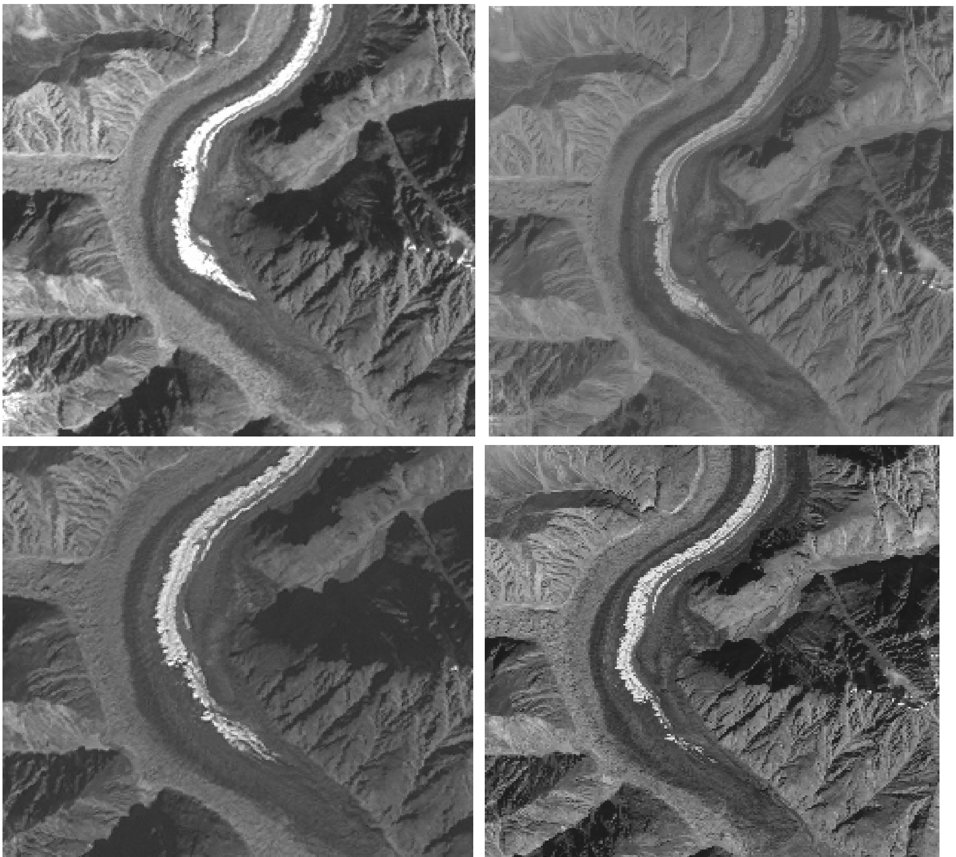

Figure 5: **Damage to Siachen Glacier observed from the eye of Landsat satellite at different times.**

Fowler and Archer (2006) have tried to prove that the glaciers of Upper Indus Basin UIB (HKH region) are thickening and expanding based on meteorological data from some PMD stations and hydrological data of WAPDA stations. They claimed that diurnal temperature range (DTR) has increased and runoff reduced. They must check the health of data used and also based on 3 or 4 stations data making such a big claim for such a large basin does not look very scientific. Also cloud cover over most of the stations (included in their study) has increased when compared meteorological normals (1931-60) with (1961-90). It proved that logically DTR could not increase as mostly clearer skies would be the basic requirement. Regarding discharge data, runoff from UIB finally reaches Tarbela Dam and water reserves showed significant increase during the last two decades. Moreover, the interacting atmosphere with cryosphere has shown warming trend which is gradually accelerating and lot of reduction in ice mass has been incurred.

Global research results compiled by IPCC in its four Assessment Reports are presented below:

- FAR(1990): The observed warming is likely to have been due to natural variability;
- SAR(1995): There are obvious evidences to detect the anthropogenic influence on climate;
- TAR(2001): New and strong evidences indicate that the observed warming in the past 50 years is likely to have been due to anthropogenic influence;
- For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.
- It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.
- Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century.

"Very likely" denotes the possibility of above 90%, "likely" states the possibility of at least 66%.

Conclusions:

Global warming is an undeniable fact evident from the most sensitive indicators in the form of frozen fresh water which is the lifeline of billions of people. Himalaya-Karakoram-Hindukush ranges interconnected with each other house world's largest number of Mountain Glaciers. In this way, they possessed the largest ice mass after the polar regions. As the warmer atmosphere interacts with these ice reserves, they are suffering from faster melting. Increasing warming rate leaves the alarming signals that their life span is reduced to several decades only. In recent changes observed in climatic behaviour, the anthropogenic factor is more pronounced than the natural one. The results of isothermic dynamics, changes in frequency and duration of heat waves, hydrodynamics and cryodynamics are discussed in this paper.

Pentad analysis of summer temperatures including data from various sources (1981-2008) revealed that 30°C isotherm has moved to 725m above the elevation where it existed three decades before. A study conducted in the same area on the basis of meteorological data only showed the position of that isotherm at 350m by the end of 2005 (Rasul et al., 2006). It reflects that warming is a continuous process and it is invading the higher elevations from the plains along the southern slopes of HKH ranges.

There was a rare occurrence of heat waves (temperature >35°C) at an elevation above 1500m in 1970s but now continuous spells of 40°C have been recorded. The frequency of moderate as well as severe heat waves has increased to almost double now as compared to 25 years before. These heat waves have not only become frequent but also persistant over longer time scales. The spatial extent has also increased by about three folds. Due to the increase in frequency, intensity and prevalence of heat waves, the stream flow has increased resulting into downstream floods occasionally.

Anthropogenic related warming has badly damaged the Siachen Glacier which had been the war-front between Pakitani and Indian forces since mid 1980s. Large human presence and their related military activities caused 4°C increase in temperature on the average in that areas. Satellite estimates show that Siachen has reduced its snout by 1.9 km from 1989 to 2006. It is worth-mentioning that not only it has contracted longitudinally but also has lost about …….% layered ice thickness. Study on Batura, Baltoro and Biafo is in progress and initial results show a depleting trend in general.

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