A Study of Glaciers in Northern Pakistan

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ABSTRACT

Glaciers serve as a natural regulator of regional water supplies. Pakistan's glaciers are spread over an area of about 16933 Km^2. Pakistan is a home of 108 peaks above 6000m, and numerous peaks above 5000 and 4000. Five of the 14 highest independent peaks in the world are here. These glaciers are enormous reservoirs of fresh water and their melt water is an important resource which feed rivers in Pakistan. Glacier depletion, especially recent melting can affect agriculture, drinking water supplies, hydro-electric power, and ecological habitats. This can also have a more immediate impact on Pakistan's economy that depends mainly on water from glacier melt. Melting of seasonal snowfall and permanent glaciers has resulted not only in reduction of water resources but also caused flash floods in many areas of Pakistan. Using satellite data the study of glaciers, has become possible. Comparison of Landsat images of Batura glacier for the year October 1992 and October 2000 has revealed that there is decrease of about 17 km^2 in Batura glaciers. Biafo glacier has also retreated. Through this study efforts have been made to analyze future changes in glaciers because, changes cannot be assessed without baseline information on glacier extent.

ALOS data could be effectively used to compare with the historical data to detect changes in the glaciated area. ALOS PRISM data can also help in DEM generation for volume assessment.

1. INTRODUCTION

Fresh water is a finite and vulnerable resource, essential for sustaining life and development. The water resource in Himalaya is partly stored as glacier ice, i.e. capital water. There are approximately 70 large glaciers in Himalaya covering about 166.12 km^2 or 17 % of the mountain area. This is the largest body of ice outside the Polar caps, and forms a unique water reservoir. The glaciers supply 303.6 million cubic feet every year to Asian rivers, including the Indus in Pakistan. In fact this river is lifelines of millions of people (Ole R. Vetaas).

2. GLOBAL WARMING

Due to greenhouse effect absorption and emission of infrared radiation by atmospheric gases warm a planet's atmosphere and surface. On Earth, the major natural greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect Carbon Dioxide (CO_2), 9–26%; methane (CH_4), 4–9%; and ozone, which causes 3–7%. The atmospheric concentrations of CO_2 and CH_4 have increased by 31% and 149% respectively above pre-industrial levels since 1750. This is considerably higher than at any time during the last 650,000 years. About three-quarters of the anthropogenic [man-made] emissions of CO_2 to the atmosphere during the past 20 years are due to fossil fuel burning. The rest of the anthropogenic emissions are predominantly due to land-use change, especially deforestation.

The present atmospheric concentration of CO_2 is about 383 parts per million (ppm) by volume. Future CO_2 levels are expected to rise due to ongoing burning of fossil fuels, deforestation and land-use changes. The rate of rise will depend on uncertain economic, sociological, technological, natural developments, but may be ultimately limited by the availability of fossil fuels. The IPCC Special Report on Emissions Scenarios gives a wide range of future CO_2 scenarios, ranging from 541 to 970 ppm by the year 2100. Fossil fuel reserves are sufficient to reach this level, if coal, tar sands or methane clathrates are extensively used.

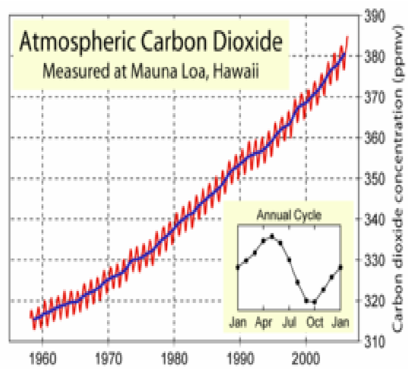

Figure: 1
Shows recent increase in atmospheric CO_2. The monthly CO_2 measurements display small seasonal oscillations in an overall yearly uptrend; each year's maximum is reached during the northern hemisphere's late spring, and declines during the northern hemisphere growing season as plants remove some CO_2 from the atmosphere.

One of the important factors relates to the evaporation of water. CO_2 injected into the atmosphere causes a warming of the atmosphere and the earth's surface. The warming causes more water to be evaporated into the atmosphere. Since water vapor itself acts as a greenhouse gas, this cause still more warming; the warming causes more water to be evaporated, and so forth. Another important feedback process is ice-albedo feedback. The increased CO_2 in the atmosphere warms the Earth's surface and leads to melting of ice near the poles. As the ice melts, land or open water takes its place. Both land and open water are on average less reflective than ice, and thus absorb more solar radiation. This causes more warming, which in turn causes more melting, and this cycle continues. Due to global warming, the average global temperature for 2004 rose to 14.60˚ Celsius making it the fourth warmest year on record. October and November of 2004 were the hottest of those months on record since recordkeeping began in 1880. February of 2004 was the second warmest, and March, April and December were the third warmest of those three

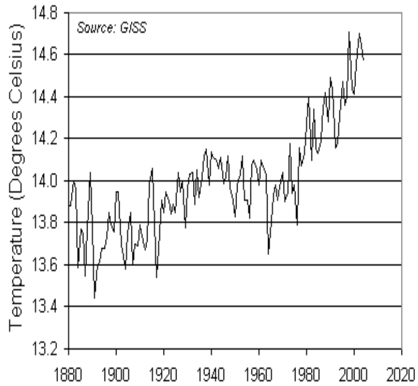

Figure: 2
Shows observations of NASA's Goddard Institute for Space Studies which come from the global series indicate continuous trend of rising global temperatures. The average temperature of 14.01˚ Celsius in the 1970s rose to 14.26˚C in the 1980s. In the 1990s it reached 14.40˚Celsius. And during the first five years of this new decade, it has averaged 14.59˚C (NASA, 2004)

3. PAKISTAN SCENARIO

Studies have shown that land surface temperatures have raised more than sea surface temperatures and that temperatures in higher elevations are rising more rapidly (Liu and Chen, 2000; Beniston et al., 1997). Therefore mountain areas such as the Karakoram and Himalaya region of Pakistan have also been affected due climate change.

According to a study carried out by GTZ for WAPDA analyzed trends in temperature and precipitation in the Northern Areas for the last century by making use of the climate data at the Meteorological Office in Lahore and Gilgit.It was found that at Skardu seasonal and annual temperature have risen over the last century. Mean annual temperature through the century has increased by 1.40˚C with the mean annual daily maximum rising more (2.35˚C) than the mean annual daily minimum (0.54˚C). But the study notes that winter temperatures have risen far more than summer, with an increase of about 30˚C during January-March or up to 0.51˚C in winter maxima per decade since 1961. This is a common feature within the Northern hemisphere and implies a link between regional and global climate (Fowler and Archer, 2004). This temperature increase is calculated to represent an upward shift of almost 400 meters in the frost line and hence whether the area will receive snow or rain and as a consequence how much snow will be available for melting during the warm season. During the spring to summer season a more modest warming trend is noted, with mean temperature rising by only 0.77˚C (Archer, D. R. 2001).

4. CASE STUDY

SUPARCO has conducted studies based on the applications of satellite/ground based data for water resources and environment monitoring. SUPARCO recently conducted a pilot study on Glacier in Northern Pakistan. Temporal satellite images of Landsat 5 TM for the year 1992 and Landsat 7 ETM+ for the year 2000 of Batura and Biafo Glacier were acquired and analyzed

4.1. Batura Glacier

Batura Glacier one of the largest glaciers outside the polar region. It lies in the north of Passu 7,500 meter above sea level, located geographically at 36^{o} 30`N to 36$^{o}$ 40`N and 74^{o} 22` 33``E to 74$^{o}$ 52` 30``E. It feeds River Hunza in northern Pakistan which flows west to east. River Hunza is joined by the Gilgit and the Naltar Rivers before it flows into the Indus River. It was observed that the ice covered and ice free areas in the year 1992 was 98 km^{2} and 25 km^{2} respectively, whereas in the year 2000, the ice covered area reduced to 81km^{2}, consequently increasing the ice free area to 42km^{2} (Rahmatullah Jillani, 2006).

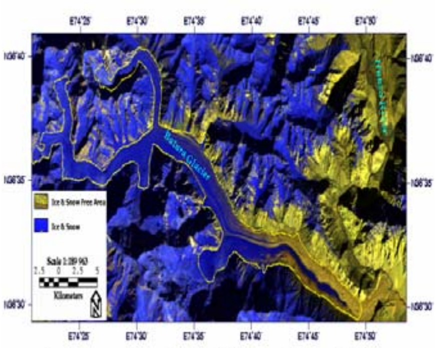

Figure: 3
Image segment to be classified from Landsat 5 TM (Oct 1992) of Batura Glacier, the following bands were used: TM2 (blue); TM3 (green); TM4 (red). Blue color shows snow and ice covered area and green color show snow free area.

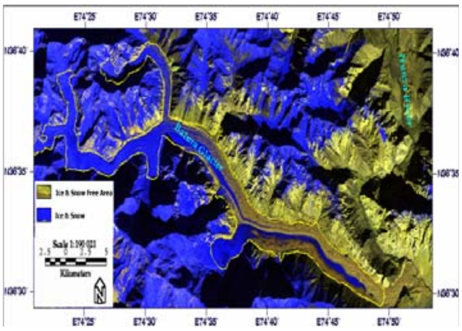

Figure: 4
Image segment to be classified from Landsat 7 ETM+ (Oct 2000) of Batura Glacier, the following bands were used: TM2 (blue); TM3 (green); TM4 (red). Blue color shows snow and ice covered area and green color show snow free area.

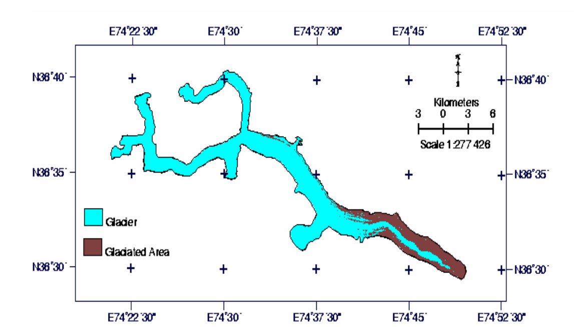

Figure: 5
Classified and calculated Normalized Difference Snow Index (NDSI) of Batura image of 1992

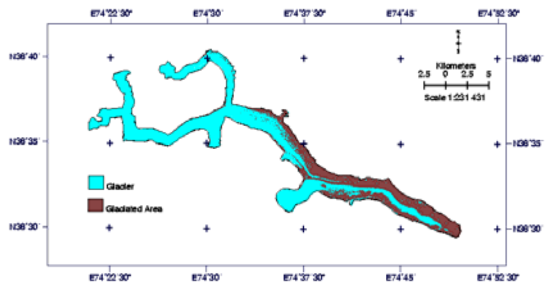

Figure: 6
Classified and calculated Normalized Difference Snow Index (NDSI) of Batura image of 2000

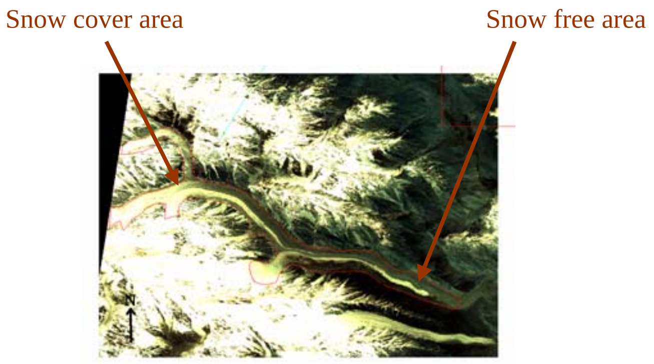

Figure: 7
Image segment to be classified from ALOS AVNIR (May 2007) of Batura Glacier, the following bands were used: AVNIR4 (red); AVNIR3 (green); AVNIR2 (blue)

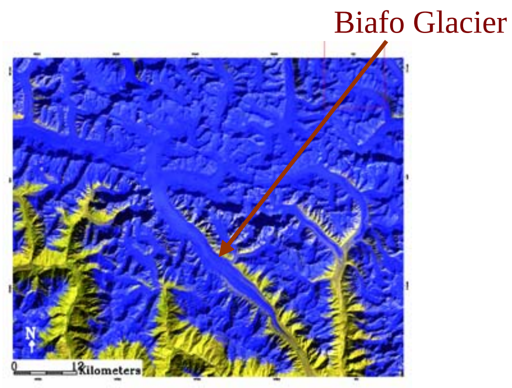

Figure: 8
Image segment to be classified from Landsat 5 TM (Oct 1992) of Biafo Glacier, the following bands were used: TM2 (blue); TM3 (green); TM4 (red). Blue color shows snow and ice covered

As May is the suitable month for the estimation of snow accumulation on glacier,
As shown in figure 7: Visual analysis of AVNIR (May 2007) and Landsat (1992 and 2000) images of Batura glacier reveals that snow covered area has reduced.

4.2. Biafo Glacier

Biafo Glacier is the third largest glacier in the Karakoram and the fourth largest in Asia(Hewitt, K,1989). The Biafo Glacier is located on the south-facing slopes of the Karakoram Range in the Baltistan area of Ladakh. It lies in the center of Shigar River Basin located geographically at 35^{o} 19\`N to 36$^{o}$ 07\`N and 74^{o} 53\`E to 76$^{o}$ 75\`E. The main steam originating from this glacier is Barldu River flows into the Shigar River which in turn is a tributary of the Indus River.
The analysis indicates that snow and ice cover and free area in 1992 was 92.807 km^2 and 20.916 km^2 respectively, and in 2000 the ice cover area reduced to 86.250 km^2.

We have used the band ratios and NDSI techniques to investigate the change in area.

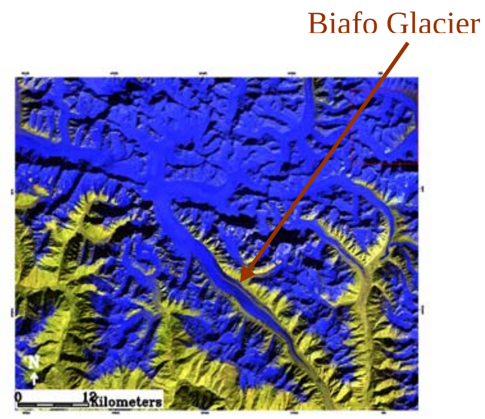

Figure: 9
Image segment to be classified from Landsat 7 ETM+ (Oct 2000) of Biafo Glacier, the following bands were used: TM2 (blue); TM3 (green); TM4 (red). Blue color shows snow and ice covered area.

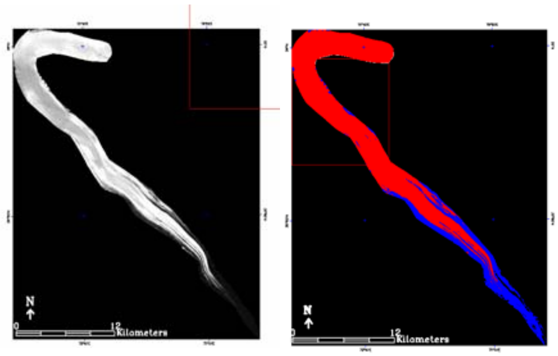

Figure 10:
Calculated and classified band ratio (TM3/TM5) of 1992 images

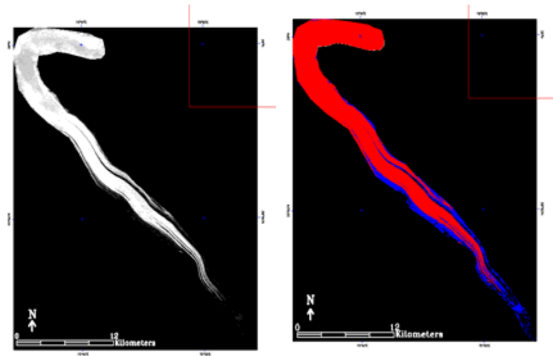

Figure 11:
Calculated and classified band ratio (TM3/TM5) of 2000 image

5. Reduced Level of Water in the Indus River System

The Indus River, its tributaries originate in the Karakoram, Hindukush, and the Himalayan regions along the north and north eastern borders of Pakistan. The Indus System rivers form a link between two great natural reservoirs, the snow and glaciers in the mountains and the groundwater contained by the alluvium in the Indus Plains of the Punjab and Sindh Provinces of Pakistan. The water from the Indus River and its tributaries supports the bulk of the agricultural water supply for its 130 million people. Dams on the main stem of the Indus River and its tributaries produce about 45% of the electrical energy for Pakistan.

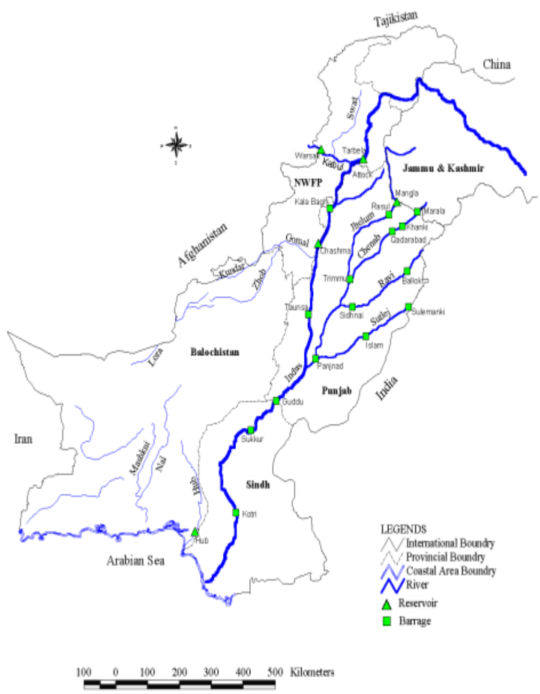

Figure 12:
Showing Indus River System and its Tributaries (Asim R. Khan)

Table 1:
Showing annual flow-rates of major rivers between 1922-61, 1985-1995 and 2001-02

River	Average Annual Flow (1922-61) MAF	Average Annual Flow (1985-95) MAF	Average Annual Flow (2001-02) MAF
Indus	93	62.7	48.0
Jhelum	23	26.6	11.85
Chenab	26	27.5	12.38
Ravi	7	5.0	1.47
Sutlej	14	3.6	0.02
Kabul	26	23.4	18.9
Total	189.0	148.8	92.62

The table 1: shows average annual flow-rates of major rivers between 1922-61, 1985-1995 and 2001-02. The figures indicate sharp decrease in water flow in the rivers during last several years. The low level of water-flow in the rivers is an indicative of reduced quantity of water in the glaciers. The situation in River Indus clearly indicates decrease in quantity of water by 32% during 1922-61 as against the period of 1985-1995 and further reduced to 23.44% during 2001-02 compared to 1985-1995. It is in fact significant reduction of 51.6% in the last eight decades (IUCN Report).

6. CONCLUSION

Glaciers are major sources of water, studying the aspects and temporal changes are vital for planning, development water resource conservation, flood monitoring and mitigation activities.Additional anticipated effects include agriculture, increased intensity and frequency of hurricanes and extreme weather events and spread of diseases such as malaria and dengue fever. Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming. As per IPCC 2001 report retreat, sea, changes in rainfall pattern, increased intensity and frequency of extreme weather events, are being attributed in part to global warming. Other expected effects include water scarcity, changes in mountain snow pack, adverse health effects from warmer temperatures, and the spread of diseases.Rising temperatures could bring large-scale drought in critical agricultural regions worldwide, extreme temperature drops in some regions and searing heat in others, and civil unrest and mass migrations from spreading insecurity about water and food supplies.

RECOMMENDATIONS

- There is need to conduct comprehensive study on our glaciers
- Develop a model to determine water melt off from glaciers
- Water conservation plan should be enforced at national level

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