Glaciers

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INTRODUCTION

Geological survey of India is carrying out glaciological studies in the Himalayas for the last 100 years. Systematic scientific monitoring started since 1974. Besides, since 1985 GSI is engaged in glaciological studies at Antarctica also where fluctuation of ice sheet is being monitored along with studies on accumulation and ablation studies of snow. Basically the following studies are being carried out:

1. Monitoring the recession/advancement pattern of the glacier snout (secular movement studies) in different river valleys of Himalaya and detailed glaciological study to decipher the dynamics of the glacier. About 8 to 10 glaciers, located in different climatic zones of Himalayas (like Kashmir Himalayas, Himachal Himalayas and also the Northeastern Himalayas) were monitored for the past 10 years. This monitoring included mass balance of the glacier, hydrometry of glacier melt, flow movement of glacier along with climatic parameters. A detailed study of Hamtah glacier in the Chandra catchment of Lahaul and Spiti Himalaya, Himachal Pradesh was carried out over the past few years.
2. Geological survey of India prepared an Inventory of Himalayan Glaciers on 1:50,000 scale. The inventory is prepared as per the guidelines of TTS of WGMS as detailed below.

SECULAR MOVEMENT STUDIES

Secular Movement Studies of Glaciers in Parvati and Beas Basins, Kullu District, Himachal Pradesh

Snout monitoring of glaciers viz. *Glacier No. 115 and Glacier No. 25* (Sara Umga) in the Parvati basin were undertaken on 1:5,000 scale and glacio-geomorphological mapping on 1:50,000 scale covering an area of 15 sq km of the proglacial region was undertaken. *Glacier No. 15,* also named as Mantalai glacier, falls in Survey of India Toposheets No. 52E/9 &13. This avalanche-fed glacier originates east of 6127 peak and flows in a NE direction for a distance of 6.50 km. It occupies a total surface area of 11.70 sq km and has a total ice volume of 0.819 cu. km. The snout of the glacier is in the form of an ice wall. The ice cave is located towards the left margin of the glacier from which the melt water emerges joining the main Parvati River about one kilometre downstream. In the proglacial area a small proglacial lake besides a few dried up lakes was observed. The glacier receded by 350 m since 1989 with an average annual recession of 23.3 m and has vacated an area of 0.07 sq km in the intervening period. *Glacier No. 25* named also as the Sara Umga Glacier originates west of 5410 peak and is the largest glacier of the Beas fourth-order basin having a length of 15.25 km and surface area of 55.89 sq km. Its ice volume is estimated to be 5.589 cu. km. This southwesterly oriented glacier falls in SOI Toposheets No. 52H/8 & 12. The snout is spread over an expanse of about 300 m from west to east. The melt water issuing from the ice cave, located towards left margin, debouches into a broad outwash plain. The glacier is flanked on both sides by lateral moraines. The lateral moraines are at a much higher elevation and extend downstream of the present-day snout indicating considerable shrinkage of the glacier. The glacier has receded by 650 m since 1989 with an annual retreat of 43.30 m and has vacated an area of 0.75 sq km.

Secular Movement of Selected Glaciers in Ravi Basin, Chamba District, Himachal Pradesh

Snout of two glaciers viz. *Tal* and *Manimahesh* located in Budhil fifth-order basin of Ravi basin was monitored and glacio-geomorphological mapping on 1:50,000 scale covering an area of 20 sq km in the proglacial region was completed. *Tal Glacier* falls in SOI toposheet No. 52 D/15. It originates at 4,920 m asl and after flowing southwestwards for 3.95 km, it terminates at 4,300 m asl. It occupies a total surface area of 4.03 sq km and has a total ice volume of 0.161 cu. km. Recession in the past has resulted in the thinning of the glacier ice and the lower part of the glacier was detached from the main body along the rock face, just downstream of the present snout. At present the melt water comes down like a waterfall. The area around Ghewla *nala* and upstream typically shows development of fluvio-glacial terraces. During the last 42 years (1963-2005), the glacier has receded by 1,675 m at an average of 39.88 m/year. During this period, it vacated an area of 0.706 sq km in its proglacial regimen. *Manimahesh Glacier* falls in SOI Toposheet No. 52 D/11. The 4.60-km-long glacier originates at 4,960 m asl and flows towards north covering an area of 4.58 sq km and has 0.137 cu. km of locked-up ice. Its proglacial region is a mixture of ground/recessional moraines with linear country outcrops protruding out. The glaciation must have extended up to a little downstream of Dhanchu as revealed by the terminal moraine hump. During the last 37 years, the glacier receded by 1,075 m with an average retreat of 29.05 m/year. The area vacated is estimated at 0.679 sq km.

Recessional Pattern of Glaciers in Bhaga Basin, Lahaul & Spiti District, Himachal Pradesh

Snout of two glaciers viz. *Yoche Lungpa* (5Q212 11 179) and *Mulkila* (5Q212 11 170), located in Bhaga fifth-order basin of Chenab basin (5Q 212), were mapped on 1:5,000 scale covering an area of 0.70 km^2. Glacio-geomorphological mapping, in an area of 12 sq km, was carried out on 1:50,000 scale in the proglacial region. Glacier *Yoche Lungpa,* falls in SOI Toposheet No. 52 H/6. As per the inventory details of Bhaga basin, this 13.20- km glacier originates at 6002 m asl, occupies a total surface area of 18.86 sq km and has

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a total ice volume of 1.320 cu km. The snout of the glacier is in the form of a large ice wall (about 50m thick) with a well-developed ice cave. The proglacial region comprises large boulders, dead ice mounds and ground/recessional moraines (ice cored at places). The different sets of lateral and terminal/recessional moraines were mapped. During the last 43 years, (1963-2006), the glacier has receded by 840 m at an average of 19.53 m/year and has vacated a total area of 0.212 sq km in its proglacial regimen. *Mulkila Glacier in* Mulkila is a 14.60-km-long north-northwesterly oriented valley glacier that originates at 6,040 m asl and falls in SOI Toposheet No.52 H/6. It occupies a total surface area of 28.63 sq km and has 2.863 cu. km of locked-up ice. The snout of the glacier is exposed as a large ice wall (70-80m thick) with a small ice cave. The glacier has carved out a large proglacial valley with little geomorphological details. Both, left and right lateral moraines are, however, well preserved near its confluence with Yoche Lungpa stream. During the last 43 years (1963-2006), the glacier receded by 635 m with an average retreat of 14.77 m/year and the total area vacated by the glacier has been estimated to be 0.105 sq km.

Glaciological Studies on Hamtah Glacier, Lahaul and Spiti District, Himachal Pradesh

Detailed glaciological studies constitute an important aspect of glaciological studies. Studies on *Hamtah glacier* included glacier melt, solute concentration and suspended sediments. A decade-long monitoring programme since 2000, includes assessment of annual mass balance, summer and annual ice flow, monitoring of melt water discharge, amount of suspended sediment load, recording of microclimatic parameters, heat balance studies, snout monitoring and geomorphological mapping on 1:5,000 scale. The annual mass balance for the years 2003-04, 2004-05 and 2005-06 was ~ (-) $6.42x10^6$ m^3 of water equivalent (specific net balance of (-) 1.86 m), ~ (-) $2.24x10^6$ m^3 of water equivalent (specific net balance of (-) 0.614 m) and ~ (-) $4.8092x10^6$ m^3 of water equivalent with a specific net balance of (-) 1.391 m respectively.

For 2003-04 the maximum and minimum values of horizontal component of velocity (U) were 21.27 m/y at 4,528 m asl and 2.06 m/y at 4,074 m asl respectively. The vertical component of velocity (Uz) registered a maximum upward shift of (+) 0.699 m between 4000-4200 m asl and a downward shift of (-) 2.332 m between 4,200-4,400 m asl. For 2004-05 the maximum and minimum values of horizontal component of velocity (U) were 25.46 m/y at 4527 m asl and 1.32 m/y at 4,074 m asl respectively. The vertical component of velocity (Uz) recorded a maximum upward shift of (+) 0.03 m between 4,000-4,200 m asl and a downward shift of (-) 0.92m between 4,200-4,400 m asl. For 2004-05, the maximum and minimum values of horizontal component of velocity (U) were 20.143 m/y at 4,543 m asl and 5.815 m/y at 4,178 m asl respectively. The vertical component of velocity (Uz) recorded a maximum and minimum shift of (-) 1.65 m and (-) 1.02 m between 4,400-4,600 and 4,000-4,200 m asl respectively. In 2003-04, the total melt water discharge was $24.65x10^6$ m^3 with an average daily discharge of $0.30x10^6$ m^3. In all, 498 samples were collected for assessing suspended sediment load. Melt water discharge was $29.82x10^6$ m^3 with an average daily discharge of $0.41x10^6$ m^3, and 432 samples were collected for assessing suspended sediment load in 2004-05 and melt water discharge was $14.17x10^6$ m^3 with an average daily discharge of $0.30x10^6$ m^3, 288 samples were collected for assessing suspended sediment load in 2005-06.

Heat balance studies including measurements of sunshine duration and albedo were carried out. For 2003-04, the total sunshine duration was 372.8 hrs with an average daily sunshine of 4.5 hrs. The albedo values range from 2.2 to 4.2% with an average of 12.97% for bare ice. For 2004-05, the total sunshine duration was 384.5 hrs with an average daily sunshine of 4.6 hrs. The albedo values range from 20.3 to 9.1% with an average of 11.8% for bare ice. For 2005-06, the total sunshine duration was 236.6 hrs with an average daily sunshine of 4.2 hrs. Albedo values range from 25.4 to 8.4% with an average of 14.86% for bare ice.

The various components of microclimate recorded for the three years are shown in below table.

Parameters	2004	2005	2006
Mass balance ($x10^6 m^3$ of w. e.)	(-)6.42	(-)2.24	(-)4.81
Av. Daily discharge ($x10^6 m^3$)	0.30 (82 days)	0.41 (72 days)	0.30 (47 days)
Av. Daily Sus. Sed.(tonnes/day)	99.98	130.48	157.86
Met Parameters	82 days	83 days	57 days
Range max. temp. (^oC)	19.0 to 6.5	17.5 to 5.0	16.5 to 6.5
Range min. temp. (^oC)	8.5 to (-)1.5	8.0 to (-) 2.5	8.5 to (-)1.5
Precipitation liquid (mm)	298.0	352.8	274.5
Precipitation solid (cm)	0.4	11.0	3.5
Average wind Speed (km/hr)	11.75	11.4	11.6
Average relative humidity (%)	79	86	82

Monitoring of the glacier snout on 1:5,000 scale revealed recession of the glacier that has vacated an area of 0.006725 km^2 between 2004-2006. Glacio-geomorphological mapping was carried out along the lateral margins and in the proglacial regime of the glacier on 1:5,000 scale covering an area of 1.80 sq km (2004-2006).

GLACIER INVENTORY

Glacier Inventory (level 3 & 4) of Kishanganga Basin, Kashmir, J&K

Kishanganga, a fourth-order basin (as per inverse Strahler system for glacier inventory) within the third-order Chenab basin (5Q21) drains north of Jhelum. The Kishanganga originates from the group of glaciers near Kaobal Gali and joins the river Jhelum near Muzaffarabad (in Pakistan). This east-west-trending basin covers an area of 7032.63 sq km. The southern boundary of the basin is the water divide with Jhelum basin, the eastern boundary basins whereas the northern boundary separates it from the Indus basin.

There are six fifth-order basins of which five have glaciers. These are *Dharian* (5Q213 01), *Gumot* (5Q213 03), *Barai* (5Q213 04), *Sarewala* (5Q213 05) and *Kishanganga* (5Q213 06). Barai basin has 15.42% area that is glaciated with 83 glaciers. *Gumot* has 21 glaciers. The glacier inventory data

for the basins is expected to help the water management of Kishanganga basin.

Thematic Compilation of Glacier inventory of Uttaranchal Himalaya

Uttaranchal Himalaya has thirteen districts of which six districts viz. Uttarkashi, Tehri-Garhwal, Rudraprayag, Chamoli, Bageshwar and Pithoragarh are glaciated. In all, these six districts contain 968 glaciers covering an area of 2884.15 sq km against the total geographical area of 30,618 sq km. The total ice volume locked up in these glaciers is of the order of 213.75 cu. km. Chamoli district, with 310 glaciers covering 13.76% of the total geographical area, is the most glaciated district while Tehri-Garhwal district with only 13 glaciers, covering 2.28% of the area. *Gangotri* glacier, the source of the sacred river Ganga, is in theUttarkashi district. This is the largest glacier spanning 30.2km length and an area of 143.59 sq km. Chamoli, Uttarkashi and Pithoragarh districts account for 73.5% of the total geographical area of these six districts, contain 91.1% of glaciers, 91.2% of glaciated area and 92.6% of locked-up ice of entire Uttaranchal Himalaya. These three districts play a key role in hydropower development of Uttaranchal state.

Thematic Compilation of Glacier Inventory of Himachal Himalaya

Under this item, watershedwise and districtwise thematic compilation of glacier inventory data of Himachal Himalaya was undertaken. The state of Himachal has twelve districts of which six are glaciated. In all, there are 2,100 glaciers covering an area of 3,799.07 sq km (6.82% of total area) in which 227.06 cu km of ice is locked up. Lahaul & Spiti district with 1,127 glaciers and 2,125.80 sq km of glaciated area is most glaciated while Shimla district having nine glaciers that cover an area of a meager 0.46 sq km is least glaciated. The Bara Shigri glacier, which is 27 km long and covers an area of 136.75 sq km, is the largest glacier in the entire Himachal Himalaya.

Thematic Compilation of Glacier Inventory of Jammu & Kashmir Himalaya (F.S. 2005-2006)

Under this item, watershedwise and districtwise thematic compilation of glacier inventory data of Jammu & Kashmir Himalaya was undertaken. Jammu and Kashmir State covers an area of 222,236 sq km (of which 78,114 sq km is occupied by Pakistan and 5,180 sq km by China). The mountain ranges in Jammu and Kashmir State are Pir Panjal, Ladakh, Great Himalayan, Karakorum and Zanskar. Several closed (lake) basins viz. Pangong Tso, Kaigar Tso, etc. are also located within the State of Jammu & Kashmir. The State is divided into 14 districts. Out of these, seven districts that have glaciers are Srinagar, Pulwama, Anantnag, Baramulla, Leh, Kargil and Doda. Leh district is the most glaciated. Siachen, the largest glacier outside the Polar region (73km long), is located in this district. Srinagar is the least glaciated district with prominent Harmukh group of glaciers and Gangbal glacial lake. Synthesis of glacier inventory data has revealed that there are 3,133 glaciers in the J & K Himalaya covering an area of 6846.01 sq km. The total ice content in these glaciers is 518.37 cu km.

PUBLICATIONS

Compilation of the glacier inventory data of H.P. and Uttaranchal for those basins that are not included in the GSI Spl. Pub. No. 34 was carried out. The digitized maps of the individual fifth-order basins with international border were sent to Survey of India. The compilation of material for the revised and updated Special Publication in camera-ready format was carried out. "Proceedings on workshop on Gangotri glacier" are available as GSI. Spl. Pub. No. 80, 2005.

BIBLIOGRAPHY

Detailed Glaciological studies on Hamtah glacier, Lahaul and Spiti district, Himachal Pradesh: Rec. Geol. Surv. India, v. 138, pt. 8, 2005, p. 166-168.

Detailed glaciological studies on Hamtah glacier, Lahaul and Spiti district, Himachal Pradesh: Rec. Geol. Surv. India, v. 139, pt. 8, 2007, p. 136-139.

Generation of baseline data on secular movement of selected glaciers in Ravi basin, Chamba district, HP (Yoche Lungpa and Mulkila glacier), Rec. Geol. Surv. India, v.139, pt. 8, 2007, p. 139-141.

Glacier Inventory (level 3 & 4) of Kishanganga basin, Jammu and Kashmir: Rec. Geol. Surv. India, v. 138, pt. 8, 2005, p. 171.

Secular movement studies of selected glaciers in Parvati and Beas basins, Kullu district, Himachal Pradesh (Mantalai and Sara Umga glaciers): Rec. Geol. Surv. India, v. 138, pt. 8, 2005, p. 168-170.

Synthesis of hydro-meteorological and glaciological variables of glaciers in Uttaranchal, HP and J&K Himalaya for establishing possible correlation: Rec. Geol. Surv. India, v. 138, pt. 8, 2005, p. 171-172.

Thematic compilation of glacier inventory of Himachal Himalaya. Rec. Geol. Surv. India, v. 139, pt. 8, 2007, pp 141.