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Morphometric Characteristics of Glaciers in Doda Valley, Zanskar Basin, J & K

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Abstract

Inventory of the glaciers is of prime interest to evaluate the nature of changes in glacier dimensions and also to establish relationship between climatic change and dynamics of glaciers. As glaciological studies in high altitude terrains are very difficult by conventional methods remote sensing data is used to map and monitor of permanent snowfields and glaciers. The study area covers Doda sub-basin, with about 13 individual glaciers with one of them ranked as the second largest glacier in India, of larger Zanskar basin in Ladakh of Jammu & Kashmir. It is about 2088.46 sq km in area. Its elevation ranges from 3071- 6401 m above msl. An attempt is made here to study morphometric parameters like, length, width, area, perimeter, orientation, thickness, area accumulation ratio (AAR) and specific mass balance, of the glaciers using multi-temporal satellite data (FCCs as well as digital data of bands 234 of IRS LISS III) of July to September period (when snow cover is at its minimum and permanent snow cover and glaciers are fully exposed) of 1975, 1992, and 2001 in conjunction with topographical map of 1962. Altitude information is generated from Digital Elevation Model (DEM) generated with Shuttle Range Topographic Mission (SRTM) data and some inputs from SOI toposheets. The analysis reveals a decreasing trend of AAR indicating possibility of faster retreat of glaciers. The study also reveals negative mass balance compared to the recorded positive mass balance in 1975 and 1992.

Keywords: *Glacier Morphometry, Remote Sensing Data, Doda Valley*

Introduction

Morphometric analysis of the glaciers is an essential requirement to evaluate the nature of changes in glacier dimensions and also to establish relationship between climatic change and dynamics of glaciers. In the Indian Himalaya, glaciers cover approximately 23,000 sq km of area and have one of the largest concentrations of glacier-stored water outside the polar regions. Change in climate directly affects glacier mass and thereby, the water resources. Melting from snow-bound areas during summers forms an important source of water for many perennial rivers originating in the higher Himalaya. Further, acceleration in worldwide glacier mass loss over the last few decades has significant implications in terms of global sea level rise. The glacial terrain being very difficult to have access to and limitations of conventional methods of mapping, remote sensing data plays a crucial role in glacial domain mapping. Optical range bands give good registrations of glaciers in remote sensing data. An attempt is made in the present exercise to work out various morphometric parameters of 13 selected individual glaciers of Indian Himalayas. Similar such studies on glaciers using remote sensing data were carried out by Dozier and Hall (1987) using remote sensing data. In Indian Himalayas Kulkarni et al., (2002 & 2005) carried out studies using remote sensing data on various aspects of glacial retreat.

Study Area

Doda Valley in Zanskar basin covering about 2088 sq km with many glaciers in Ladakh Himalayas in the state of Jammu & Kashmir (Fig.1A) is taken for morphometric analysis. In fact, the second largest glacier (Durang Drung) in Indian Himalayas is in this Doda Valley. The elevation in the study area ranges from 3071 to 6401m above msl.

Data & Methodology

Digital Remote Sensing data of October 1975 (Landsat MSS), September 1992 (Landsat TM), September 2002 (Landsat ETM+), August 2001 (IRS-1C LISS III) and Shuttle Range Topographic Mission (SRTM) Thermal Data along with Survey of India topographical maps on 1:50,000 scale of 1962, are used for the study. Data sets of August-October period were selected as snow cover during this period is usually at its minimum and glacier areas are fully exposed.

The oldest information about extent of glaciers in the study area is extracted from SOI topographical maps (on 1:50,000) of 1962. The remote sensing data is subjected to various enhancement techniques to highlight the difference between glacial and non-glacial areas. Boundaries of 13 selected glaciers (Fig.1B) were delineated from topographical maps as well as satellite data (Fig.2). In fact, the digital elevation model has been generated using SRTM data. FCC and various ratio images of remote sensing data were then draped over DEM for to have perspective view (DTM) of glaciers (Fig.1B). Normalised Difference Snow Index (NDSI) was generated with bands 2 and 5 (of Landsat ETM+) and the resultant image with excellent differentiation was used to digitize glacier limits. A reconnaissance field survey was done in the study area during July 2007 to delineate various glacier landforms in the area. Position of some of the glacier snouts in Doda valley were recorded through hand field GPS.

Morphometry of Glaciers

Several morphometric parameters like length, width, area, perimeter, orientation were estimated directly. Glacial accumulation area is measured with respect to snow-line altitude. Snow-line altitude is obtained by measuring the distance between ablation area (where snow-melting is the dominant process) and accumulation area. Another important parameter called Area Accumulation Ratio (AAR) is a ratio

Table 1: Some morphometric parameters of 13 selected glaciers in Doda valley
(The three rows for every glacier are for years 2001, 1992 & 1975 from top to bottom)

Glacier Code	Length (m)	Area (sq. km.)	Snout Position (height in m)	Transient Snow Line Position (height in m)	Ablation Area (sq. km.)	Accumulation Area (sq. km.)	AAR (%)	Thickness (m)	Specific Mass Balance (cm)
G1	23663.2	64.51	4090	5250	33.28	31.23	48.41	174.40	-3.54
	24224.9	69.10	4081	4675	10.06	59.04	85.44	178.27	87.44
	24645.4	70.46	4078	4550	7.78	62.68	88.95	179.39	95.99
G2	13103.1	16.59	4200	5300	13.54	3.05	18.38	112.25	-76.44
	14102.8	20.33	4165	4900	6.38	10.95	63.18	113.88	33.35
	15808.6	24.59	4156	4820	6.27	14.32	69.54	120.53	48.82
G3	13657.1	24.41	4025	5160	12.85	11.56	47.35	127.43	-5.97
	14307.2	28.81	4005	4650	7.50	21.31	73.96	134.51	59.56
	14714.3	32.12	3988	4550	7.12	25.00	77.83	139.34	68.95
G4	14705.5	59.00	3950	5220	31.65	27.35	46.35	169.50	-8.40
	14886.9	70.97	3936	4850	19.9	51.07	71.95	179.80	54.68
	15460.2	73.33	3924	4675	17.51	55.82	76.12	181.68	64.79
G5	9214.01	11.54	4620	5260	7.94	3.60	31.19	99.50	-44.85
	9332.47	14.06	4590	5020	3.39	10.67	75.88	106.27	64.23
	9963.4	15.92	4578	4975	2.92	13.0	81.65	110.74	78.25
G6	5102.24	3.92	4825	5260	2.72	1.20	30.61	68.84	-47.28
	5198.24	4.58	4818	5300	2.68	1.90	41.48	72.67	19.37
	5408.1	4.85	4815	4260	2.44	2.41	49.69	74.130	26.60
G7	7459.97	6.80	4290	5300	3.68	3.10	45.72	83.24	-10.83
	7630.53	7.94	4610	5160	3.14	4.80	60.45	87.749	26.72
	8098.5	8.09	4598	4975	2.00	6.09	75.27	88.30	62.74
G8	8365.86	23.29	4580	5140	13.45	9.84	42.24	125.49	-18.12
	8013.73	27.17	4576	4600	3.39	23.78	87.52	131.97	92.50
	9357.4	29.12	4570	4550	2.32	26.80	92.03	134.98	103.40
G9	5579.75	12.41	4580	5320	8.60	3.81	30.70	101.95	-47.28
	5660.10	14.60	4570	5280	4.07	10.53	72.12	107.61	55.07
	6032.5	15.86	4564	4900	1.93	13.93	87.83	110.60	93.25
G10	7685.85	28.63	4570	5270	17.32	11.31	39.50	134.23	-25.41
	7848.46	31.01	4562	5200	10.46	20.55	66.26	137.76	40.85
	8011.9	34.93	4556	4875	3.00	31.93	91.41	143.18	101.90
G11	5174.14	5.05	4800	5360	2.69	2.36	46.73	75.17	-8.40
	5816.32	6.02	4788	5260	2.50	3.52	58.47	79.85	21.90
	6148.4	6.33	4780	4180	2.53	3.80	60.03	81.23	25.69
G12	8583.13	21.25	4250	5260	12.25	9.00	42.35	121.77	-18.12
	9085.51	23.85	4230	5020	7.76	16.09	67.46	126.47	43.75
	9288.9	24.17	4218	4930	4.60	19.57	80.96	127.02	76.57
G13	8737.66	13.83	4580	5370	8.39	5.44	39.33	105.69	-25.41
	9170.12	14.01	4565	5200	7.24	6.77	48.32	106.14	27.58
	9384.3	15.26	4559	4950	3.25	12.01	78.70	109.20	71.06

between accumulation area and total glacial area. Specific mass balance is computed using AAR. Glacial snout positions of most of the glaciers are delineated directly from the remote sensing data and for some with GPS positions. In fact, the glacier and snow/ice covered area of the total study area has been divided into 147 glaciers/polygons. The glacier and snow/ice covered area in the total study area has varied in different years/sets of data showing a decreasing areal extent. It was 552.65 sq. km in 1962 (from SOI Toposheet), 538.96 sq. km. in 1975, 507.82 sq. km. in 1992 and 452.28 sq. km in 2001. Depth of glaciers has been calculated using a formula proposed by Kulkarni (1992) and Kulkarni et al., (2004):

$$\mathbf{H = -11.32 + 53.21\ F^{0.3}}$$

where 'H' is the mean glacier thickness (m) and 'F' is the glacier area (km^2). Specific mass balance of glaciers was calculated implicating AAR in the formula proposed by Kulkarni et al., (op cit):

$$\mathbf{b = 243.01 * X - 120.187}$$

where 'b' is the specific mass balance in water equivalent (cm) and 'X' the AAR.

Discussion and Conclusion

The individual morphometric characteristics of the 13 selected glaciers of three time periods of satellite data are presented in Table 1 and a look into the parameters reveal that there are minor to major changes in the linear, areal and volume characteristics of all the glaciers in the study area from 1962 to 2001. Most of the glacier snouts are mainly located at more than 4000m above msl. There is general recession of snouts of all the 13 glaciers to various distances. The advancing and retreating snout positions are clearly visible through the presence of terminal moraines. Naithani et al., (2001) have observed that recession of snout is very common to most of the glaciers in the Himalayan region and that the recession is irregular in quantity and time of occurrence. It is obvious glacier recession is the best indicator of climatic changes. Table 1 reveals that all the 13 glaciers have retreated to a certain distances.

Transient snow line position of all 13 glaciers has changed from 1975 to 2001. Just for example, transient snow line position of G1 glacier is 5250m in 2001, reduced to 4675m and 4550 m in 1992 and 1975 respectively. Similarly accumulation areas of all the glaciers have reduced between 1975 and 2001.

Accumulation area for each glacier will vary from year to year depending upon the snow-line altitude at the end of the ablation season. Accumulation area of each glacier is reduced from year 1975 to 2001, whereas ablation area of each glacier is very much increased during 1975 to 2001. Especially in the case of small glaciers including snow/ice which number around 134 in the study area, the accumulation area has also reduced drastically from 1975 to 2001. Small glaciers are considered more sensitive to global warming (Dobhal et al., 1996).

Mass balance is one of the important parameters which is influenced by global warming. Mass balance is usually referred to as a total loss or gain in glacier mass at the end of the hydrological year (Heilskanen et al., 2002). Though in the years 1975 and 1992, there is positive specific mass balance but in the year 2001, specific mass balance of all glaciers was negative. The negative values in all the morphometric parameters indicate some kind of a climatic change towards warm temperatures.

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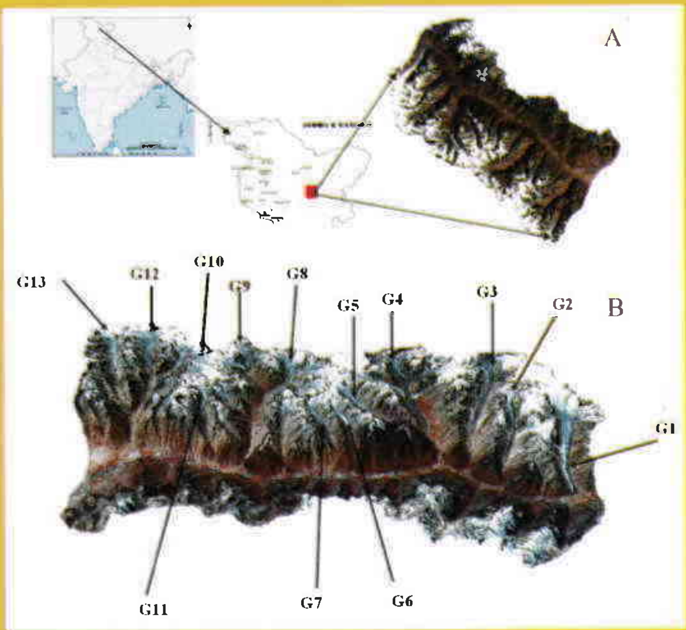

Fig.1

Location of the study area (A) and DTM of Doda Valley with the glaciers (G1-G13) selected for analysis (B)

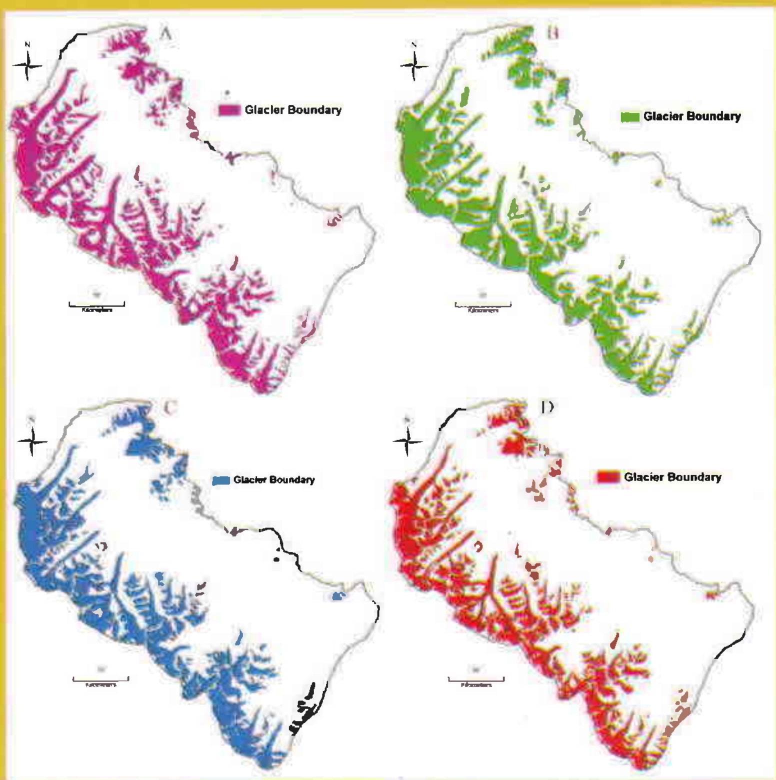

Fig.2

Areal extent of glaciers as in SOI map of 1962 (A), Landsat MSS of 1975 (B), Landsat TM of 1992 (C) and IRS-1C LISS III of 2001 (D)