STUDY OF RECESSIONAL PATTERN OF GLACIERS OF DHAULIGANGA VALLEY, UTTRAKHAND, INDIAN HIMALAYA

Rahul Singh*

ABSTRACT:

The glacier study is important in the sense that it has a very direct relation with climate change. Any change in the climate can be read through glacier response. A number of Himalayan glaciers are reported to be shrinking. The retreat of Chipa glacier and Jhulang glacier in Dhauliganga valley was studied by interpreting time series optical satellite images obtained from Landsat, ASTER and IRS LISS III sensors. The change of terminus position was measured and retreat was monitored with respect to the terminus position in a topographical map (1:50,000) of 1962. The satellite data of 1989 and from 2000 to 2004 and 2012 were used for monitoring the retreat of the glacier and the result was compared with the field measured values.

***Index Terms*—** Glacier, glacier retreat, Himalaya, chipa glacier,jhulang glacier, satellite images

* Reaserch Scholar Dept of CSE NIT Jalandhar 144011 india

1.INTRODUCTION

Glaciers in the Indian Himalaya provide an important environmental and economic service by releasing melt waterfor the Northern and North-Eastern part of the country during the dry season, May–September, when little to no rainfall occurs. The Himalayas have the largest concentration of glaciers outside the polar caps with glacier coverage of 33,000 sq. km; the region is aptly called the "Water Tower of Asia" as it provides around $8.6x10^6m^3$of water annually [1]. Melt water from these glaciers form an important source of run-off into the North Indian Rivers Glacial-retreat monitoring plays a vital role in glacio-hydrological and climate change studies [2], [3]. Glaciological studies in high altitude terrain and under extreme weather conditions as in higher Himalayas become difficult by conventional means. Satellite remote sensing has a great potential to monitor glaciers due to their synoptic view, repetitive coverage and up-to-datedness. Remote sensing appears to be the only means of monitoring the retreat if it is to be carried out for a large number of Himalayan glaciers, where field methods are difficult to implement due to rough weather and terrain conditions [4]. The verification of remote sensing studies with the field data is also very important. An attempt has been made to identify and monitor the chipa and jhulang glacier snout in the satellite imagery obtained from various sensors and measure the retreat of this glacier and also comparing the result with the field measured values.

Glaciers are one of the key indicators of climate change as they are very sensitive to climatic variations. A small change in climate may lead to a large change in both glacier volume and length. The time interval between the climate change and the observed change in the glacier depends on response time, different for each individual glacier; depending on size, slope and the orographic disposition. Dhauliganga basins are located in the Central Indian Himalaya, representing an extremely rugged terrain, with high peaks and steep hill slopes.Data of present snout positions of all the two glaciers were compared with the data of previous work and thus total retreat, rate of annual retreat and the area vacated were computed for all the glaciers. Chipa glacier shows an average retreat rate of 18.25 m/year during the period of 2000-2012,During the periods of 2000-2004 and 2004-2012 total glacial length retreat of Jhulang glacier was 23 m and 36 m with an average annual retreat rate of 5.75 m and 4.5 m respectively. During 2000-2004 period, Jhulang glacier has an advance in the middle portion, whereas the left and right lobes retreated.

In Uttarakhand climate depends on altitude and location. Climate ranges from subtropical in the southern foothills, average summer temperatures of about 30° C (about 86° F) and winter temperatures of about 18° C to warm temperate conditions in the middle valleys with summer temperatures usually hovering around 25° C and cooler winters. Cool temperate conditions dominate the higher areas, where the summer temperatures are usually around 15 to 18° C and winters temperature drops below the freezing point.

2. STUDY AREA:

The Chipa glaciers drain melt water into Dhauligangariver whereas Jhulang glacier drains into LassarYankti (a major tributary of Dhauliganga). Dar is the last village connected by fair weather road. A metalled road connects Nyusobla to Pithoragarh via Dharchula sub-division. Dhar connected with Jhulang glacier through a foot track (~ 65 odd kilometres). Chipa glaciers are in the right bank of the Dhauliganga basin on the trek to Jhulang near the village of Baling and Dantu village respectively.

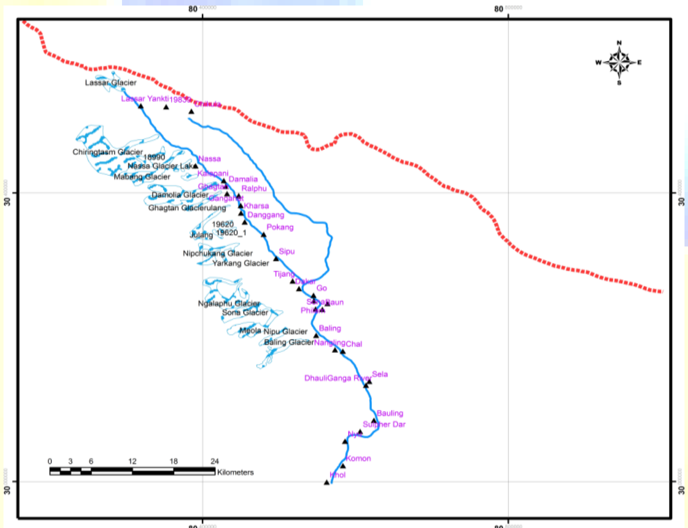


Fig-1 : Trek route in Dhauliganga valley

3. Previous Work:

Historical records of glacier front fluctuation in the Himalayas and Trans-Himalaya extended back to 150 years (Mayewski and Jaschke, 1979)[17]. The earliest studies concerned with the movement of glacier termini were made for Chong kumdan Glacier in A.D. 1812 (IzzetUllah, 1842)[12]. For glaciological work, Milam glacier was first visited in 1817 by Colonel Hodgson. The demarcation of the snow line in 1840 by W.T. Blanford marked the advent of glaciological studies in Himalayas in true sense. His publications include “Notes on Glaciers in Hindustan” and “Notes on age and ancient glaciers of the Himalayas” (Blanford, 1873,1891).[5]

After Colonel Hodgson(1822)[11], Milam glacier was subsequently visited by Weller[11] (1847), Cotter and Brown[7] (1907) and Heim and Gansser[10] (1939). Cotter and Brown[7] (1907) documented the snout front of the Milam Glacier for the first time in 1906. They also recorded the statements of old residents suggesting the recession of glacier since 1849. Thereafter, Mason[16] (1938), Jangpangi and Vohra[13](1959), Jangpangi[16] (1975) and Swaroop and Shukla (1999)[20] again surveyed the glaciers and recorded the recession of the snout front.

The glaciers of Dhauliganga and LissarYankti valley were studied by Capt. Grinlinton during September 1912. The glaciers examined by him were Baling (Chipa, S.O.I. Toposheet 1961), Sona (S.O.I. toposheet 1961), Cholungli, Nalphu, Nipchicang, Kharsa (Jhulang, S.O.I toposheet 1961), Chinchinmouri and Ralphu (Grinlinton, 1914). The snout of the Chipa glacier was not surveyed but the altitude of ice cave was fixed at 3249.168 (10660 feet amsl). Snout monitoring of the Chipa, Meola and Jhulang glaciers were again done by Shukla, et al. (2003).

4. DISTRIBUTION OF GLACIERS IN DHAULIGANGA BASIN

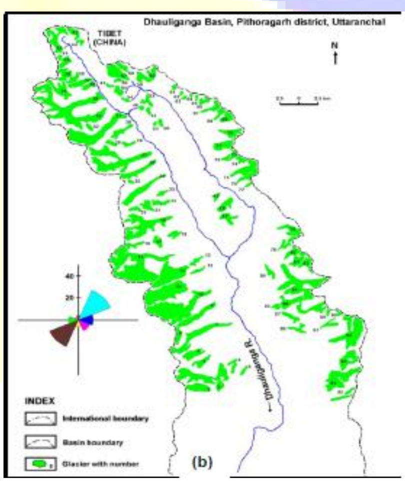


Fig.-2: Glacier Inventory map of Dhauliganga basin.

Dhauliganga Basin

A 'U' shaped valley also known as a glacial trough is formed by the process of erosion. It has a characteristic 'U' shape, with steep sides, and a flat bottom. The cross sections of the Goriganga and Dhauliganga valleys have been prepared at the same place after generating DEM using ASTER data of 30 m resolution (Fig.- 3 and 4). Their cross sections demonstrate the typical 'U' shaped valley profile all along the reaches of Chipaand Jhulang glacier valleys (Fig.- 3 and 4).Both the valleys show prominent "U"-shaped profile right from glacial snout up to the level of 2400 m asl suggesting that during glacial maxima the main valley trunk glaciers of Dhauliganga must have come down to a level of about 2400 m asl.

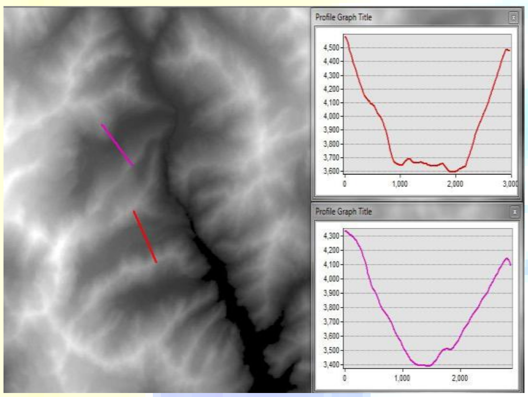


Fig.- 3: Cross sections of Dhauliganga valley.

Fig.- 4: Cross sections of Dhauliganga valley.

5. DOCUMENTATION OF RECESSION PATTERN OF GLACIERS Systematic documentation of the recessional /advancing pattern of glaciers is not only helpful in the climate variability studies but also in the computation of loss or gain in the form of ice and snow. The study of recessional patterns of Chipa and Jhulang glaciers from Dhauliganga valley.

Chipaglacier:

As per the glacier inventory 2010, about 10 km long Chipa glacier (Lat. 30° 10’ 55”; Long. 80° 29’ 45”) is an east facing glacier. It originates from 5800 m asl peak. Melt waters of the Chipa glacier join the Dhauligangariver at Balling at an elevation of 3527 m asl (fig-5). The average width of the valley is 0.65 km. Beside mapping of the snout, a detailed geo-morphological map was also prepared in the pro-glacier area. Two sediment samples were collected for OSL dating. Among the prominent geomorphic features mapped are: two parallel to sub-parallel right and left lateral moraines, which extend all along theChipa valley (Fig.-6 and 7). The snout front of the glacier is almost lying across the valley in which middle part of it showing two small protruded lobes, out of which right side lobe has an ice cave through which the melt water emerges. The snout data of 2012 was compared with the snout position of 2000 (Shukla, et al. 2003) and 2004 (SPOT and GeoEye images of Google Earth) and total glacial retreat and total area vacated was computed. The total snout retreat during 2000-2004 was 73 m with an average annual retreat of 18.25 m/y. The total area vacated was found to be 0.0126 km2 with an average area vacation of 0.00315 km2 /y. The total snout retreat during 2004-2012 was 146 m with an average annual retreat of 18.25 m/y; and total area vacated was of the order of 0.0336 sq km with an average vacation rate of 0.0042 sq km/ y. The data of retreat and area vacated by Chipa glacier since 1961 are given in Table-1.

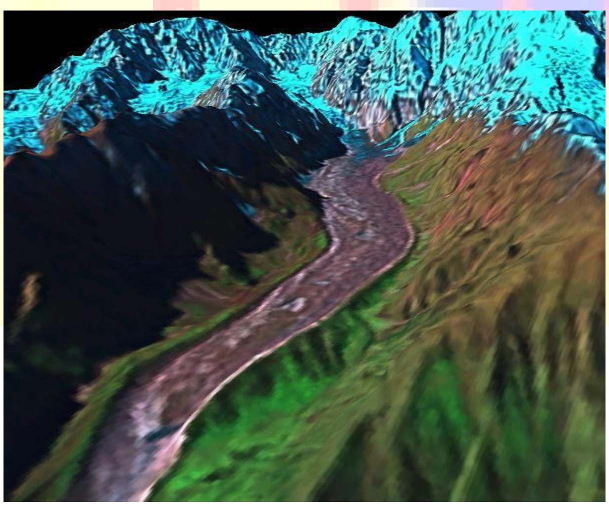


Fig: 5. Digital Elevation Model (DEM) of Chipa glacier.

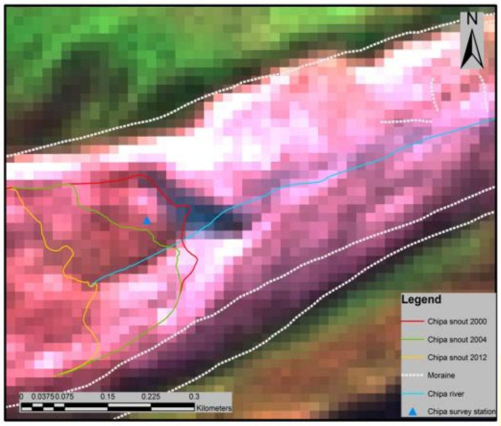


Fig.- 6: Time series snout map of Chipa glacier

Table-1: Comparison of retreat and area vacated by Chipa glacier

Chipa Glacier	Total retreat (m)	Annual retreat (m/y)	Total area vacant (km^2)	Annual area vacated (km^2/y)
1961-1978	550	32.35	0.085	0.005
1978-2000	500	22.72	0.080	0.0036
2000-2004	73	18.25	0.0126	0.00315
2004-2012	146	18.25	0.0336	0.0042

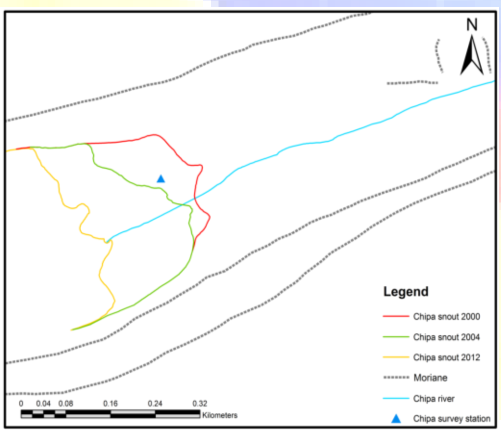


Fig.- 7: Time series snout map of Chipa glacier

Jhulang glacier

Jhulang glacier is a NE facing glacier and its melt water directly drains into LassarYankti river, the main tributary of Dhauligangariver. As per the inventory details of glaciers, it is 7 km long glacier (0.7 km) accumulation and 6.3 km ablation zone, with an average width of the valley 0.6

km (Fig.-8). The glacier was initially mapped by Grinlinton in 1912 as Kharsa glacier (Grinlinton, 1914). The S.O.I. toposheet number 62B, on quarter inch scale, has shown it as Kharsha, while as S.O.I. toposheet number 62B/7 on 1:50,000 scale has named it as Jhulang glacier. Snout and important geomorphological features were identified and mapped. Four sediment samples were collected for OSL dating. During the mapping four sets of both left and right lateral moraines were mapped. Three left and two right lateral moraines form an arcuate shape in lower parts which can be attributed to the merginging of lateral and recessional moraines (Fig.- 9 and 10).

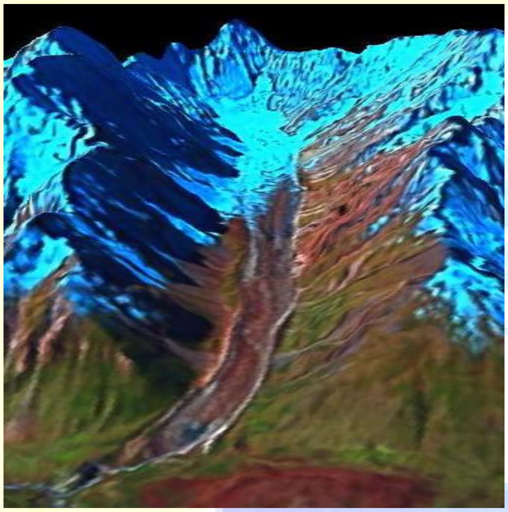


Fig.- 8: Digital Elevation Model (DEM) of Jhulang glacier.

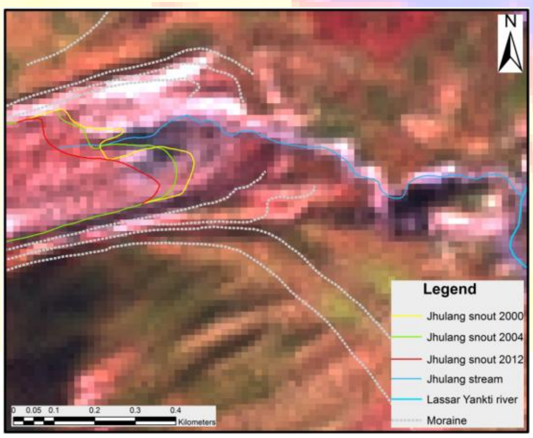


Fig.- 9: Snout map of Jhulang glacier

The left portion of the snout has a serac faces and two ice caves in lower part, through which melt water emerges. The entire ablation zone of Jhulang glacier is covered by a thick cover of supra-glacial debris. The lower part of the ablation zone is highly crevassed. Snout position of

Jhulang glacier in 2012 was compared with the snout position of 2000 (Shukla, et al. 2003) and 2004 Google Earth images, and secular movement both in terms of frontal retreat and area vacated by glacier (Fig.- 9 and 10) was computed. The glacier retreated 5.7 and 4.5 m/y during 2000-2004 and 2004-2012 periods respectively, whereas it vacated an area of 0.0025 and 0.0023 km2 /y (Table-3). During 2000-2004, the middle portion of snout advanced by 34 m with an average annual advance of 8.5 m/y. The data of advance and retreat of different lobes and area vacated by the glacier are given in Table-2. Fig.-11 depicts advance/retreat of different lobes of Jhulang glacier snout during period 2000-2004.

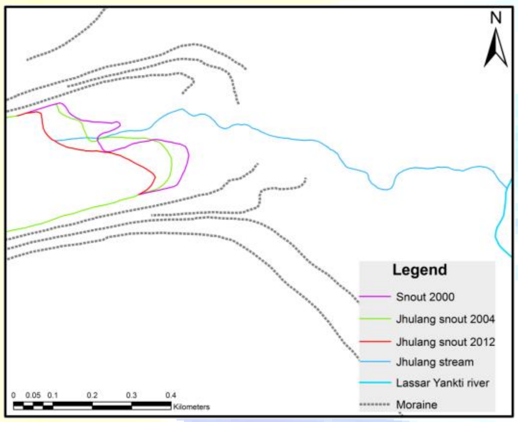


Fig.- 10: Snout map of Jhulang glacier

Table-2: Retreat/Advance of snout of Jhulang glacier during 2000-2004

Period (2000-2004)	Total retreat (m)	Annual retreat (m)	Total area vacated (km^2)	Annual area vacated (km^2/y)
Left lobe	-18	-4.5	-0.004275	-0.00107
Middle lobe	34	8.5	0.002426	0.0006
Right lobe	-40	-10	0.003261	-0.0008

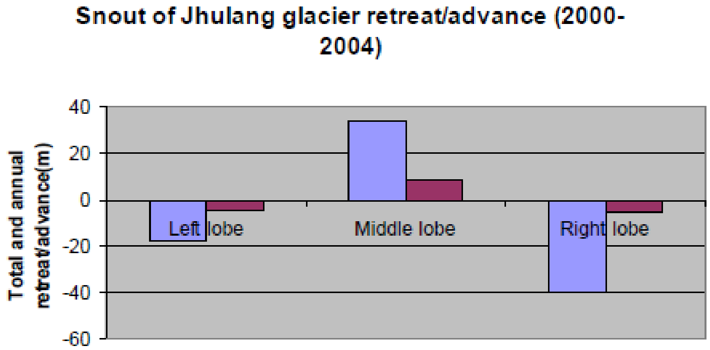


Fig.- 11: Advance/retreat of different snout lobes of Jhulang glacier.

Table-3: Retreat and area vacated by Jhulang glacier during different periods

Period	Total retreat (m)	Annual retreat (m/y)	Total area vacant (km^2)	Annual area vacated (km^2/y)
1962-2000	400	10.53	0.0700	0.00184
2000-2004	23	5.750	0.0100	0.00250
2004-20012	36	4.500	0.0187	0.00230
2000-2012	54	4.500	0.0287	0.00240

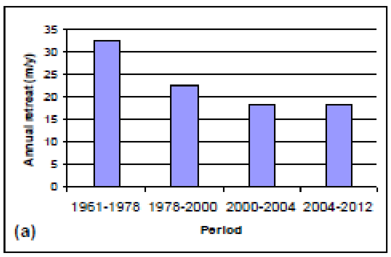
6. DISCUSSION AND CONCLUSION

Dhauliganga basin has 96 glaciers with a glacierised area of 217.35 km^2. Two glaciers *viz.* Chipa and Jhulang glaciers of Dhauliganga basin were selected for secular movement respectively. The Chipaand Jhulang glaciers of Dhauliganga basin are being observed in 1912, 2000, and during present survey in 2012.

In order to evaluate inter-annual recession pattern of glaciers and past glacio-geomorphological history of Ghaghra valley, the pre-field basemaps were prepared for an area of 1060 sq km on 1:50,000 scale, based on Survey of India toposheets, aerial photographs, Google and Satellite imageries (Landsat ETM+ pan-sharpened images of year 2004), ASTER elevation data (30 m R) of the study area (Fig.-5 and 8).

The selected glaciers were monitored by mapping the snout position on 1:5000 scale using Total Station. Besides monitoring the lower limit of glacial snout, detailed mapping was carried out in the pro-glacial area to map the important geomorphological features. Glacio-geomorphological mapping was also carried out on 1:25000 scale in selected areas to decipher signatures ofpalaeo-glaciation in the area.

Current snout position of Chipa glacier was compared with the snout position of year 2000 ((Shukla, et al. 2003)) and year 2004 (Google image). It shows a total retreat of 73m and 146 m with annual average retreat of 18.25 m/y during periods of 2000-2004 and 2004-2012 respectively. During these periods the total area vacated by the glacier was 0.0126 sq km and 0.0336 sq km with annual area vacation of 0.00315 km2/y, and 0.0042 km2/y (Fig.-12 a and b). The Fig.- 12a show the annual retreat during 1961-1978, 1978-2000, 2000-2004 and 2004-2012 period.



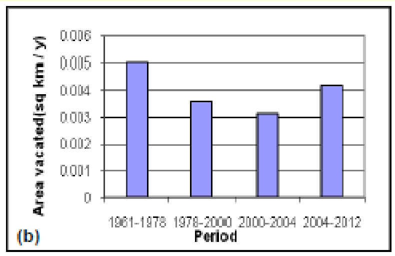
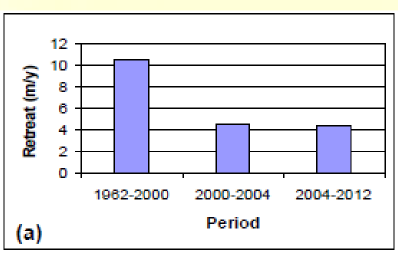


Fig.- 12: Annual retreat (a) and area vacated (b) by Chipa glacier during different periods

For secular movement study of Jhulang glacier, the older snout maps of 2000 (Shukla, et al. 2003) and 2004 GeoEye images of Google Earth were compared with the data collected in 2012. The data clearly indicate that during period of 2000-2004, the glacier advanced by 34m in the middle portion, whereas the left and right parts of the snout retreated by 18m and 40m respectively (Fig.-11). Data of snout retreat and area vacated by the glacier are shown in Fig.- 13 a and b.

During 1962-2000, 2000-2004 and 2004-2012 period snout front of Jhulang glacier retreated by 400 m, 23 m and 36 m respectively. During the same periods, the average annual retreat was 10.52 m/y, 5.6 m/y and 5.5 m/y, respectively. The total area vacated during the above mentioned periods was of the order of 0.07sq km, 0.01sq km and 0.019 sq km with an average annual area vacation of 0.0018 km2/y, 0.0025 km2 /y and 0.0023 km2/y respectively.



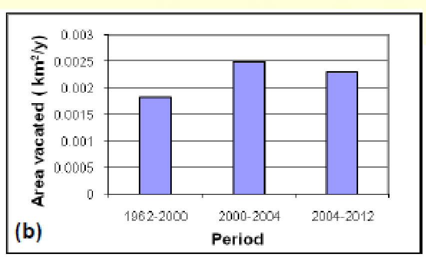


Fig.- 13: Annual retreat (a) and annual area vacated (b) by the Jhulang glacier.

Comparative study of the retreat rate of the all the glaciers studied during 2010-12 and 2012- 13 clearly indicate that the glaciers ofDhauligangaviz. Chipa (18.25 m/y) and Jhulang (4.5 m/y).

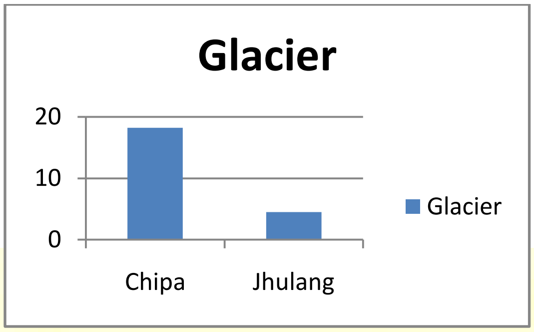


Fig.- 14: Comparative glacier retreat of glaciers of Dhauliganga basins

The retreat rate decreases when we move from south to north (longitudinally low gradient to high gradient). Thus the glaciers of low altitude melting faster than high altitude glaciers.The repeat observation of the two glaciers have revealed that excepting Chipa and Jhulang, glaciers having shown either same or lower rate of retreat during recent past (Fig.-15).

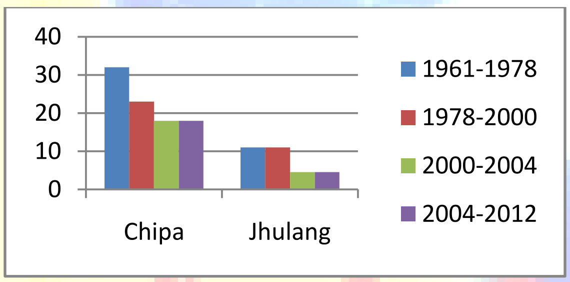


Fig.- 15: Annual retreat of Chipaand Jhulang glacier during different period

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