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Characteristics of Himalayan Glaciers

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Abstract :

The Himalayan glaciers nursed in the highest valleys of the world and southern most in the northern hemisphere are rather unique. Extreme environmental and meteorological regimes are encountered by these glaciers and so in a way may be different from the glaciers in other regions of the world. The current remote sensing satellite systems present excellent data from which the required glacier parameters for its various features can be derived. Some recent results are presented and discussed in terms of the uniqueness of Himalayan glaciers.

Introduction :

The presence of glaciers in Himalaya was detected by various explorers and surveyers more than a century ago. This was rather a surprise for them because according to the Alpine glaciologist of that time in Europe, the existance of glaciers in the tropical region mountains of Himalaya could be ruled out. The major interest of study at that time was the movement of glaciers because this could explain the presence of boulders on certain locations that did not fit in the geology of the surrounding rocks.The glaciers were found to move, of course very slowly (few inches a day) and carry along with them boulders and debris.

In the Himalaya it was found that at the head of streams originating from high valleys, glaciers were existing feeding them and bringing along with them boulders and debris breaking from the mountains due to weathering. One of the earliest observation of the glacier movement was reported about a century ago on Pindari glacier in Garwal Himalaya and it was detected to be 9.4 inches per day on clear ice and 4.8 inches per day on side morrains (Atkinson, 1882).

The height and inaccessibiligy of the Himalayan glaciers has always been an impediment for any large scale and intensive study. This seems to have vanished in the face of remote sensing satellites circling the earth in polar orbits and sending multispectral data of terrestrial features including glaciers. At present there are three remote sensing satellites that can be used for glacier studies. These include IRS, Thematic Mapper and SPOT. Their data is in multispectral bands in the visible and Infrared region of the electromagnetic spectrum including Thermal band in T.M. So now we are in a position to map the various glacier features and derive the required parameters. It is to this that we owe all of our future work in Himalayan glaciers.

Albedo and Spectral Reflectance :

The spectral reflectance properties of various glacier features are the key to their identification from multispectral satellite data. The Himalayan glaciers being very dirty accumulate lot of debris on the ablation zone resulting in low albedo from these features. This can be as low as 10-20% in some cases. The winter snow which can have an albedo of about 90% gets reduced to 60% when it gets dirty. This gets reduced further in the main body of the glacier due to compactation of snow into ice bringing the debris particles closer. This reduced albedo is an advantage because it does not amount to saturation of the satellite sensor system and so the identification of the glacier features can easily be carried out.

In the event of reduced albedo the glacier tends to absorb more solar radiation resulting in increased rate of melting. The debris makes a difference of about 40% in albedo value, so the Himalayan glaciers which in general are dirty and move more debris compared to other glaciers in higher latitude, will melt faster. There will also be difference in the solar radiation received by the south facing glacier to the north facing glacier and so the melt rate will also be different.

No dry snow :

In the higher reaches of Himalayan glaciers there seems to be no dry snow. In general one always finds wet snow. The liquid water content also seems to be quite high. So the sequence of the various metamorphic processes that are happening on and in the glacier from snow to ice could be at variance with the hypothetical one. Very large crystal structures are sometime seen near the equilibrium line and seems as if certain level of crystal growth is taking place. In certain parts of the glacier very hard rocklike black snow is present. It would seem that both in time scale and sequence the metamorphic processes in operation in Himalayan glaciers from fresh snow in accumulation zone to the ice in the ablation zone are at variance with the ones happening in the glaciers in higher latitudes. An intensive field work is necessary to understand these processes.

Rain on the Glacier :

During the winter months the Western Disturbances inject precipitation into the Himalayan system which results in snowfall in the higher reaches. It has a frequency of 4-5 activities per month. In case it is highly active can result in rain in the northern plains. The monsoon is active in the summer months and provides the major part of the precipitation of the year's total. It is interesting to note that the precipitation occuring in the Himalaya during the snow accumulation period as part of the total yearly precipitation goes on progressively decreasing from Western part to the eastern part. It is 22% in Kashmir, 11% in Himachal, 6% in Garwal, 4% in Nepal and 2% Assam (Gulati, 1972). It would seem that with so little snow perciptitation in Nepal and Assam, the glacier and snow melt contribution would be insignificant to the rivers orignating from these watersheds. But it must be realized that their contribution to the run off is very significant in the lean period when the monsoon precipitation is absent.

The rainfall during the monsoon period is generally in foothills and lower reaches of Himalaya. But sometimes a very strong monsoon depression crosses Himalaya and gives rain and snow on the glacier. Such an event happened during 2-5 July, 1959 to a German expediation to Batura glacier in Karakoram. This brought disaster and loss of life to the expedition and flood and havoc in the downstream valley (Finsterwalder, 1960). The occurence of such events are not so infrequent but in general these go unreported because these might have remained unobserved. In another unreported incident in July 1988 rainfall in the upper catchment area of permanant snow near Beas Kund brought unprecedented flood in Beas river near Manali.

ELA and AAR :

These are the most important parameters of any glacier and indicative of its basic characterisitcs. Equilibrium Line Altitude (ELA) is indicative of separation of ablation area from the accumulation area of a glacier. Compared to the glaciers in higher latitudes, ELA of Himalayan glaciers is at much greater heights. As the melting rates are higher, these glaciers have to maintain larger accumulation areas, and so the Accumulation Area Ration (AAR), which is the ratio of the accumulation area to the total area of the glacier, will be higher. ELA is also indirectly related to the mass balance of a glacier (Braithwaite, 1984). Its monitoring indicates the behaviour of mass balance. In spiti - Parbati glacial complex in H.P. spread over an area of 3500 square kilmeter, 23 glacier are indentified from Thematic Mapper Imagery of the area for the pass on 9 September, 1984, and the various parameters of the glaciers determined (Dhanju, 1990). The values of ELA and AAR are given in the table below.

Table showing AAR and ELA of Spiti Parvati glaciers

Sr. No.	AAR	ELA	Sr. No.	AAR	ELA
1	.91	4426	13	.91	4180
2	.80	5050	14	.78	5120
3	.98	4380	15	.88	5220
4	.78	4920	16	.23	4960
5	.77	4900	17	.68	4960
6	.85	4820	18	.58	4410
7	.81	4440	19	.67	4820
8	.79	4920	20	.54	4920
9	.78	5310	21	.78	4760
10	.75	5100	22	.70	4950
11	.83	4970	23	.80	4720
12	.95	4690			

The 23 valley glaciers occupy a total area of 693 sq. Km alongwith there are also 162 Hanging glaciers occupying an area of 186.5 sq. km. So the total glaciated area in the Spiti-Parbati glacial complex is 879.5 sq. km which forms 25% of the total area of 3500 sq. km.

The AAR is also related to the Mass balance of the glacier. In general it has been found that AAR of less than 0.5 would mean negative mass balance, 0.5 to 0.8 indicates a steady state and greater than 0.8 shows a strongly positive mass balance of the glacier. If we apply the above criteria to the 23 glaciers for which the values of AAR and ELA are given in the table, then we find that only one glacier has AAR less then 0.5, fourteen glaciers have the value of AAR from 0.5 to 0.8 and eight are having values higher than 0.8 of AAr. The lone glacier indicated above has an area of 2.75 sq. km which means very small accumalation area and large ablations area full of boulders and rocks. This has all the indication of a rock glacier. Fourteen glaciers as indicated by the AAR values are in a steady state and eight in positive mass balance condition. So non of the glaciers are expected to be retreating, in fact some of them may be advancing.

If we compare the values of ELA with the corresponding values of AAR, we find that there is a general tendency that with the increase in the ELA, the value of AAR decreases. This means that as the general elevation of the valley glacier increases ie the glacier is located in a higher valley, there is an increase in the ablation area of the glacier, this may result in loss of melting because the ice will stay for a longer period in the ablation area. So glaciers in very high valleys will tend to conserve themselves having long residence time.

Glacier Meltwater :

The winter snow accumulation peaks in March and the snowline comes down to an altitude of about 2100 meter. The melting of the seasonal snow starts from April onward and the snowline recedes to an altitude of 5400 meter by September. The area of Himalaya above this line remains under glacier and permanant snow cover. For the Himalayan area of 4.6 million square kilometer calculated from baseline of 1500 meter and lying east of 70^{o} E longitude and south of 40^{o} N latitude, the area under glacier and permanant snow cover forms 12% of this area (Dhanju, 1983).

During the period from September till about November, the contribution from glacier melt to river runoff is quite significant, so the stream flow is composed of glacier melt from high reaches, reasonal snowmelt from the middle catchments and rainfall from foothills. The assessment of each of the component requires an appropriate model for each incorporating pertinent parameters. During the lean period seasonal snowmelt which is dominant in the earlier part of the melt season diminishes and glacier melt becomes an important component of the inflow to the reservoir system.

The input energy for glacier melt comes from solar radiation. Since the process of glacier melt is quite complex, merely assessment of solar radiation budget and the glacier area may not be sufficient, the thermal properties of the various features of the glacier must also be considered. Another important factor that may also be relevent for glacier melt is the subterrain thermal energy that may be present in Himalaya due to high seismic activity. The presence of hot water springs in many areas is indicateive of the presence of the subterrain thermal energy. How far it may be responsible for supply of this thermal energy for glacier melt, it may be difficult to calculate but some method can be found for its estimation. It is quite possible that the Thematic Mapper satellite data in the thermal spectral band can be used for this purpose. This can give us the thermal properties of the glacier features as well as of the surrounding area.

Remarks.

It is evident that a major thrust area can be evolved in glaciology by using remote sensing data and techniques so the level of information presently available for Himalayan glaciers can be greatly enhanced. The methods of analysis that have ben evolved so far are suffieient to make the analytical techniques to the applied on operational scale. Photo-interpretation methods for remote sensing imagery and computer classification techniques on digital data can be used for extracting the required glacial parameters. In field studies the determination of liquid water content of wet snow and insight into the metamorphic processes happening on the glaciers are to be emphasised.

No worthwhile glaciermelt model exists for Himalayan glaciers. It is important to develop one based on the environmental and meterological parameters of each of the catchment. The modelity of approach can be worked out by developing an integrated model for snow and glaciermelt. Meterological, terrain and environmental models can be integrated to formulate a sort of continuous model that can take care of glacial and snowmelt on a catchment or a regional scale. It can be quite a challenging task.

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