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# The Role of Avalanches in Mass Budget of Glaciers

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## Abstract

Avalanches are important factors in the nourishment of many glaciers (for example the avalanche glaciers or the Turkestan glaciers). The contribution of avalanches to the nourishment of different glaciers varies from 10 to 60% of the total snowfall accumulation. Many glaciers with avalanche nourishment are situated in the Tien Shan, the Himalayas and other mountain regions.

Avalanche ablation of glaciers occurs when slush snow avalanches along the glacier lobe or when ice breaks from the glacier body.

The avalanche in the mountain plays a considerable role in the appearance of mountain landscape. For example we have information on 17 500 avalanches being observed in Alps every year (Iveronova, 1962). Avalanches in the USSR are known in all of the mountain regions from north to south and from west to east (Lossev, 1961, 1966). In other words, every year, enormous masses of snow are avalanched from mountain slopes to valley bottoms. While part of the avalanched snow is accumulated on the glacier surfaces, not all glaciers have avalanche nourishment. Naturally such nourishment is common only in glaciers surrounded by avalanche slopes. For example, we have corrie glaciers, valley glaciers and special types of glaciers which are mainly nourished by avalanches such as the Turkestan and other avalanche glaciers.

No information has been available on the measurements of avalanche nourishment *in situ.* Thus avalanche nourishment must be calculated on the basis of rate of snow avalached into valley bottoms from slopes. For some mountain regions the avalanche snow rate was determined (Table 1).

The area of the glacier basin is larger than the glacier surface area and therefore

**Table 1.** The avalanche snow rate

| Region | Percentage of avalanche snow cover on slopes | Authors | Period of observation |
|---|---|---|---|
| Tchon Kizilsu River, Tersky Alatau range, Tien Shan | 0.3～30 average 10 | Iveronova, 1962 | 1956–1959 |
| Gorelik River basin, Zailiysky Alatau, Tien Shan | 10 | Sosedov and Seversky, 1963 | 1960–1961 |
| Naugarzan River basin, Kuraminsky range, Tien Shan | 10 | Lossev, 1960 | 1955–1956 |
| Khibiny | 1 | Anisimov, 1958 | 1933–1940 |
| Alps | 10～25 | Allix | 1933–1940 |

**Table 2.** Additional snow nourishment of glaciers

| The percentage of avalanching snow to maximum snow cover | The percentage of snow avalanche nourishment to maximum snowfall accumulation | |
|---|---|---|
| | on the valley glaciers | on the small glaciers |
| 0.3 | 0.3～ 0.6 | 0.5～ 2.0 |
| 1 | 1 ～ 2 | 1.5～ 6.5 |
| 10 | 10 ～20 | 15 ～ 65 |
| 25 | 25 ～50 | 38 ～165 |
| 30 | 30 ～60 | 50 ～200 |

additional avalanching snow accumulation may be very large. For valley and small glaciers of the Caucasus the ratio of the glacier surface to glacier basin area was calculated. This ratio varied from 0.50 to 0.95 for valley glaciers and from 0.15 to 0.65 for small glaciers (Tsomaya, 1963).

The maximum snow cover depth on the slopes over the glaciers roughly equals the maximum snow cover depth on the glacier surface. The ratio under the above mentioned assumption provides the calculation of additional snow avalanche nourishment for valley and small mountain glaciers (Table 2).

The data on the size of snow avalanche cones may provide additional information concerning avalanche nourishment. The thickness of the avalanche cone sometimes reaches several ten meters. During the exceptionally snowy winter of 1910/11 in the gorge of Belaya River (West Caucasus) an avalanche snow cone of a 100 m depth was observed. It takes the several years until snow cone melted away. In the summer of 1937 in the Kitayskaya River mouth (West Caucasus) an avalanche snow cone of an 80 m depth was observed. The measured thicknesses of snow in 15 avalanche cones in the Ochapari Valley (West Caucasus) varied from 11 to 55 m (Tushinski, 1959).

In the Tien Shan avalanche snow cones thickness of 40～50 m are known. In the high mountain fringes of the West Tien Shan, avalanche cones with snow thickness of 10～20 m were often observed.

The surface area of a 20 m depth avalanche snow cone is approximately $10^2$ or $10^3$ $m^2$ and their volume comes to about $10^3$ or $10^6$ $m^3$. Often the whole valley bottom is covered by joint avalanche snow cones.

Avalanching of snow from slopes varies from place to place. Calculations of snow avalanching rate from slopes in the Khibiny Mountains showed that during the winter of 1935/36 from the slopes of the Ukspor Plateau in the region of Kukisvumchorr Settlement, 20% of the maximum slope snow accumulation was avalanched, and from the plateau slope in the region of Bolshoy Vudjvr Lake, 4% of the maximum snow cover was avalanched (Molochnikov, Puzanov, 1938).

Avalanching of snow from slopes greatly varies from year to year. Iveronova's observations (1962) at the Tohon Kizilsu River source (the East Tien Shan) showed that from the slopes of similar exposition, avalanching varies from 0.3 to 30%.

Significant avalanching of snow is not necessarily connected with a large snow accumulation on the slopes. In the case of small snow accumulation, numerous avalanches may result from intense thaws or heavy snowfalls. For example the big avalanche snowfield at the source area of Chimganka River in 1961/62 was larger than that in 1960/61, though in the winter of 1960/61 the snow accumulation exceeded that in 1961/62. In the winter of 1961/62 the great size of the big avalanche snowfield could be explained by the thaw avalanches and vernal avalanches (Shulc, 1963).

The relationship between the snow avalanches and snowfall is complex. Generally speaking variations of avalanche nourished glaciers do not represent the changes of the snowfall, but represent the changes of the avalanche regime.

There are many articles dealing with the qualitative characteristics of the role of avalanche nourishment in glaciers of different mountain regions. It has been reported that many avalanche nourished glaciers are located at the Karakorum and the Himalayas (Wiche, 1960; Kick, 1962). Gigantic dendritic glaciers were observed in these mountain regions, for example, the Chogo Lungma glacier (the length of the main ice stream is 45.4 km, and the nourishment source is mainly snow and ice avalanches), together with the Mane glaciers lacking in firn basins and which are mainly fed by snow avalanches (Kick, 1962). The glaciers of Turkestan type are well known in the mountains of the Central Asia. In addition Kisin and others (1961) wrote about avalanche nourished glaciers in the East Caucasus. There are also information on avalanche nourished glaciers in the Codar range, Kamchatka and the Urals.

That avalanches contribute to glacier nourishment has been described. Another effect of avalanches on glaciers is the avalanche ablation known as a kind of the mechanical ablation. This form of ablation was described by Yablokov (1963). He observed slush avalanches on the steep glacier lobe in the Sandalash River basin (the Tien Shan). The wet or slush avalanche slid from the surface of the Sandalash Glacier. This avalanche was 5～10 m wide, 30 m long and 20～25 cm thick.

Such avalanches were also observed by L. S. Govorukha (personal communication) on the ice cap of Franz Joseph Land. Nobles (1967) wrote that in the Arctic regions (Baffin Island, Greenland, Axel Heiberg Island) which are characterized by low and moderate slopes, slush avalanches are more common than dry snow avalanches. Observations on the development of slush avalanches suggest the possible mechanisms for the development of these avalanches. The following condtions for release of slush avalanches on low and moderate glaciers slopes are suggested: 1) unpercolating underlying surface, namely ice at temperatures below the freezing level; 2) moderate snow cover and 3) intense snow melting. These conditions may be observed on glaciers with infiltration-congelation or congelation zones of ice formation. Nobles (1965) wrote that the slush avalanches in northwest Greenland may be a much more common and widespread phenomenon than has been recognized hitherto. In this region the slush avalanches are kilometer or more in length, up to several hundred meters wide and may move on slopes as low as 2°.

The exsistense of gigantic ice avalanches on glaciers are also known. A great ice avalanche occurred in Santa Valley, Peru, on January 10th 1962. This avalanche was caused by the breaking off of the west front of the hanging glacier on the summit of Huascaran. The estimated amount of avalanched ice was 2.5 to $3\times10^6$ m$^3$. Gigantic ice avalanches of this type occurred in the Alps on the Allalin Glaciers on August 30th 1965. The estimated avalanched glacier ice was $10^6$ m$^3$. This type of mechanical ablation is a rare phenomenon but its effect on glaciers may be very large.

## Conclusions

1) Avalanches together with snow drifts constitute an additional source of nourishment for mountain glaciers.

2) Additional avalanche nourishment of glaciers may vary from 1~2 to 200% to maximum snowfall accumulation and it depends on the rate of snow avalanching upon the glacier surface and the ratio of glacier basin area to the glacier surface area.

3) The avalanche nourishment of glaciers is a widespread phenomenon in many mountain regions especially in Central Asia.

4) Avalanche ablation of glaciers in the form of slush and ice avalanches is known as a kind of mechanical ablation.

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