DISTRIBUTION OF SNOW COVER IN THE MOUNTAINS OF CENTRAL ASIA

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INTRODUCTION

The assessment of snow cover on mountain terrain has received little attention, mainly because of the acute shortage of information on the kind and distribution of snow cover in mountains. From the present conventional surveys, it is impossible to determine the snow conditions on most of the mountain terrain by earlier methods. The author has developed a method that remedies the situation and allows one to evaluate the snow conditions in mountain territory, including for regions that have not been studied. The method is based on known regional relationships of snow conditions (periods of formation and decay, thickness and wetness of snow cover), with due regard to the influence of zonal, regional, and local factors. Important components of the calculation model are the information on the inferred firn line (the climatic snow limit on a glacier), and annual accumulation of solid precipitation and maximum snow storage at this level as calculated from the method presented in this paper.

Based on the method developed by the author, functional relationships have been obtained of the distribution of snow characteristics on the mountains of Central Asia. On the basis of these investigations have been undertaken on the influence of the absolute height, exposure, kind of sloping surfaces, and orientation of basins with regard to the prevailing direction of atmospheric moisture transport and orography on the distribution of snow cover in mountains.

BASIC DATA

Methodical evaluations have been based mainly on the data of the standard snow surveys in the Pamir, Tian Shan, Gissaro-Alai, Altai, Caucasus, Djungarskiy Alatau, and Alps. The information mainly used was contained in a catalogue of glaciers and scientific publications in hydroclimatology and glaciology for the Hindukush-Karakoram, Tibet plateau, and Kuen-Lun.

The method of assessing of the influence of local factors on the distribution of snow cover is based on the data of many year-round measurements at a special snow-measuring network (northern Tian Shan), including 35-60 (depending on the year), snow measuring platforms, which differed in absolute height, exposure, and kind of sloping surface.

The method of calculating the elevation of the climatic snow line is based on the empirical dependence of the mean elevation of the firm line on the glacier area. In the mountain regions of the world (Eurasia, North America) this dependence has an asymptotic character, and similar parameters that have made it possible to generalise the results of the definitions into a unified universal relationship (Fig. 1). It has been found that the glacial range in mountains decreases sharply as the glacier area increases to a certain limit and does not depend on morphological type of glacier and increasing area (Fig. 1). The paper presents empirical models for calculating the lower limit of a firn line.

Calculation of the height distribution of snow characteristics is based on typification presented by the author; for the conditions in the Pamir, Tian Shan, Djungarskiy Alatau, and Altai, eight types of vertical distribution of snow storage and three types of stable snow cover periods were found (Seversky and Blagoveshensky 1983, Seversky and Pimakina 1980).

RESULTS

The analysis results of all accessible information about the snow cover in various regions of Eurasia, from the Alps in the West to the Altai-Sayon mountain system in the East, and from Kibin in the Scandinavian mountains in the north to the Pamir and Karakorum in the south, provide the opportunity to confirm that the snow-cover distribution in mountains of the interior continental regions depends on the following important relationships.

Similar conditions of relief and the position of the region, with respect to the periphery of mountainous countries, correspond to uniform character (type) in the spatial distribution of snow conditions. These show a close relation to absolute height and geographical location of a certain point. It should be noted that the distribution of snow cover periods is more stable than the height distribution of snow storage.

Hence, the period of stable snow cover in the mountains of Central Asia are grouped into three types of vertical distribution. The first type, with the strongest vertical gradients of the considered conditions, is typical for orographically-open basins on the western periphery of mountainous countries. The second is for peripheral basins unfavourably-oriented with respect to the prevailing directions of moisture-bearing airstreams. The third, with the smallest vertical gradients, is for orographically-closed interior continental regions.

All three types are the same according to the character of the vertical distribution of the period of formation of stable snow cover. The greatest differences are found in the periods of decay of snow cover. The formation of snow cover is influenced by both the precipitation regime and temperature conditions which vary more or less smoothly over the territory. However, differences in periods of decay of snow cover depend mainly on the values of total snow storage.

The vertical distribution of maximum snow storage varies considerably: for the same territory, eight types of snow storage distribution with absolute elevation have been found.

1. The first type of this distribution, other factors being equal, is determined by the orientation of the macroslopes of mountain ridges towards prevailing directions of the moisture-bearing air streams (Fig. 3).

2. The vertical gradient of snow storage in the major snow basins decreases from west to east, the largest values of the gradients characterise the west slope of the Scandinavian mountains. These values are reduced by one half in the West Caucasus and even more at the western periphery of the Tian Shan and Altai. Within separate regions, changes of snow storage in the direction from west to east are not substantial in comparison to the change in function of absolute elevation in geographic latitude.

3. The influence of the effects of mountain massifs and orographic barriers is clearly indicated in the snow cover distribution in mountains. The first is apparent in a monotonic decrease of snow storage from the periphery to the interior of the mountainous country. The second is indicated in the sharp contrasts of the snow conditions on the windward and leeward slopes of

ranges, which present obstacles to the moisture barrier air streams. A clear example of the second effect is the distribution of snow storage on the slopes of the Katun Range in the Altai (Fig 4). In the Uba river basin, approaching the Katun range, snow storage increases drastically to a maximum at the ridge zone with a drastic decrease beyond the ridge; at a distance of 40-50km values decrease to those typical for the vast interior mountain region of the Altai.

4. The maximum snow storage continuously increases to the climatic snow line elevation in the mountains of the interior continental regions of Eurasia. From available information one can confirm that, above the snow line, the snow storage increases with elevation, at least to elevation contours to 200-400m below the ridges surrounding the mountain glacier basin (excluding separate peaks); above this level and approaching the catchment divides, the snow storage decreases in accordance with the redistribution of snow due to wind and avalanche action.

5. In most mountain regions, substantial redistribution by wind is found only above the upper forest limits; it is especially great in the ridge regions of the glacier-neve zone. Relatively large snow storage at the upper forest limit is a result of the redistribution of snow by wind. A second maximum of snow storage is found in many basins in the lower third part of the slopes of closed river valleys and at a distance of 200-400m below the ridges.

Characteristics due to local factors are superimposed on the general spatial pattern of snow conditions in mountains. Regarding the level factors, orientation of slope, character of vegetation, and wind conditions influence the distribution of snow cover. In some cases, the horizontal contrasts are larger than the vertical contrasts because of the importance of these factors. So, according to the influence on periods of snow cover in the Zailiskiy Alatau, a change of orientation from north to southwest corresponds to a change in absolute elevation by more than 1000m (Seversky and Seversky 1990, Seversky 1989 and Sosedov 1967). With the vertical gradients of maximum snow storage characteristic of the Zailiskiy Alatau, a change of orientation from north to east (west) corresponds to a decrease of absolute elevation by almost 1,000m. However, a decrease of snow storage from meadow slopes to coniferous forest is double the change corresponding to a decrease in absolute elevation from 2,500 to 1,500m.

The influence of slope orientation and vegetation character in the temperate snow region is greater than the influence of absolute elevation. In snowier regions, contrasts in exposure diminish. In the snowiest regions at the western periphery of mountainous country these differences are small and determined by differences of exposure and losses by snow evaporation.

The characteristics of the distribution of snow cover in the mountains considered here are found in all interior continental regions of Eurasia. A comparative appraisal leads to the conclusion that the horizontal distribution of snow conditions, due to macroorientation of slopes, location of the regions with respect to the periphery of mountainous countries, and the influence of local factors, are greater than interregional and vertical differences.

REFERENCES

Seversky, I. V., and Blagoveshensky, V.P, 1983. 'Appraisal Of Mountain Territory Avalanche Danger', In *Almaty Science KazSSR*, 217.

Seversky, I.V. and Pimankina, N.V., 1980. 'Experience in Calculating Periods of Stable Snow In Mountains Of Middle Asia And Kazakhstan By Standard Meteorological Information'. In *Materials of Glacier Research Chronicle Discussion*. Issue 37 (pp71-79).

Seversky, I.V., and Seversky E.V., 1990. *Snow Cover and Seasonal Freezing of The North Tian Shan Soil*. Yakutsk, 180.

Seversky, S.I., 1989 'Influence Of Slopes Exposure Upon Snow Distribution In Mountains'. In *Geocryological Researching in Mountains of USSR, Yakutsk* (pp152-162).

Sosedov, I.S., 1967. *Researching Balance of Snow Moisture on Mountain Slopes*. Almaty. 197.

Figure 1. The dependence of firn line altitude on the area of glacier 1 - The Altai, Sayani; 2 - The Djungarskiy- Alatau; 3 - the Tion Shan; 4 - the Pamir - Alai; 5 - the Bolshoi Caucasus; 6 - the Alps; 7 - full field of points; 8 - zone where the glacier area is shown outside the scale (F 20km^2)

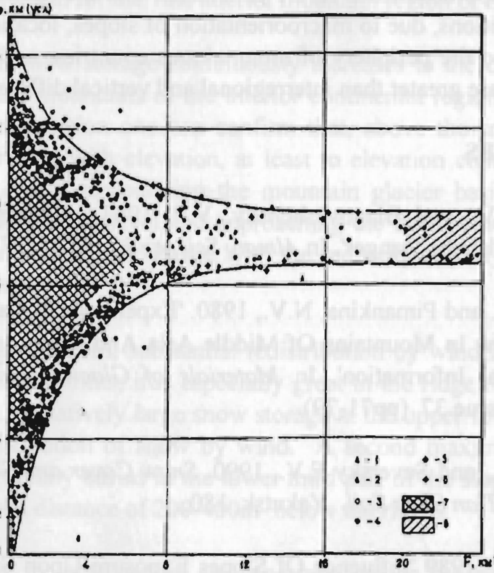

Figure 2. The altitude relations of the firn referred and upper forest limits and subalpic brushes. Mountain regions: 1 - the Altai, Sayani; 2 - the Djungarskiy Alatau; 3- Tien Shan; 4 - the Pamir, Gissaro-Alai; 5 - the Caucasus; 6 - the Urals; 7 - Kamchatka; 8 - Himalayas, the Karakorum, Tibet, Alashan

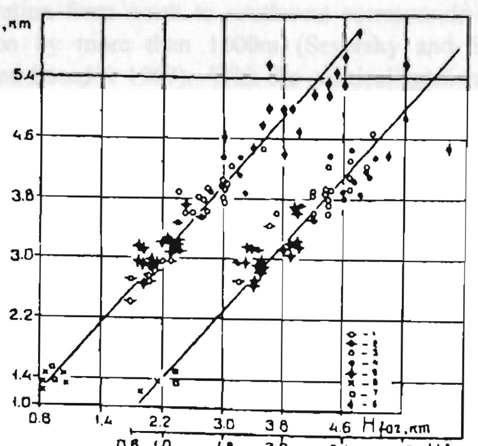

Figure 3. The standard dependences of the water maximum stock norms in snow cover W or the absolute H and the orientation in peripheral regions of the Tian Shan, the Pamir, and the Gissao Alai. Figures at the regress line mean an azimuth of the main river valleys dip

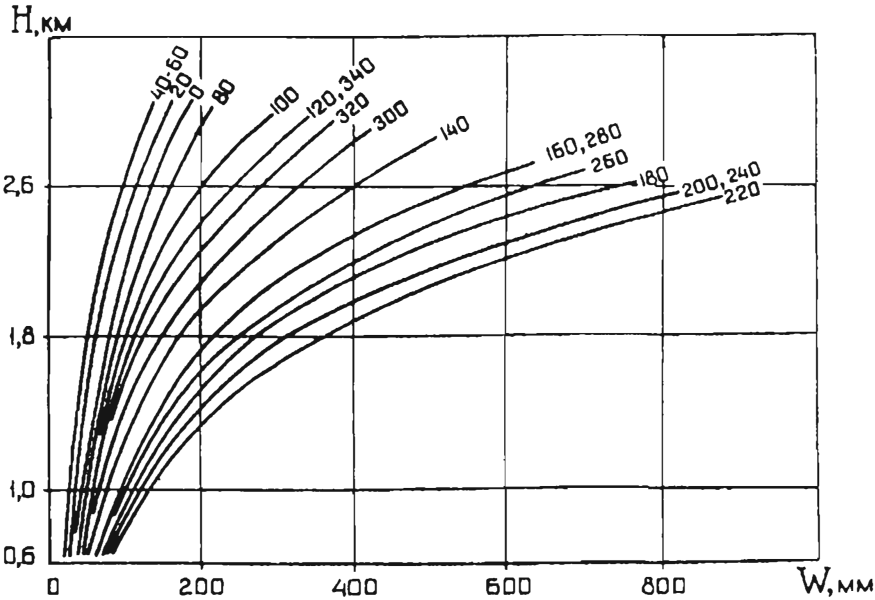

Figure 4. Distribution of average maximum snow stocks (put at a 2,000m height) on the Altai depending on a distance of orographic barrier (the Koksui ridge). 1 - by data of routine snow survey, 2 - by data of total precipitation measurements