THE USE OF SNOW LINE DATA FOR THE ASSESSMENT OF WATER RESOURCES IN THE HIMALAYAN-HINDU KUSH REGION: RESULTS AND PROBLEMS

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The assessment of precipitation, snow accumulation, and runoff in the alpine zone is very difficult because of many reasons. The altitudinal dependencies are not justified physically and hide the differences in water resources between the valleys which are orographically differently protected from atmospheric moisture fluxes. Using some ideas of H. Ahlmann (1924), we (Krenke 1973,1982) have developed an alternative method based on the equality of ablation and accumulation at the snow line according to its definition. Accumulation depends on solid precipitation, and ablation on summer air temperature. The interpolation, and even extrapolation, of summer air temperature could be done with better accuracy than that of precipitation. Still, to implement this idea the number of problems has to be settled.

The Determination of the Equilibrium Line Height

To know the yearly amount of ablation or accumulation, we have to use the highest position of the snow line. On a glacier, it is close to the equilibrium line where ablation and accumulation are exactly equal to each other. The discrepancy is explained by the superimposed ice in the accumulation area or by the firn transported down to the ablation area due to glacier movement. Still, for a few years these discrepancies between two values are small compared to the other errors involved in the method. That is why we will use the term "equilibrium line" as a synonym for the highest position of the snow line on the glacier.

According to our previous analysis, the equilibrium line height could be estimated with sufficient accuracy as the average between the highest and the lowest points of the glacier. We have used the catalogues, maps, and satellite images at our disposal. The local variability of the snow line height in the Central Asia is characterised by the standard deviation equal to 250 metres. It depends on the glaciers' morphology, exposition, and size. To avoid its influence, we have grouped the glaciers in groups of 10 to 15, thus lowering the role of the local variability to about 60 to 70 metres, which corresponds to about 0.3-0.5°C of summer air temperature. The special correction is used for cases of unusual glacier distribution in the groups by types or expositions.

Extrapolation of the Summer Air Temperature up to theEquilibrium Line Height

The vertical summer temperature gradient in the area was investigated by Lebedeva(1993). It changes from 0.55°C per 100 metres in the wet areas to 0.72°C in the dry areas. These gradients could be used in four different ways.

a. The "Points to Points" method: the altitudinal difference between the meteorological station and the average height of the equilibrium line for the glacier group is multiplied by the vertical gradient.
b. The "Points to Field" method: the isolines of equal heights of equilibrium lines are plotted, and the temperature is estimated above each meteorological station, thus making it possible to take into account the horizontal temperature differencies.
c. The "Field to Points" method: isolines of equal temperature adjusted to the fixed height of 4,000m are plotted, and the summer temperature at the equilibrium line is determined from the points with the same position on this map.
d. The "Field to Field" method: used in the present study. Two maps are compared with each other and the summer air temperature at the equilibrium line is determined for the regular network according to the altitudinal difference between the two maps. This procedure does not take into account the cooling above the glacier surface. According to field experience, it changes from 0.5° to 2.5°C depending upon the air temperature and size of the glaciers. The corresponding corrections are implied.

The Calculation of Ablation and Accumulation at the Equilibrium Line Height

To move from summer air temperature to ablation and thus to accumulation, global, and regional formulas are used. The global formula (Krenke and Khodakov 1966) is as follows.

$$A = (T + 9.5)^3,$$

where
A = yearly ablation (accumulation) in mm and
T = the avarage summer air temperature in °C. The accuracy of the global formula is about 18%, but it still appears to be higher (10%) in the Pamirs and the Karakoram. The results of calculation using the global formula are shown in Fig.1.

According to Fig. 1, accumulation is above 2,500mm in the wet areas fed by moisture from the Atlantic flow and Bengal monsoon. Along the southern slopes of Central Himalayas, accumulation is of the order of 1,500-2000mm. In dry leeward areas it decreases to 500mm.

Assessment of Precipitation, Glacier Runoff and Total Runoff

According to field data and simple theoretical considerations, the glacier runoff could be assumed by the first approximation to be equal to the accumulation at the snow line and thus calculated from its maps. The glacier runoff from the Hindu Kush is equal to seven cubic kilometres; from Karakoram, 17 cubic kilometres; and from the Himalaya, 36 cubic kilometres, totalling about 60 cubic kilometres.

The solid precipitation is less than accumulation because the accumulation includes the drift snow and avalanches. The coefficient of concentration depends on morphological types of the glacier and its basin. Plotting the map of the snow line height, we have mostly used the big glaciers. According to our detailed field study in IHD-representative basins and according to the snow line deviation from other types, this coefficient is equal to about 1.25 on such glaciers. Thus, amount of solid precipitation varies similar to the accumulation from 2,000mm in wet areas and 400mm in the dry areas and is equal to 1,600mm along the southern slopes of Himalayas. The liquid precipitation at such heights everywhere are less, even far less than 20%. So the total precipitation over the alpine zone changes from 2,400mm down to 400mm. According to the field experiments in the alpine zone, the runoff from total precipitation is equal to about 0.85, thus changing from 1,500-2,000mm in the wet to 350-500mm in dry areas. The total runoff from the alpine zone is about 400 cubic kilometres.

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Fig 1: The accumulation on the glaciers in the Hindu Kush-Himalayan mountains. 1, main ranges, 2, main rivers, 3, isolines of equal accumulation (in parenthesis - solid precipitation)