COMPILATION AND USE OF COMPLEX NIVAL-GLACIOLOGICAL MAP

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Abstract

Nival-glacial phenomena which, as a rule, substantially affect economic activity, exist over almost the area Russia and other Northern countries during the winter period. Most often one must deal with a complex of nival-glacial phenomena interacting both among themselves and with the surrounding environment - with a nival-glacial system. During the economic development of an area, and even simply during its settlement, one must know what types of features prevail there. One of the most convenient forms of information about the distribution of nival-glacial phenomena and their interactions in specific conditions is the complex nival-glaciological map. The maps depict the distribution, frequency and intensity/magnitude, and potential impacts of such natural hazards as avalanches, mudslides, icings and glacier pulsations, and are used in the planning of construction and the maintenance of roads and other transportation corridors during winter and spring. A method for compilation maps of nival-glacial phenomena is proposed for an area of the Pamir in Central Asia. At present we are finishing digital version of this chart on the base of GIS GeoGRAF software.

1 The nival-glacial systems

The nival-glacial systems are natural systems, which include snowcover, snow avalanches, snow drifts, glacial mudflows and slush flows, icing, glacier pulsations, ice gorges in the river and other [2].

In our paper we consider dangerous nival-glacial phenomena only.

The affects of the nival-glacial systems on human activity is defined in terms of the overall intensity of each of its elements, i.e., the "glacial activity" of the area [2]. Three levels or grades of activity are identified for each of the natural nival-glacial phenome-na considered: 1 - weak, 2 - medium, and 3 - strong.

Avalanches: 1 - less than one avalanche per linear km of valley bottom and a maximal snow volume of less than 10,000 m^3; 2 - 1-5 avalanches per linear km of valley bottom, and a maximal avalanche volume of 10,000-100,000 m^3; 3 - more 5 avalanches per linear km of valley bottom, and maximal avalanche volume of over 100,000 m^3.

Glacial mudflows and slush flowing: 1 - maximal discharge of less than 100 m^3/sec, volume less than 200,000 m^3, distance of flow less than 10 km; 2 - maximal discharge 100-1,000 m^3/sec, volume from 200,000-1,000,000 m^3, distance of flow up to 25 km; 3 - maximal discharge over 1,000 m^3/sec, volume over 1,000,000 m^3, distance of flow over 25 km.

Icings: 1 - period of existence less than 180 per year, area less than 0.001 km^2, mean thickness 0,1 m, maximal thickness up to 1 m; 2 - period of existence 180-260 days, area 0.001-1 km^2, mean thickness 0.1-1 m, maximal up to 5 m; 3 - period of existence more than 260 days, area more than 1 km^2, mean thickness more than 2 m, maximal thickness more than 5 m.

Snow drifts: 1 - thickness on roads up to 1 m; 2 - thickness on roads 1-2 m; 3 - thickness on roads more than 2 m.

Glacier Pulsations (for the analysis of pulsating glaciers the area of glaciers per unit area of mountains can be used as first approximation of the extent of glaciation): 1 - 10-20%; 2 - 20-40%; 3 - over 40%.

2 Compilation of the map

The compilation of a map of natural nival-glacial phenjmena is done in several stages. The first stage involves the gathering of information about separate nival-glacial phenomena for a specific area. Maps of snow avalanches, glacial mudflows and slush flowing, and icings, refined on the basis of data in [1,4] and field observations conducted in the Pamir of the Central Asia by the Laboratory of Applied Glaciology, Institute of Geography, Russian Academy of Sciences served as a basis for determination of the quantitative characteristics of the activity of the phenomena listed above. A map of the glaciation of the Pamir [3] was used for glaciers. Snow drifts were estimated from values known from observations or data in [1], with consideration of spatial variations in the depth of the drifts. As a result of the first stage, five maps of individual natural nival-glacial phenomena at 1:3,000,000 scale were produced at varying degrees of detail.

A second stage consists of the compilation, on the basis of maps of the individual features obtained above, of a map of the distribution of the natural nival-glacial features of the Pamir. First areas were identified, the boundaries of which coincided with the boundaries of the distribution of the several individual features of glacial activity. Then the presence of the separate phenomena and magnitudes of their activity were determined within these areas. The following symbols were adopted for nival-glacial phenomena on the map: S - snow avalanches, D - snow drifts, M - glacial mudflows and slush flowing, I - icings, and G - glaciers subject to glacial shifts/pulsations. A numerical index is used to designate the activity level of each feature, for example, M_1, S_2, I_3. etc. The alphanumeric indices are notated on the map in descending order of intensity relative to their effects on human activity - avalanches, snow drifts, glaciers, mudflows, icings. In particular cases, when the extent of glaciation of an area reaches over 60%, glaciers become more important than avalanches or snow drifts. In the event of the noncorrespondence of the boundaries of individual phenomena within an area, its boundary becomes the boundary of the feature that is most important in the particular area, that is, the feature that is most active and has the greatest effect on human activity. For most of the areas the boundaries of the separate phenomena were close, their lack of congruence was within the range of 1-1.5 mm at the scale of the map. Therefore, a map of the distribution of natural nival-glacial phenomena of the Pamir (see Figure 1) was compiled as a result of the second stage.

The third stage features the regionalization of territory according to degree of potential impact on human activity. Three levels of glacial activity in an area are identified: 1) areas where one-two phenomena complicate economic activity, requiring adjustments in particularly snowy winters; 2) areas where particular phenomena significantly complicate human activity, where interaction effects (of several phenomena) are possible, and where preventive/ameliorative measures are necessary; 3) areas whose economic development requires significant expenditures for protection from nival-glacial phenomena, either individual phenomena or combinations of phenomena.

On the basis of qualitative analysis we designated the following characteristics as typical of these areas: 1) areas with glacial activity in Category 3 (intense) are characterized by the presence of at least one element with an index of 3 or no less than four elements with an index of 2; 2) areas with glacial activity in Category 2
are characterized by the presence of at least one feature with index of 2 or no less than four elements with an index of 1; 3) areas with glacial activity in Category 1 are characterized by the presence of 1-3 phenomena with with an index of 1. The notion that the presence of four

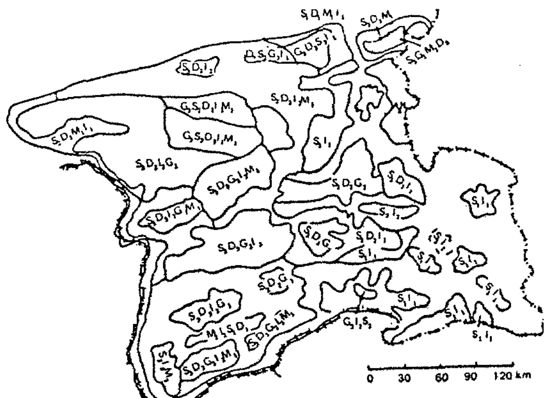

Figure 1: Distribution of the nival-glacial phenomena of the Pamir. Symbols explained in text

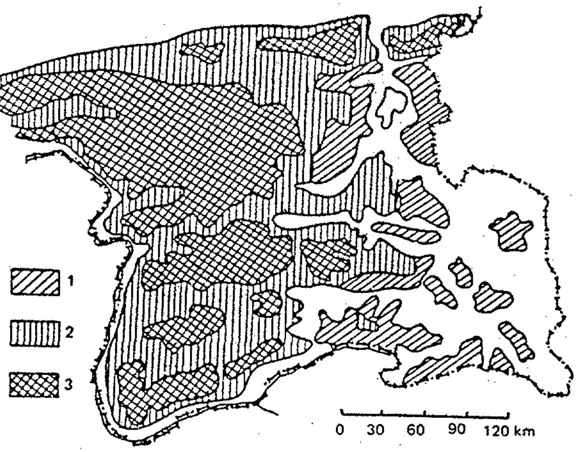

Figure 2: Regionalization of the Pamir in terms of its "glacial activity". 1 - glacial activity of Category 1; 2 - glacial activity of Category 2; 3 - glacial activity of Category 3

features in an area having the same index will increase the glacial activity level by one is based on the assumption that the degree of influence on human activity of one element of high activity is much greater than one-two elements of lower activity, which usually interact only weakly among themsezlves. The presence of three and especially four features greatly increases the probability of their interaction and thus influence on human activity, which is difficult to explain without such interaction.

As a result of the third stage a map was compiled of the regionalization of an area according to glacial activity (see Figure 2), which shows the degree of possible effects of the complex of natural nival-glacial phenomena on human activity.

The fourth stage consists of the combination of natural nival-glacial phenomena and the regionalization of an area in terms of its glacial activity, as resultt of which we obtain a complex engineering-glaciological map, on which the glacial activity of an area is shown by colored pattern/areal symbols, and the distribution of nivsl-glacial phenomena by indices (point symbols). Such a map is not shown here because of the impossibility of color reproduction (in this publication).

Supplemental information is an important component of the map. All elements of nival-glacial systems, including nival-glacial phenomena, are related to one another and with surrounding environment. We shall now consider a simplified diagram of the interactions of these phenomena (see Figure 3). Of all the environmental factors affecting nival-glacial phenomenf four basic meteorological agents are analyzed: the amount of solid precipitation, wind velocity, sum of negative air temperatures during winter, and sum of positive air temperatures during the period of thawing. These factors affect the year-to-year variability of the investigated phenomena most greatly.
We shall now examine some of these relationships without considering the mechanisms behind them. Some of the phenomena are independent, for example , glacier pulsations; others depend immediately on several factors, for example slush flows; between certain phenomena a direct dependency relationship exists (the higher the snow drifts, the greater usually the avalanches); and between still others there is inverse relationship (the higher the snow drifts, the less normally the development of icings).

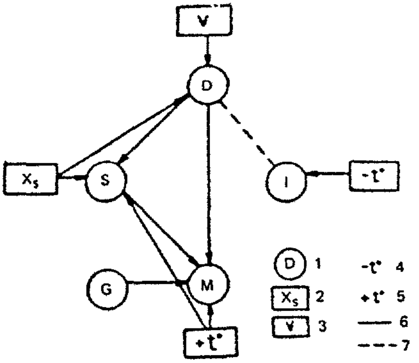

Figure 3: Diagram of the interaction of individual nival-glacial phenomena and environmental agents. 1 - nival-glacial phenomena; 2 - solid precipitation; 3 - wind velocity in winter; 4 - sum of negative air temperatures; 5 - sum of posotive air temperatures during the period of thawing; 6 - relationships between the phenomena and agents - linear dependency; 7 - relationship between the phenomena - inverse relationship

In the chart there are also included: Diagram of combinations of nival-glacial phenomena under different conditions of terrain and Diagram of the changing activity of natural nival-glacial phenomena over the course of a year.

3 Applications

A map complied in such a way permits us to determine with sufficient objectivity the presence of natural nival-glacial phenomena both in space and in time. We shall consider two possible instances of the use of such a map: for determining the advisability of construction and for examining the conditions of transport at a specific time.
At present time the digital version of the chart is completing with using of GeoGRAF. GeoGRAF is one of GIS Software products, designed by Institute of Geography, Russian Academy of Sciences.

4 Conclusions

The method of infirmation-gathering about natural phenomena developed by us permits the compilation of a map of any area at a wide range of scales. Such a map,
especially its digital version, even at small scales permits the gathering of essential information about the presence of natural nival-glacial phenomena in a particular area. Maps of this type can be used for both research and applied purposes.

References

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