Some Results of Long-term Variability of Avalanche Activity in the Mountains of the CIS

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Abstract

The work presents an analysis of the long-term variation of avalanche activity in mountains of the former USSR (CIS) on the basis of data gathered by regular observations. The periods of activation and reduction of avalanche formation were determined as being of different synchronisation across separate groups of regions. The common territorial time curves of avalanche activity were derived for 11 of the 13 mountain areas of the CIS analysed. For the Tien Shan and the Caucasus, the general tendencies in the long-term variation of avalanche formation were differentiated in more detail. For some regions, a relationship was established between avalanche formation and climatic factors (air temperature, winter precipitation). The decreased avalanche activity during the last few years, as revealed on the basis of the analysis, is confirmed by the independent observational data.

Introduction

The problem of studying the long-term variations of hydrometeorological characteristics, e.g., precipitation, river flow, and avalanche activity, is of great scientific and practical importance, and that is why it has long attracted the attention of scientists. Druzhinin (1970) determined that a sudden change in the sun's activity is the cause of a reverse in the long-term trend of numerous natural processes, including atmospheric circulation and other important meteorological phenomena. The problem of the long-term variation of avalanching in the former USSR has attracted the attention of such scientists as Turmanina (1970), Oleinikov (1983), Kakurina (1987), and Okolov (1986). Sezin (1982) determined a relationship between avalanche activity and atmospheric circulation, and it may be safe to assume that avalanching periods can be connected with the regularity of the atmospheric processes whose sharp turning points correspond to the 11-year solar cycle. This work attempts, by following in the footsteps of former investigations, to present the long-term variations of avalanche activity on the European territory of the CIS, the Caucasus, Kazakhstan, Central Asia, Siberia, and the Far East. Among heir trends were distinguished periods with low and high numbers of avalanches, ompared with the mean long-term values. And there was also revealed a homogeneity in the intensity of variations of avalanching in individual regions. Here the fact has been taken into account that the tendency of extreme avalanche activity is observed in the years preceding sun reference years, i.e., in the years of the sign change in solar activity increment. This is described in Kakurina (1987).

Data

The long-term variations of avalanche activity were estimated on the basis of data from areas of stations for comprehensive avalanche observations. The longest data series have been compiled for such areas as the Khibins (54 years), the eastern Caucasus (42 years), and the western Tien Shan (34 years). The data series of the majority of snow-avalanche stations (SAS) are for observational periods of less than 20 years (62.4%), and their data were used only for Siberia and Far Eastern territories. For purposes of a synchronous analysis, the 30-year period of observation from 1960-61 up to 1989-90 was taken as the most representative one (i.e., the one with the most comprehensive observational data). A total of 43 stations was selected, of which 17 are on the European territory of the CIS and Caucasus, 13 in Kazakhstan and Central Asia, and 13 in Siberia and the Far East.

Method

In the study of the long-term variations of different elements, the technique of moving averages was used. The object of this technique is to smooth out observation series by averaging over sequential annual periods. One can more clearly imagine the cyclic variations, without any displacement of the interphase limits between the cycles of intensive and low avalanche activity, when applying the differential integral curves or summarised curves of deviations from the mean long-term value (Bykov and Kalinin 1967), for the construction of which the continuous observational series is used. For the calculations of such curves as $f(t)=\Sigma(k_i-1)/C_v$, the deviation of modulus coefficient for the chronological series of avalanche occurrences from their mean value (k_{av}-1) were consequently summarised. The periods of intensive and low avalanche activity were bounded by the main turning points of the curve. The time period in which $k_{av}-1>0$ corresponds to the phase of increase in avalanche activity, and the period in which $k_{av}-1<0$ corresponds to its decrease, i.e., at $k_{av}-1 = (l_k - l_n)$,

where,
l_k is the end coordinate of the integral curve, l_n the beginning one, and
n is the number of years in the period analysed.

For determining general regularities of the cyclic variations, three principal gradations were used: phases of increased, moderate, and decreased avalanche activity. The demarcation of these phases was made on the basis of the main turning points of the differential integral curves. Factors with negligible effect on changes in avalanche activity, caused not by macrosynoptic processes but probably by local anomalies, were not taken into account.

Result

The use of differential integral curves makes it possible to investigate the cyclic variations of avalanche activity from the data of snow-avalanche stations of different regions, i.e., to reveal the degree of phase synchrony or asynchrony in avalanche formation. For the solution of this problem, three types of synchronous curves of avalanche activity were chosen and averaged from 13 avalanche-prone areas (the Khibins, Carpathians, northern Caucasus, Caucasus, Zailiyskiy Alatau, Tien Shan, Pamirs, Altai, Kuznetskiy Alatau, Baikal region, Zabaikalje, the North-east, and Sakhalin Island).

The first type includes curves with a phase of decreased avalanching 14-17 years in duration and a phase of increased avalanching 15-17 years in duration. Such regions as the Khibins, Carpathians, the Caucasus, some basins of the Tien Shan, the North-east, Kuznetskiy and Zailiyskiy Alatau, Northern Caucasus, and Sakhalin Island belong to this type. In the last four regions, less qualitative information was used, based on the limited actual observational series restored by regression equations. The Caucasus region was sub-divided into two subregions: the western Caucasus and eastern Caucasus. In the western sub-region, the phase of increased avalanching is longer, with a module coefficient $k_i = 1.72$. The second sub-region is characterised by a significantly shorter duration of this phase (for 3 years) and a greater modulus coefficient $k_i = 1.97$. It can be supposed that this is connected with the continental nature of the climate of the Eastern Caucasus.

The second type includes curves where the phase of low avalanching activity is 9-12 years, followed by 15-17 years of increased avalanche activity. Such regions as the Pamirs, Zabaikalje, and some basins of the Tien Shan belong to this type.

The third type is characterised by a 16-year period of increased avalanching and 8-11 years of reduced avalanche activity. Some regions of the Tien Shan, the Baikal region, and the Altai belong to this type. It should be mentioned that, for the Altai, defining the period of increasing avalanche activity was limited by the incomplete data series. The most carefully studied area of avalanches, the Tien Shan region, was distinguished by the presence of all three curve types. There, even within one mountain region, such as the western Tien Shan some snow-avalanche stations belong to the first type (Kamchik, Naugarzan), others to the second (Angren, Kyzylcha), and some to the third (Dukant, Oigaing).

The identification of more detailed characteristics of periodical processes within one big region may, on the one hand, indicate statistically bad sampling, while on the other it may reflect some sub-genetical effects of avalanche formation. On the whole, the snow-avalanche stations, where constructive metamorphism is more active and wind activity greater, due to low temperatures and insignificant snow cover, are mainly related to the first type. It should be noted that the regions identified above as belonging to the first type are also characterised by relatively high wind activity (excluding Zailiyskiy Alatau). The snow-avalanche stations with sufficiently large amounts of snow and suppressed constructive metamorphism are related to the third type. As for the second type, the avalanching conditions of Angren and Itagar are nearly the same, but Kyzylcha, given the snow accumulation conditions and weak wind activity there, is objectively assignable to the third type, so that its inclusion within the second type of sub-region is still problematic. The longest duration of increased or decreased avalanche activity is 18 years, with most recorded durations of the decreased phase of avalanche activity not exceeding 14 years, and those of its increased phase 12 years (Table 1). The shortest period of sudden increase in avalanche activity was recorded in 1968-1969 in the first sub-region of the Tien Shan, being characterised by an abnormal increase of avalanche activity observed within a general pattern of decrease.

Table 1: Distribution of the Longest Duration of Different Avalanche Formation Phases (n) and Their Average Modulus Coefficients (k_1, k_2, k_3) by Regions

NN	Region	Avalanche formation phases					
		Low activity		High activity		Moderate	
		n	k_1	n	k_2	n	k_3
1	Khibins	15	0.74	14	1.29	-	-
2	Carpathians	14	0.76	15	1.28	-	-
3	Northern Caucasus	15	0.37	10	1.84	5	1.10
4	Caucasus type 1	14	0.22	16	1.71	-	-
5	Caucasus type 2	15	0.35	13	1.97	-	-
6	Zailiyskiy Alatau	15	0.56	6	2.06	9	1.02
7	Tien Shan type 1	11	0.62	16	1.30	1	0.97
8	Tien Shan type 2	10	0.38	15	1.49	-	-
9	Tien Shan type 3	15	0.73	6	1.77	-	-
10	Pamir	12	0.55	15	1.35	-	-
11	Altai	11	0.76	3	1.86	-	-
12	Kuznetskiy Alatau	14	0.40	11	1.88	3	1.05
13	Baikal region	8	0.62	7	1.44	-	-
14	Zabaikalje	9	0.50	17	1.33	-	-
15	North-east	18	0.38	12	1.98	-	-
16	Sakhalin	17	0.60	8	1.58	-	-
	Average	14	0.53	12	1.63	4	1.03

An analysis of the natural anomalies of that period (Aksarin 1973 and Aksarin et al. 1973) shows that the hydrometeorological cataclysms at the time were largely affected by the intensive development of the northern meridional processes during the four months of the winter period (1968-1969) and by the formation of blocking anticyclones along the eastern part of the European territory of the USSR, giving rise to extreme stability during two months. This caused the abnormal intensive and extensive precipitation which, in turn, touched off large avalanches in areas where they were not recorded before. One interesting result observed came during the analysis of the territorial spread of the modulus coefficient for the increase and decrease phases of avalanche activity. It was determined that, to the south and east of the Khibins, the modulus coefficients of the decrease phase of avalanche activity drop: the Khibins (k_1=0.74), the Caucasus (k_1=0.35), Kuznetskiy Alatau (k_1=0.40), the Tien Shan (k_1=0.54), Zabaikalje (k_1=0.50), and the North East (k_1=0.38); and they increase during the phases of increased avalanche activity: the Khibins (k_2=1.71), Kuznetskiy Alatau (k_2=1.88), the Caucasus (k_2=1.71), the Tien Shan (k_2=1.55), Altai (k_2=1.86), and the North-East (k_2=1.98). As is known, the effect of continentality becomes more pronounced in the southern and eastern directions, and this is reflected in the modulus coefficients. An analysis of the differential integral curves of avalanche activity has shown that the starting time, duration, and modulus coefficients of the increase and decrease phases of avalanche activity are different at different stations. Nevertheless, despite these individual features among the long-term variations of avalanche activity, in certain regions a similar character of phase beginnings was observed. A diagram (Fig.1) was constructed to arriving at a clearer idea of the spatial distribution of the long-term variations of avalanche activity.

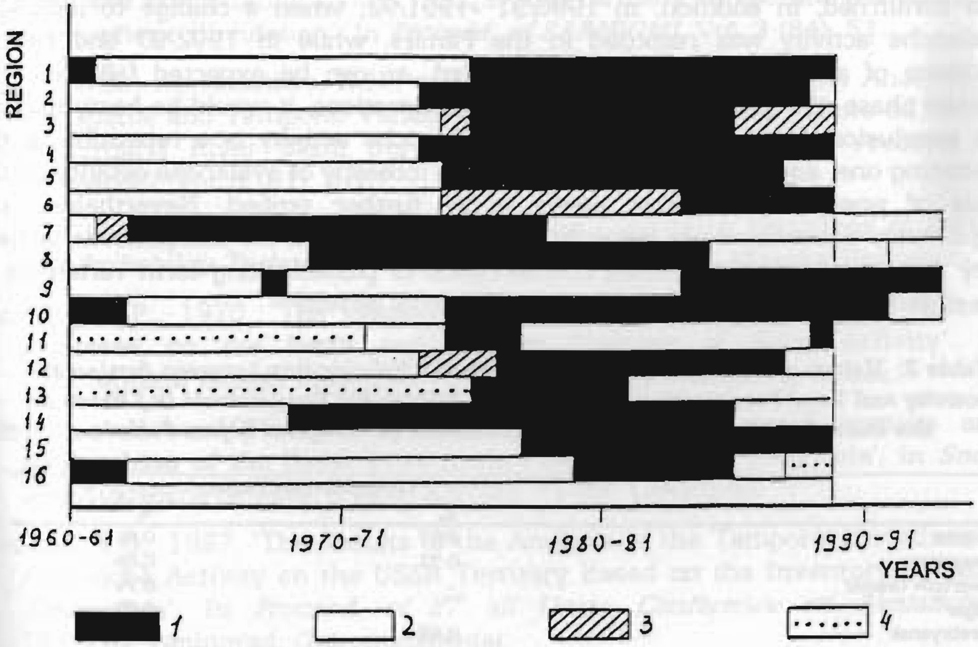

Figure1: Diagram of Cyclic Variations of the Avalanche Activity in Mountain Regions of the CIS

1 - low activity, 2 - high activity, 3 - moderate activity, 4 - data are absent. The numbers of the regions (Y-axis) correspond to the ones in Table 1

Considerable similarity is observed in the change of phase of cyclic variation of avalanche activity, in practically all regions except Tien Shan and Zabaikalje. Up to the mid-1970s, a phase of weak avalanche activity was observed everywhere, and then a phase of its increase followed. In Tien Shan sub-region, with a curve of the third type, an increase of avalanche activity had been noted since 1962; in the second sub-region (type 2) since 1969; in the third sub-region (type 1) since 1983. An 'even transition' of phase of increased avalanche activity from one region into another seems to be in place, i.e., increased avalanche activity in one sub-region is compensated by weak avalanche activity in the other two sub-regions. Synchronic phase change of avalanche activity in the mentioned areas is connected with the direction of the principal air flows, cyclones, and anticyclone movement, and, as a consequence, with precipitation amounts and air temperature. The danger of avalanches in winter is determined not only by the amount of snow or the total precipitation; such factors as the precipitation regime and temperature conditions of the cold period also play a significant role (Oleinikov 1983,1988). In order to substantiate these results, an effort was made to assess the degree of correlation between the avalanche activity in certain winter periods and the precipitation regime and air temperature of the cold half of the year. As is shown in Table 2, the significance of these coefficients is rather high. The sampled cycles of the long-term variations of avalanche activity for the Tien Shan and the Pamirs were tested on independent material. The observational data from snow-avalanche stations of different types were used for 1990/91 - 1993/94. The tendency for avalanche activity to decrease for the Tien Shan sub-regions and to increase for the Pamirs was confirmed, in addition, in 1990/91 -1991/92, when a change to increased avalanche activity was recorded in the Pamirs, while in 1992/93 and later a decrease of avalanche activity was recorded, as can be expected following the chosen phase of definite duration. Despite observations, it would be hasty to draw the conclusion that every new cycle of avalanche activity is a repetition of the preceding one, and that is why forecasting the intensity of avalanche activity on the basis of previous tendencies needs to be further probed. Nevertheless, the regularities determined are not only presented as a basis for independent testing, they also serve as experimental corroboration of possible long-term variations in the climate, as an argument bearing on avalanche activity.

Table 2: Values of Correlation Coefficients for the Relationship between Avalanche Activity and Total Precipitation (k_x) and Mean Winter Air Temperature (k_t) Based on the Data of Various Avalanche Stations (SAS) for Irregular 5-year Periods

	Correlation coefficients	
	k_x	k_t
Angren	0.57	0.92
Naugarzan	0.71	0.68
Severtsov Glacier	-	0.74
Itagar	-	0.66
Serebryansk	0.68	0.92
Luzhba	0.87	-
Omsukchan	0.76	-

Summary

The main results can be formulated as follows:

- regions on CIS territory have been identified as undergoing synchronous variations of avalanche activity, and the longest durations of the phases of low, moderate, and high avalanche activity have been estimated;
- for different CIS regions the tendency, of mainly regional character, was defined for the long-term change of weather conditions to correlate with temporal indices of the intensity of avalanche formation;
- on the basis of the investigations carried out, one can suppose that the indices of the intensity of avalanche activity are functionally related to the continental character of the conditions, because the modulus coefficients become lower with an increase in the degree of continentality.

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