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EVALUATION DE LA CONTRIBUTION DE LA NEIGE ET DES GLACIERS AU BILAN HYDRIQUE DES RIVIERES

METHODS FOR COMPUTATIONS OF ONSET DATE AND DAILY HYDROGRAPH OF THE OUTBURST FROM MERTZBACHER LAKE, INYLCHEC GLACIER, TIEN-SHAN

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ABSTRACT A method for prediction of the lake outburst date based on application of air temperature, total cloudiness and presipitation data at the Koilju meteorological station is proposed for a simplified and rather regularly repeated model of filling Mertzbacher lake and water outbreak from it. The information about its volume and hydrograph of outburst wave are among the major characteristics of Mertzbacher lake regime. The new method for solving this problem is based on separation of the volume measured at a gauging station into two parts formed by: (a) water drainage from Mertzbacher lake; (b) usual influx of water due to snow and ice melting in a basin. The algorithm of an outburst wave computation is described. It requires only standard hydrometeorological data.

INTRODUCTION

Mertzbacher lake having the volume of about 0.2 km³ formes annually in the region of the confluence of the northern and southern branches of the Inylchec glacier and outbursts as a rule, at the end of the ablation season. While Mertzbacher lake has been known since 1903, the history of its regular but short-term studies accounts for only about 50 years. Assessment of quality of initial information of hydrometeorological regime in the Inylchec river basin and on characteristics of Mertzbacher lake necessary for solving the problems of the present study showed that the following data are the most appropriate in view of their completeness and regularity:

- the results of observations made at the Koilju meteorological station for the period 1951-1988;
- runoff measurements at the Inylchec river (gauging station "Ustije") considering water outbreak from Mertzbacher lake;
- information on dates of outburst onset and its duration;
- the results of glaciological measurements and computations.

The materials mentioned above were used for development of methods: (a) predicton of the date of onset of outburst from Mertzbacher lake, (b) estimation of the drained water volume, (c) computation of the hydrograph of an outburst wave through the gauging station "Ustiie" at the Inylchec river. This station located of about 50 km from the end of Inylchec glacier. It should be noted that previously G.E. Glazyrin and L.N. Sokolov (Glazyrin, Sokolov,1976) as well as Yu.B. Vinogradov (Vinogradov, 1977), have developed mathematical model to compute the hydrograph of an outburst wave of the glacier dammed lake. Analysis of the Glazyrin-Sokolov model structure has revealed that initial data necessary for its application is next to impossible to get (namely, cross section area of the conduit inside a glacier before an outburst, lake area as the function of its depth, empirical coefficients) and the results of computation strongly depend on some parameters that are unknown a priory.

PREDICTION OF THE DATE OF AN OUTPURST ONSET

To develop a model for prediction of the onset time of water outbreak from Mertzbacher lake the cases with more or less reliable dates of single outburst have been selected beginning in 1951.

At the first stage of investigation the simple scheme of Mertzbacher lake regime to be as follows:

- filling of the lake up to the critical level begins at the onset of snow and ice melting in the area of the Northern Inylchec glacier basin, limited by an ice dam which blocks Mertzbacher lake;
- outbreak of water is the direct result of exeeding the threshold of an ice dam seeping ability in normal conditions.

It is evident that within the described scheme of the lake regime the meteorological parameters affecting the total layer of melting in the basin of the Northern Inylchec glacier should be the major factors determining the time of the lake readiness to outburst. A formula for computation of the average melting intensity during a pentade as a function of air temperature at the Koiljy meteorological station is used to determine the dates of beginning of the snow and ice melting period in the Northern Inylchec glacier 5 basin. The expression:

$$\hat{M}_5 = 0.75\ \overline{T}_5 + 1.2 \qquad (1)$$

is based on the measurements at the Inylchec glacier within the altitudial range of 3.2-3.4 km. Here M - is the average layer of melting during a pentade, T - is the mean air temperature for the same pentade. Having taken the left side of this formulae to be zero and using the gradient of temperature as 9.0 deg/km we find that the first calendar pentade, when mean air temperature exeeds 2.9°C at the Koijlu meteorological station can be considered as the beginning of the snow and ice melting period in Mertzbacher lake basin.

Correlation analysis has revealed quite a close relation ($r = 0.94$) between outburst dates (D) and sums of mean air temperature for pentades at the Koiliu meteorological station. But this form of relation $D = f(T)$ can't be used for prediction of the time of an outburst onset. With this connection, all the three potential predictors used to forecast the date of an outburst have been transformed in the following way. The earliest date of July 25 was selected from the set of sixteen years of D. Then 3 days were subtracted and the 22-nd of July was taken as the date of release a forecast of an outburst. Further, values of mean air temperature T, indices of total cloudiness C and precipitation Q were summed up to 21 July from the first pentade of the year with mean air temperature > 2.9°C at the Koilju meteorological station. The resulted sum for every year were subtracted from the mean long term values of T, C and Q but now they are related to the whole period of time from the first pentade in the year when $T > 2.9$°C up to the mean date of an outburst. The described procedure allows to use sums of T, C and Q accumulated by July 21 in a forecast in a case of existing the relation between the sums, their residuals and the date of an outburst.

Multivariate linear regression analysis showed that such a relation actually exists and, finally an equation has been developed to predict D:

$$\hat{D} = 308 - 0.67\Delta T - 0.30\ \Delta C - 0.11\ \Delta Q \qquad (2)$$

where $\hat{D}$ - is the numbers of days in a calendar year from January, 1; ΔT, C and ΔQ were described above in details. The combined correlation coeffisient (r) of the expression (2) is 0.86.

COMPUTATION OF THE VOLUME AND HYDROGRAPH OF AN OUTBURST WAVE

It is quite evident that the volume of daily runoff of Inylchec river in the period of Mertzbacher lake outburst is formed simultaneously owing to the quite differient sources:

- regular influx of snow and ice melting water in the watershed basin situated above the gauging station named "Ustije";
- catastrophic water outbreak from Mertzbacher lake.

Daily layer of seasonal and long-term reserves of snow and ice in June-September is the only factor determing the Inylchec river runoff before an outburst of the lake and after it.

The problem of separating the Inylchec river runoff in the period of outburst that we formulated above, was solved by means of selecting a multivariant function most effectively describing running average discharge before the onset of water outbreak from the lake. The following data obtained for a number of years have been considered:

- running discharge averages for a pentade with one step backward shift in time, namely, one pentade running average;
- running averages of air temperature, cloud cover indices and atmospheric pressure in current pentade from observations made at the Koilju meteorological station;
- running averages of the same meteorological elements for a pentade but with one step forward shift in time relative to

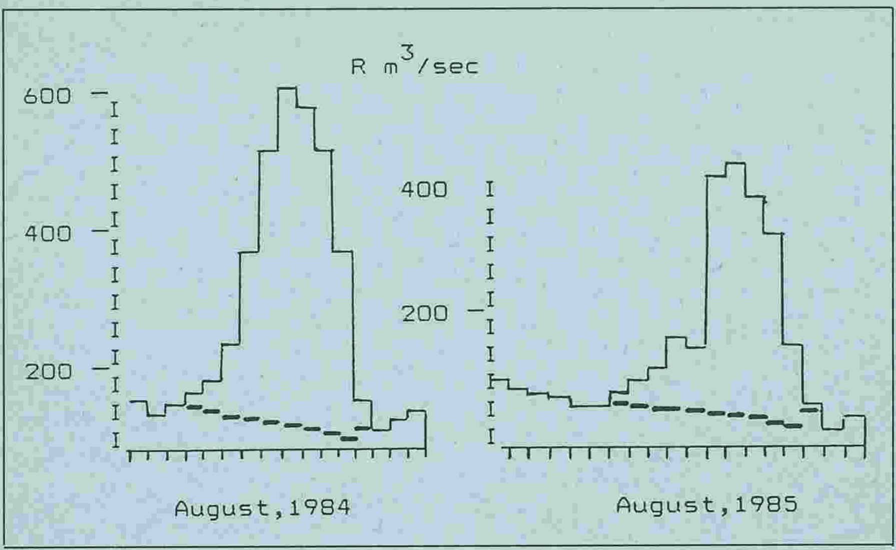

Fig. 1 The samples of average pentade running values of Inylchec river discharges in 1984-1985 (gauging station "Ustije"). Solid thick line on graphs computed pentade averages of running discharges which are not connected with volume of outburst from Mertzbacher lake.

the current mean water discharge in a pentade.

An equation has been derived to compute running averages of discharges for pentades in July-August at the Inylchec river which are not associated with an outburst of Mertzbacher lake.

$$\hat{R}_J = 0.77\, \overline{R}_{J-1} + 3.24\, \overline{T}_J - 14.53 \text{ m}^3/\text{sec} \quad (3)$$

where $\hat{R}_J$ – is the mean discharge in current pentade; R_{J-1} – is the same but shifted one step backward in time; T_J – is the mean air temperature at the Koilju meteorological station in the current pentade. Coefficient r of (3) is 0.95, mean root square error of computation of R is 8.5 m³/sec. The equation (3) was used in 1982, 1984-1987 to compute that component of the Inylchec river runoff hydrograph during the lake outburst which had formed due to daily melting of snow and ice in a basin above the the gauging station "Ustije". The results of computations are shown in fig. 1 by a thick line.

It is seen that the computed hydrograph agrees quite well with runoff measurements after the lake outburst when the usual daily melting of snow and ice becomes again the only source of the Inylchek river nourishment.

Distribution of total volume drained from the lake during the period of outburst is presented in figure 2.

Table 1 presents the combined results of computation of water volume during the outbursts. Dimensionless ordinates of empiric differential and integral distribution curves are given here for two cases of an outburst and in general for all the considered years. It is evident that differential and integral distribution curves in Table 1 represent the typical hydrographs of an outburst wave of Mertzbacher lake. Those hydrographs permit solution of the following important scientific and applied problems:

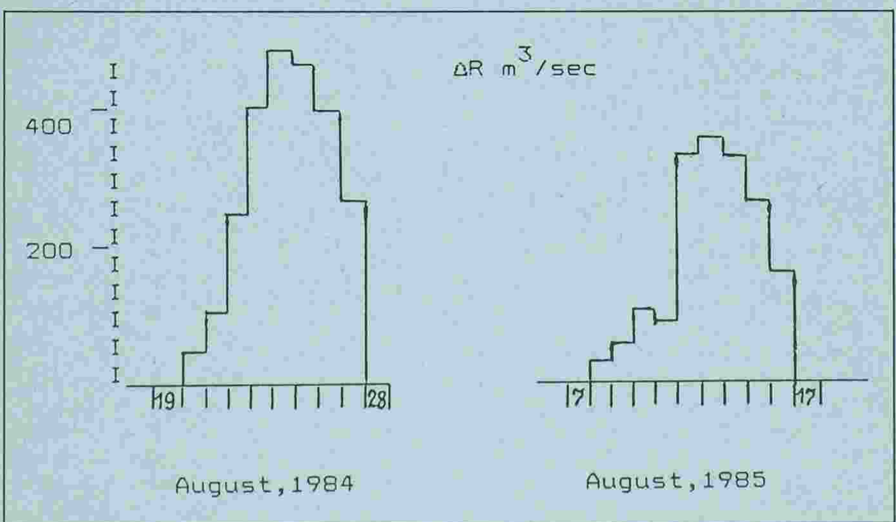

Fig. 2 Average daily discharges of Inylchec river (gauging station "Ustije") related to water outbreak from Mertzbacher lake in the period of its outburst. The abscissa axis shows calendar dates.

- to develop modified mathematical model of water drainage from the glacier dammed lake and to assess its parameters;
- to investigate the process of transformation of an outburst wave on its path from a dam of Mertzbacher lake to the gauging station "Ustije";
- to compute the hydrograph of an outburst wave for the gauging station "Ustije" if a volume of water drainaged from Mertzbacher lako has been estimated by any method at the onset of water outbreak. In any case, this volume could be estimated? a priory as 150-180×10⁵ m³. The error of this approximation is not more than 10-15%. It is expedient to present a scheme for solution of the last problem in a form of succesive computational operations.

a) Beginning from the second part of June, average values of discharge for running pentades are computed rom daily measurements of discharge at the Inylchec river (gauging station "Ustije"), and a runoff hydrograph is constructed analogous to the graph in fig. 1;
b) Beginning from the onset of Mertzbacher lake outburst which is estimated by deviations from regularities of daily course level in the river or by any other technique, we calculate continiously during eight days a part of the Inylchec river runoff which is not related to the outburst of the lake using formulae (3) and (9);
c) A formula:

$$v_J = V_{LK}\,[F(t) - F(t^{-1})] \quad (4)$$

is used to determine the every day runoff volume passed through the gauging station during 8-day period after Mertzbacher lake outburst. Here v_J – is the runoff volume in t-th day, V_{LK} – is the lake volume at the beginning of its outburst which was computed or estimated tentatively, F(t) and $F(t^{-1})$ – are the averaged ordinates of integral distribution function taken from Table 1. So, the quality of the hydrograph of an outburst wave from Mertzbacher lake computed at the gauging station "Ustije" of the Inylchec river depends on reliability of the method for estimation of the lake volume.
d) Having summed runoff volumes, obtained from computations given in (b)-(c), we will get a total runoff volume of Inylchec river for every day during the period of an outburst.

Thus, the presented in (a)-(c) algorithm of computations allows to get a gydrograph of total runoff of the Inylchec river and, separately, an outburst wave of Mertzbacher lake without hydrometric measurements during the period of an outburst.

RUNNING AVERAGES IN THE CONSIDERED COMPUTATIONS

Application in the described method of running averages of variables during a pentade instead of daily values is intended to smooth rundom runoff fluctuations due to possible error of hydrometric measurements of extreme discharges of an outburst wave in unstable channels.

Table 1. – Characteristics of the outburst wave hydrograph of Mertzbaher lake.

Month Days	Dates	Runoff m^3/sec	Volume mln.m^3	Increment	Ordinates of distribution curves differential (d)	integral (I)	The same ordinates averaged for 5 outbursts (d)	(I)
August 1984								
1	20	40	3	3	0.014	0.014	0.041	0.041
2	21	105	9	12	0.043	0.057	0.067	0.107
3	22	245	21	33	0.100	0.158	0.113	0.221
4	23	395	34	67	0.163	0.321	0.190	0.411
5	24	500	43	110	0.206	0.526	0.191	0.601
6	25	475	41	151	0.196	0.722	0.171	0.773
7	26	410	35	186	0.167	0.890	0.144	0.917
8	27	270	23	209	0.110	1.000	0.082	1.000
August 1985								
1	9	55	5	5	0.033	0.033		
2	10	105	9	14	0.060	0.093		
3	11	90	8	22	0.053	0.146		
4	12	345	30	52	0.200	0.347		
5	13	360	31	83	0.207	0.553		
6	14	330	28	111	0.187	0.740		
7	15	275	24	135	0.160	0.900		
8	16	170	15	150	0.100	1.000		

Besides that if average water discharges for two successive moving pentades and five values of mean daily discharge at the beginning of a calendar period, over which a running averaging is done are available, it is easy to transfer from presentation of information in the form of pentade averages to daily values. Let's make up a general expression for this procedure.

It is evident that running average values of the first $x_{n,1}$ and second $x_{n,2}$ pentades may be written as follows:

$$x_{n,1} = \frac{1}{n}\left(x_1 + \sum_{i=2}^{i=5} x_i\right) \qquad (5)$$

$$x_{n,2} = \frac{1}{n}\left(x_5 + \sum_{i=2}^{i=5} x_i\right) \qquad (6)$$

where n=5 is the number of averaged terms of initial set, x_1 and x_5 are the first and sixth terms of the initial set Having subtracted (6) from (5) and write down the result related to the unknown value of x_5, we obtain

$$x_5 = x_1 + n(\bar{x}_{n,2} - \bar{x}_{n,1}) \qquad (7)$$

and similarly

$$x_7 = x_2 + n(\bar{x}_{n,3} - \bar{x}_{n,2}) \qquad (8)$$

then, finally, in general form:

$$x_{i+k} = x_k + n(\bar{x}_{n,k+1} - \bar{x}_{n,k}) \qquad (9)$$

i = n --N, k = 1 -- N - n

where N - is the total number of terms in the initial set, n=5 is the number of terms in a sample for running averaging.

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