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VARIABILITY OF SNOW COVER CHARACTERISTICS IN THE TRANSBAYKAL

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Translation of "Izmenchivost' kharaketeristik snezhnogo pokrova ~~v us~~loviyakh zabaykal'ya," Trudy Glav. Geof. Observ., No. 130, 1962, pp. 78-83

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16. Abstract

Results are presented of an experimental verification of the Transbaykal of theoretical developments by the A.I. Voyeykov Main Geophysics Observatory to improve the efficiency of snow measurement photographs.

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VARIABILITY OF SNOW COVER CHARACTERISTICS IN THE TRANSBAYKAL /78*

R. K. Govsh

Results are presented of an experimental verification of the Transbaykal of theoretical developments by the A. I. Voyeykov Main Geophysics Observatory to improve the efficiency of snow-measurement photographs.

Snow-measurement observations currently made at stations and posts are very cumbersome, especially in the harsh winter of the Transbaykal, and the extant technique does not ensure a sufficiently accurate analysis of the characteristic average magnitudes of the height and density of the snow cover on large areas.

It is common knowledge that selection of the route and number of measurement points for snow surveys in a certain region is determined by variability in the height and density of the snow cover. It is most expedient to use the structural function [1] to characterize variability in snow cover height and density. By structural function of a certain magnitude for a specific interval we mean the average square of the difference in its values at the ends of this interval. By knowing the magnitude of dispersion of the snow cover height and the value of the structural function, we can compute the error in determining the average snow cover height for routes of different length with varying number of measurement points.

Special snow surveys were set up in the winter of 1959 - 1960 at individual stations in the Transbaykal Administration of the Hydrometeorological Service to study the horizontal variability in snow cover height and density. The stations were selected so that they reflected the main landscape zones of the Transbaykal (Table 1).

The height of the snow cover from the measurement lines indicated in Figure 1 was measured every 10 m, and density every 200 m.

The materials were processed and dispersion and structural function were calculated according to the technique developed in the

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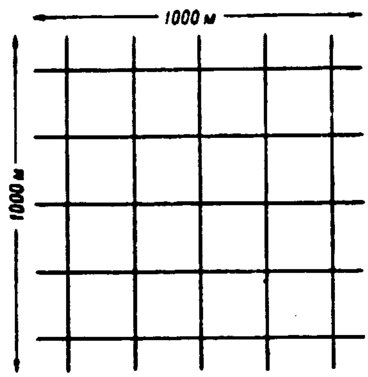

Figure 1. Plan of Measurement Lines for Special Snow Surveys

A. I. Voyekov Main Geophysics Observatory.

Table 1 presents the dispersion magnitudes for stations where special snow surveys were made.

TABLE 1. DISPERSION OF SNOW COVER HEIGHT IN THE WINTER OF 1959-60 /79

Station	Dispersion σ^2_h	Notes
Baunt	9.68	Mountainous taiga
Kalakan	9.54	"
Krasnyy chikoy	4.98	"
Borzya	0.81	Steppe
Chita	32.39	Forest-steppe

The calculated structural function values are presented in Table 2.

It is evident from Table 2 that when the interval between the measurements increases, the structural function values rise. This rise, however, cannot continue unlimitedly, since any of the studied magnitudes always has certain change limits.

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TABLE 2. VALUES OF STRUCTURAL FUNCTION IN THE WINTER OF 1959-60

Station	Distance between points (m)									
	10	20	50	60	70	100	200	300	400	500
Baunt . . .	7,2	11,6	17,8	18,8	19,5	19,6	18,8	19,1	23,6	25,8
Kalakan . . .	16,2	17,5	18,9	19,0	19,3	19,1	19,3	18,0	20,1	21,0
Krasnyy Chikoy	8,6	9,7	9,8	10,0	9,9	10,4	10,6	10,8	11,0	10,7
Borzya	0,97	1,09	1,23	1,27	1,28	1,30	1,33	1,30	1,38	1,34
Chita	42,0	51,0	63,0	65,0	64,8	63,4	63,6	61,8	70,8	62,4

The saturating value of structural function (when it remains almost unchanged) is equal to the double value of dispersion [1].

Before using the structural function to determine errors, it is expedient to smooth it. Smoothing is done graphically [2]. The values of the structural function corresponding to different values of the interval are taken from the curve obtained as a result of smoothing. Table 3 has the smoothed values of the structural function for the Transbaykal stations.

The errors in determining the average snow cover height for different lengths of the route and number of measurement points were computed for the formula

$$\overline{\delta}^2(l, n) = \frac{b_\infty}{2} - \frac{1}{n^2}\sum_{i=1}^{n-1}(n-i)\,b(i\Delta l), \qquad (1)$$

where $\overline{\delta}^2(l, n)$--total error depending on the length of the route l and the number of measurement points on it n, b_∞--value of the structural function on infinity, i--ordinal number of point measurement on the route, Δl--distance between the measurement points, $b(i\Delta l)$-- value of the structural function for the $i\Delta l$ interval. /80

TABLE 3. SMOOTHED VALUES OF STRUCTURAL FUNCTION

Station	Distance between points (m)									
	10	20	50	60	70	100	200	300	400	500
Baunt	7,2	11,6	17,8	19,0	19,4	19,4	19,4	19,4	19,4	19,4
Kalakan	16,5	17,2	18,8	19,0	19,1	19,1	19,1	19,1	19,1	19,1
Krasnyy Chikoy	8,6	9,7	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
Borzya	0,97	1,09	1,25	1,27	1,28	1,30	1,33	1,35	1,38	1,41
Chita	42,0	48,5	64,0	64,8	64,8	64,8	64,8	64,8	64,8	64,8

TABLE 4. NUMBER OF MEASUREMENTS OF SNOW COVER HEIGHT ON ROUTE 1000 m LONG $P_h \leq 1.0$ cm

Station	Number of Height Measurements
Baunt	10
Kalakan	10
Krasnyy chikoy	5
Chita	50
Borzya	2

Table 4 shows how many snow cover altitude measurements must be made on a route 1000 m long for the root-mean-square error of height aralysis not to exceed 1.0 cm.

It is convenient to use graphs for practical utilization of the results of computing analysis errors in the average snow cover height.

In order to construct a graph, the length of the route l is plotted on the x-axis, and the number of measurements n on the y-axis.

A point on the graph at which the computed error P_h is indicated corresponds to each pair of values l and n. Then isolines are made through the points corresponding to equal values of error. Figure 2 presents this graph for the Baunt station.

By using the graph, we can find the error in determining the snow cover height for any values l and n through interpolation. One can judge from the graph how the route will be selected so that the average error of snow cover height does not exceed a certain prespecified magnitude. Assume that in our example it is necessary for practical purposes for this error not to exceed 1.0 cm. In this case, l and n are needed for the selected route so that the point corresponding to them on the graph lies above the isoline P_h = 1.0 cm. The required accuracy will be attained with l = 500 m, n = 15 or l = 1000 m, n = 11 are selected.

The snow cover density was measured during special snow surveys as indicated above every 200 m. The relationship between individual measurements at these distances was insignificant, it can be ignored /81
in this case. Therefore in order to compute the snow cover density error, the known formula was used

$$\overline{\delta}_d^2(m) = \frac{\sigma_m^2}{m}, \qquad (2)$$

where $\overline{\delta}^2{}_d(m)$--density error, $\sigma^2{}_m$--density dispersion, m--number of density measurements.

Table 5 presents the magnitudes of root-mean-square error of density for Transbaykal stations.

It follows from these data that with an increase in the number of density samples, the error noticeably diminishes.

Until now we have been concerned with questions of variability /82
in height and density of the snow cover and correspondingly their

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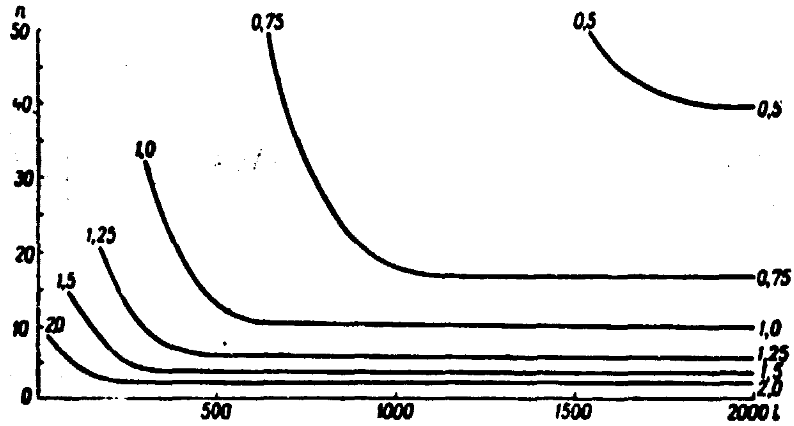

Figure 2. Dependence of Error in Determining Snow Cover Height on Length of Route and Number of Measurement Points

TABLE 5. DEPENDENCE OF ERROR IN DETERMINING DENSITY ON NUMBER OF MEASUREMENT POINTS

Station	Number of measurements				
	1	2	3	4	5
Paunt	0,0529	0,0374	0,0305	0,0265	0,0237
Kalakan	0,0283	0,0200	0,0161	0,0141	0,0126
Krasnyy Chikov	0,0141	0,0100	0,0081	0,0071	0,0063
Chita	0,0346	0,0245	0,0200	0,0173	0,0158

Station	Number of measurements			
	10	20	50	100
Paunt	[illegible]	0,0118	[illegible]	[illegible]
Kalakan	[illegible]	[illegible]	[illegible]	[illegible]
Krasnoy Chikov	0,0045	[illegible]	[illegible]	[illegible]
Chita	0,0110	[illegible]	[illegible]	[illegible]

average error over the territory. It is also very interesting to select the most expedient time intervals between the snow measurement observations. It is common knowledge that this selection is determined by errors in interpolating the snow cover characteristics in the time between the observations [1, 3].

We used observation materials from the permanent measuring rods of six Transbaykal stations (Table 6) to study temporal variability and snow cover height.

TABLE 6. BRIEF CHARACTERISTICS OF STATIONS

Station	Landscape Zone	Section	Observation Period
Kalakan	Mountainous taiga	Protected	1955-1959
Chasovaya	"	"	1952-1958
Petrovskiy zavod	"	Open	1950-1959
Chita	Forest-steppe	Protected	1947-1956
Yamkun	"	Open	1952-1956
Khorinsk	Steppe	"	1950-1955

TABLE 7. MAGNITUDES OF TEMPORAL STRUCTURAL FUNCTION

Station	Period	Length of interval (days)							
		1	2	3	4	5	10	15	20
Kalakan	Increase	2,0	3,1	4,0	4,8	5,4	9,0	11,3	14,6
	Decrease	2,5	7,6	14,0	21,2	29,3	89,5	163,5	252,0
Petrovskiy Zavod	Increase	0,6	1,5	2,2	2,8	3,4	6,4	9,4	12,0
	Decrease	3,4	7,7	12,6	16,7	22,4	51,8	81,7	114,2
Chasovava	Increase	0,9	2,0	3,0	3,7	4,5	8,1	11,2	15,5
	Decrease	3,0	6,6	11,8	16,2	21,5	50,6	83,2	115,0
Chita	Increase	0,7	1,2	1,6	1,9	2,1	3,3	4,2	5,4
	Decrease	1,8	3,0	4,1	4,9	5,8	9,6	12,9	16,0
Khorinsk	Increase	0,5	0,6	0,8	1,0	1,1	2,0	2,6	3,1
	Decrease	0,4	0,9	1,7	2,4	2,8	5,9	8,9	12,7
Yamkun	Increase	0,6	1,2	1,9	2,5	3,2	7,0	11,0	14,0
	Decrease	2,2	5,0	8,0	11,2	14,1	34,2	51,3	72,5

The calculated values of the temporal structural function for the periods of increment and decline of snow cover [3] are presented in Table 7.

In order to use the structural function in further computations, it is necessary to establish the nature of the relationship between the function values corresponding to different time intervals. The temporal structural function over the snow cover height generally is an exponential relationship

$$b(\tau)=c\tau^k \qquad (3)$$

If the graph of structural function of type (3) is constructed in logarithmic coordinates, then it will look like a straight line, since /83

$$\lg b(\tau)=\lg c+k\lg\tau. \qquad (4)$$

The exponent k is computed from the formula

$$k=\frac{\Delta\lg b(\tau)}{\Delta\lg\tau}, \qquad (5)$$

where $\Delta\lg\tau$--difference in logarithms between the two selected points on the graph, $\Delta\lg b(\tau)$--difference in logarithms of the structural function at these same points. By knowing the exponent k and the values of the structural function, we can compute the average magnitude of error for interpolating snow cover height in time [3].

Table 8 presents values of the root-mean-square error in interpolating height.

Using the graphs for the dependence of interpolation error on the magnitude of the selected time interval, we can define the frequency measurements needed to obtain intermediate values of the snow cover characteristics with preselected accuracy.

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TABLE 8. ERRORS IN INTERPOLATING SNOW COVER HEIGHT

Station	Time interval (days)								Exponent k
	1	2	3	4	5	10	15	20	
				Period of increase					
Kalakan	0,72	0,89	1,02	1,12	1,18	1,53	1,72	1,94	0,65
Petrovskiy Zavod	0,32	0,50	0,60	0,68	0,75	1,03	1,25	1,41	1,00
Chasovaya	0,43	0,64	0,78	0,87	0,96	1,28	1,51	1,77	0,88
Chita	0,46	0,60	0,70	0,76	0,80	1,00	1,13	1,28	0,62
Khorinsk	0,36	0,37	0,46	0,51	0,54	0,72	0,82	0,90	0,72
Yamkun	0,30	0,42	0,53	0,61	0,69	1,02	1,28	1,44	1,07
				Period of decrease					
Kalakan	0,28	0,62	0,84	1,03	1,21	2,12	2,86	3,55	1,55
Petrovskiy Zavod	0,64	0,97	1,24	1,43	1,65	2,51	3,15	3,73	1,18
Chasovaya	0,58	0,86	1,15	1,35	1,55	2,38	3,06	3,59	1,22
Chita	0,68	0,88	1,04	1,09	1,23	1,58	1,84	2,04	0,72
Khorinsk	0,26	0,39	0,53	0,63	0,68	0,99	1,22	1,46	1,00
Yamkun	0,39	0,48	0,94	1,12	1,25	1,95	2,39	2,84	1,23

The experimental verification on materials of individual stations that we made thus allows us to conclude that the scientific-method developments of the A. I. Voyekov Main Geophysics Observatory to improve the efficiency of snow measurement surveys are quite applicable for the Transbaykal Administration of Hydrometeorological Service Station Network. The results of calculating the average error that we obtained for several stations apparently cannot be extended to the entire territory of the administration of the hydrometeorological service. In order to improve the snow measurement surveys on the Transbaykal Administration of the Hydrometeorological Service Network using the technique of the A. I. Voyekov Main Geophysics Observatory, calculations need to be made for a large number of stations.

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