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Automated Estimation of Snow Cover Parameters and Meteorological Quantities in Mountainous Regions For Hydrological Purposes

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SYNOPSIS

The paper presents information concerning setting up of automated system for data collection, processing and interpretation and possibilities of these systems application for hydrological problems solution. The problems of optimum distribution of automated system network points is considered.

In the course of snow cover and avalanches study more and more attention is paid to the development and setting up of automated system for the data collection and processing. Such systems for solution of avalanche forecasting problems have been introduced in the French Alps and Western Tien Shan.

The main purpose of these systems is solution of problems concerning snow avalanche studies. Considerable number of sensors in these systems can be used for obtaining of information directly used in hydrological practice. It is very important due to the fact that snow cover and meteorological elements studies in mountainous regions presents insufficiently developed area of hydrometeorology. Hereat snow and weather data in mountainous regions are much in demand for numerous users building, tourist, sports, geological, mining organizations, aviation, etc.). However, each user may make his own demand to this information which, in its turn, determines the density of sensers space distribution and discreteness of their measurements.

Naturally, hydrometeorological data user determines observational specificity with the help of automated devices and set of estimated parameters.

Meterological data (air tempearture, air humidity, wind parameters, sunshine duration) are very valuable for numerous hydrological problems solution. Table 1 presents set of sensors used for such measurements and their meteorological characteristics.

For estimation of meteorological quantities both specially developed sensors and sensors employed in different meteorological remote sensing stations with unified outcoming signal in a form of:

Table 1

Meteorological parameters estimation by remote sensing technique

No.	Name of meteorological parameter	Unity	Meteorological indices: Range of measurements	Meteorological indices: Limits of absolute admitted error
1.	Air temperature	°C	-60 - +50	∓0.2
2.	Relative air humidity	%	0 - 100	∓ 5.0
3.	Wind direction	grad.	0 - 360	∓ 10.0
4.	Wind speed	$m\ s^{-1}$	0 - 60	∓ 0.5
5.	Sunshine duration	h	0.05 - 24.0	∓ 0.05
6.	Precipitation amount for the period between requested and preceeding periods	mm	0 - 200	∓ 0.15
7.	Surface temperature of deposited snow	°K	213 - 215	∓ 0.2
8.	Stratified snow surface temperature	°C	up to -60	∓ 0.2
9.	Snow depth	sm	0 - 200	∓ 2

- constant current of 0 - 5 mA
- constant current voltage of 0-1 V or 0-10 V
- frequency signals of 1-2 kHz; 2-4 kGz; 4-8 kHz
- unity code with pulse number not less than 255
- thermal converter resistance with nominal value of 100 Om at 0°C

can be used.

The use of a number of sensors is possible for the snow depth measurements including also snow stake providing estimation of pulse number proportional to the snow depth in accordance with movement of movable measuring ring sinking from reference level up to the snow surface [1]. These measurements are also possible using ultrasonic device for registration of ultrasonic wave pass from signals transmitter to the snow surface and their processing. When it is necessary the sensor can be used for estimation of water level in water bodies.

The device for radar sounding of snowpack using open wire contour is considered to be the most prospective for estimation of snow reserves including also water equivalent of newly deposited snow. This device is used for obtaining of reflexometric graph the mathematical processing of which on personal computer provides transformation of reflexometric data into dielectrical permeability carrying information on density and humidity (liquid water content) of snow.

Practically realized technique of impulse reflexometry provides estimation of line non-homogeneities along with its character and value by characteristics of reflected impulse signal.

Data on snow density are of interest for solution of the wide area of glaciological and hydrological problems solution. Information on the liquid phase occurrence is necessary for the estimation of snowmelt and snow water regeneration outset. The same information can be obtained by installations for snow tempearture measurement.

The important task of automatization is optimization of observational points selection, their location in a number sufficient for their realization accuracy of characteristics measurement.

The location of regular measurement network in mountainous conditions is impossible due to difficult access, the danger of measuring devices destroy by avalanches, slides, mudflows, etc. Measuring network should be located in safe places and ensure access to devices at least after snow dissapearance. Sensors location is limited by zones of maximum snow accumulation where they are most likely to be drifted out by snow. Their location is non-representative in places of wind drift and low snowmelt. In a whole, rational territorial distribution of devices should be determined by space-time regularities of analyzed parameters which requires organization and carrying out of special research. Each element taken for estimation requires specific approach depending on the aims and tasks of its possible application.

The most typical ones are the problems of optimum location of points for air temperature observations in mountainous basin. One of the ways of its solution is account of relief characteristics determined by a number of morphometric parameters. For objective evaluation of the local relief effect on the air temperature it is necessary to make morphometric relief analysis which consists of determination of the following characteristics:

$\ell_{\text{д}}$ - valley length;

$S_{\text{ст.гр.}}$ - valley width at the ridges height at the level of observational point;

$S_{\text{ст.д}}$ - width of the valley bottom;

$h_{\text{ст.}}$ - valley depth at observational point location;

$H_{\text{ст.}}$ - absolute height of observational point;

$H_{\text{ср.}}$ - mean height of the ridge screening the station;

$H'_{\text{ср.}}$ - mean height of the ridge opposite to screen;

X - the extent of the total system in prescribed direction;

L - distance from observational point to the plain.

Dimensionless characteristics relations were used for computation.

On the base of multifactor regression analysis the regression equations were formulated which are used for evaluation of mean daily temperature at any point of regular observations. This facilitates definition of automated observational points location more objectively.

When obseving snowpack temperature it is necessary to take strong distortion effect of direct solar radiation on southern slopes leading to thermal sensors melting out into account. It is not also recommended to install thermal stakes in areas exposed to the strong wind effect on snow cover. An "obstacle" in a form of a stand installed for temperature measurement in accumulation zone causes excess of snow accumulation. In drift zone the snow is accumulated around the stake in a layer of 20 - 40 cm depth, and excess of accumulation occures in transit zone on leeward slope.

Determination of absolute height and location orientation effect is very important for substantiated optimum location of points for snow temperature observation. For this purpose it is the most rational to make correlation analysis between reference site and sites located on different slopes. At the beginning the temperature distribution in snowpack is analyzed on these sites.

Being guided by the highest correlation coefficients obtained during comparison of synchronous observations the representative horizons are selected. In accordance with observational data obtained in Western Tien Shan this horizons are situated at 15 - 60 cm levels on different slopes. On sites with exposition closest to the reference one such depth is 30 cm for south-eastern and eastern-south-eastern orientation, respectively, while comparing with southern site it is only 15-20 cm for zone of homogeneous absolute altitude about 2000 - 2200 m.

When comparing temperature values at 30 cm depth on sites of different height but with homogeneous exposition the height gradient of 0.88°C temperature depression was obtained at 100 m which adequate with dry adiabatic one.

Comparing sites situated at one height level but having different exposition the following data were obtained (Table 2).

Table 2

Snow temperature depression from nothern exposition to southern one

Exposition	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SE	SSW SSE	S
t°, °C	0	0.1	0.2	0.3	0.8	1.3	2.6	4.0	5.4

The technique presented in this paper may be applied for any mountainous region.

For estimation of optimum composition of snow stakes network it is also necessary to determine snow accumulation differences on different slopes and heights together with correlational analysis of available data. Regularities of height distribution of snow depth in one of the mountainous regions of Western Tien Shan are presented on Fig. 1.

The results improvement gives use to multidimensional statistical relations taking along with absolute height such parameters as exposition, slope curvature and aspects into account. In case of reliable statistical correlations foundation it is possible to compute snowpack depth at any point of the space. Respectively, snow depth observations are valid only in a few basic and additional observational points.

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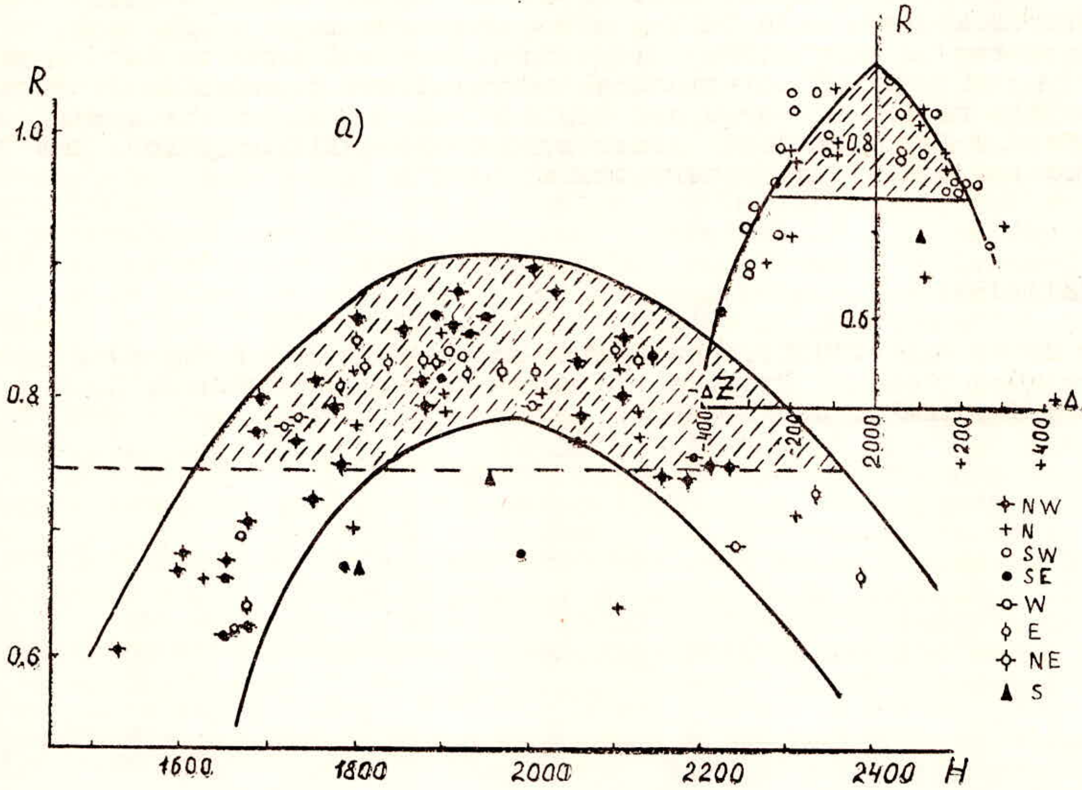

Fig.1. Variation of snow depth correlation coefficient by remote snow stake and meteorological site of Dukant snow avalanche station data depending on height (a) and relative excess (b) of locality