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USSR Report

METEOROLOGY AND HYDROLOGY

No. 5, May 1980

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MULTIVARIATE OBJECTIVE ANALYSIS OF METEOROLOGICAL FIELDS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 5-14

[Article by Professor S. A. Mashkovich, USSR Hydrometeorological Scientific Research Center, submitted for publication 14 December 1979]

Abstract: A method has been developed for the multivariate four-dimensional analysis of meteorological fields with the use of spatial-temporal optimum interpolation. On its basis, using real data, the author carried out numerical experiments for the purpose of clarifying the role of different meteorological elements in the analysis.

[Text] One of the methods for increasing the quality of objective analysis is related to the possible broadening of its information base by the use of information on several meteorological elements. Different approaches can be formulated for solution of this problem. For example, it is possible to make an independent analysis of several meteorological fields, relying in computing the field of a particular meteorological element only on the measured values of this same element and then assimilating the resulting fields. However, it is more attractive to carry out assimilation already in the course of the analysis itself. This purpose is served by multivariate analysis in which computation of the field of each meteorological element is accomplished on the basis of information on the complex of meteorological elements; the element to be analyzed may or may not enter into their list.

Approaches to multivariate analysis on the basis of optimum interpolation were already noted long ago and some computations were made (for example, see [1,3]. However, the intensive development of methods for multivariate analysis and their practical application has taken place in the last few years [8-12]. Extensive use is made of the "analysis-forecast-analysis" cycle, in which the results of the analysis are the initial data for numerical forecasting, and the prognostic fields of meteorological elements are used as the initial approximation ("preliminary field") for the next analysis. There are indications that multivariate analysis makes it possible, in proceeding to a numerical forecast, to avoid additional processing (initialization) of the analyzed meteorological fields (for example, see [12]). Multivariate four-dimensional analysis, with an "analysis-forecast-analysis" cycle, is intended, for example, for the processing of observational data for the GARP program [8].

Although even now some information has been published on the formulation and use of multivariate analysis models on the basis of optimum interpolation, many important problems have not been dealt with. For example, there is virtually no information available on the contribution as a result of taking one meteorological element or another into account, about what "sets" of meteorological elements must be used in the analysis of a specific meteorological field, and with what error it is possible to compute the distribution of a meteorological element, information on which is lacking, using data on other elements, etc. It is possible to note only the numerical experiments of Schattler [12], according to which the joint use of geopotential and wind gave no improvement in comparison with a univariate analysis.

However, an evaluation of the role of individual meteorological elements to a multivariate analysis is useful. Many new observation systems (artificial earth satellites, drifting balloons, etc.) do not yield information on the entire complex of meteorological elements, but only on some. For the correct planning of such observation systems and the effective use of the corresponding observations it is necessary to be able to answer the questions enumerated above.

Below we describe the method for joint assimilation of information on different meteorological elements, obtained from different observation systems, and present the results of numerical experiments. We give an evaluation of the possible contribution of specific meteorological elements to the analysis and investigate the possibility of restoring lacking data on one meteorological element on the basis of measurements of other elements.

The analysis model is based on the spatial-temporal interpolation of deviations of meteorological observations from some preliminary field. The structure of the field of deviations in this case is modeled. One of the important merits of the analytical method with the use of optimum interpolation is an extremely simple means for taking into account the differences in the errors in measuring meteorological elements in different observation systems.

Principal Equations

We will write the formulas for optimum interpolation in a case when the initial information for the computations is the values of several meteorological elements, and not only the element whose value we want to determine at the point to be analyzed.

Assume that we have data on m meteorological elements. The meteorological element to be analyzed can be among these elements. The points at which the values of different meteorological elements are known can coincide completely or partially and can also differ.

We will denote the number of points with measurements of the k-th meteorological element by n_k. The number of such points can be equal for different elements. We will assume further that the total number of observations used in the computations is equal to N, that is

$$N=\sum_{k=1}^{m} n_k.$$

We will examine the deviations of the meteorological elements from their values in some preliminary field. By "preliminary field" we can understand the field of prognostic values, climatic distribution, results of analysis on the basis of data for the preceding observation time, etc.

We will use f to denote the true value of the meteorological element, and by $f^{(obs)}$ and $f^{(pre)}$ -- the observed value and the value in the preliminary field respectively. Then the analyzed value of the meteorological element $f^{(a)}$ can be found using the following interpolacion formula

$$f_{j,0}^{(a)}=f_{j,0}^{(\pi)}+\sum_{k=1}^{m}\sum_{i=1}^{n_k} p_{k,i}^{j}(f_{k,i}^{(H)}-f_{k,i}^{(\pi)}), \qquad (1)$$

[a = anal; H = obs; π = pre] where k, j denote the sequence of the meteorological element and i is the number of the point at which there is information about the particular meteorological element. The subscript "0" corresponds to the point for which the analysis is made. As indicated above, it was assumed that for the k-th meteorological element there are n_k observed values.

Then by φ(obs) and φ(pre) we will denote the deviations of the observed and preliminary values from the true values:

$$\varphi_{ki}^{(H)}=f_{ki}^{(H)}-f_{ki}, \quad \varphi_{ki}^{(\pi)}=f_{ki}^{(\pi)}-f_{ki}, \qquad (2)$$

and by ψ^a the deviation of the analyzed value from the preliminary value

$$\psi_{j0}^{(a)}=f_{j0}^{(a)}-f_{j0}^{(\pi)}. \qquad (3)$$

With these notations formula (1) can be rewritten in the form

$$\psi_{j0}^{(a)}=\sum_{k=1}^{m}\sum_{i=1}^{n_k} P_{ki}^{j}(\varphi_{ki}^{(H)}-\varphi_{ki}^{(\pi)}). \qquad (4)$$

The mean square interpolation error is expressed in the following way:

$$E_j=\overline{(f_{j0}^{(a)}-f_{j0})^2}=\overline{(\psi_{j0}^{(a)}+\varphi_{j0}^{(\pi)})^2}, \qquad (5)$$

where the line denotes averaging. With (4) taken into account, formula (5) assumes the form

$$E_j = \overline{(\varphi_{j0}^{(n)})^2} + 2\,\overline{\varphi_{j0}^{n} \sum_{k=1}^{m} \sum_{i=1}^{n_k} P_{ki}^{j} (\varphi_{ki}^{(H)} - \varphi_{ki}^{(n)})} + \tag{6}$$

$$+ \sum_{l=1}^{m} \sum_{r=1}^{n_l} \sum_{k=1}^{m} \sum_{i=1}^{n_k} P_{lr}^{j} P_{ki}^{j} \overline{(\varphi_{ki}^{(H)} - \varphi_{ki}^{(n)})(\varphi_{lr}^{(H)} - \varphi_{lr}^{(n)})}.$$

In accordance with the requirement, in order for the square of the interpolation error to be minimum, we obtain the following system of equations for determining the weighting factors:

$$\overline{\varphi_{ki}^{(H)} \varphi_{j0}^{(n)}} - \overline{\varphi_{j0}^{(n)} \varphi_{ki}^{(n)}} + \sum_{l=1}^{m} \sum_{r=1}^{n_l} P_{lr}^{j} (\overline{\varphi_{ki}^{(H)} \varphi_{lr}^{(H)}} - \overline{\varphi_{ki}^{(n)} \varphi_{lr}^{(H)}} - \overline{\varphi_{ki}^{(H)} \varphi_{lr}^{(n)}} + \tag{7}$$

$$+ \overline{\varphi_{ki}^{(n)} \varphi_{lr}^{(n)}}) = 0 \quad (k = 1, \ldots, m; \quad i_k = 1, \ldots, n_k).$$

We will assume that

$$\overline{\varphi_{ki}^{(H)} \varphi_{j0}^{(n)}} = \overline{\varphi_{ki}^{(n)} \varphi_{lr}^{(H)}} = \overline{\varphi_{ki}^{(n)} \varphi_{lr}^{(H)}} = \overline{\varphi_{ki}^{(H)} \varphi_{lr}^{(n)}} = 0, \tag{8}$$

$$\overline{\varphi_{ki}^{(H)} \varphi_{ki}^{(H)}} = \eta_{ki}.$$

Then the system of equations (7) and the expression for E acquire the form

$$\sum_{l=1}^{m} \sum_{r=1}^{n_l} P_{lr}^{j} \overline{\varphi_{ki}^{(n)} \varphi_{lr}^{(n)}} + P_{ki}^{j} \eta_{ki} = \overline{\varphi_{j0}^{(n)} \varphi_{ki}^{(n)}} \tag{9}$$

$$(k = 1, \ldots, m; \quad i_k = 1, \ldots, n_k),$$

$$E_j = \overline{(\varphi_{j0}^{(n)})^2} - \sum_{k=1}^{m} \sum_{i=1}^{n_k} P_{ni}^{j} \overline{\varphi_{j0}^{(n)} \varphi_{ki}^{(n)}}. \tag{10}$$

The weighting factors P are determined from system (9). These are then used in interpolation using formula (1). It is evident that for writing system of equations (9) it is necessary to know the corresponding covariation and cross-covariation functions, the value of the measurement errors and the positioning of the points at which the measurements were made. It should be noted that the finding of the covariation functions of deviations of meteorological elements from their values in the preliminary field can involve certain difficulties. Whereas for deviations of the meteorological elements from their climatic values such functions have been relatively well studied (for example, see [6]), this cannot be said with respect to the covariations of forecasting errors. In addition, the covariations of forecasting errors can be varied with changeover from one prognostic model to another. It goes without saying that all the necessary values can be computed for each situation to be analyzed. Another possible way to solve this problem is computation of the covariations of forecasting errors in the course of dynamic-stochastic assimilation of information [2]. However, the practical realization of these two approaches is difficult. Accordingly, at the present time rather extensive use is made of simple models of statistical structure [8-12]. In order to find the cross-covariation functions of pressure and temperature, pressure and wind, temperature and wind use is made of the dynamic and hydrostatic expressions (formulas for the geostrophic wind, equations of statics). Although when using these models there is a loss of optimality of interpolation in the statistical sense, acceptable results are obtained on their basis [8]. This approach is used below.

As an illustration we will cite some covariation functions. Assume that the k = 1 corresponds to the height z of the isobaric surface, k = 2 -- to the temperature T, k = 3 and k = 4 -- to the horizontal velocity components u and v. Then

$$\overline{\varphi_{1,i}^{(n)}\,\varphi_{1,r}^{(n)}} = C_{HH}\,e^{-b_0 r_0^2};\quad \overline{\varphi_{3,i}^{(n)}\,\varphi_{1,r}^{(n)}} = C_{Hu}(y_i - y_r)\,e^{-b_0 r_0^2};$$

$$\overline{\varphi_{3,i}^{(n)}\,\varphi_{3,r}^{(n)}} = C_{uu}\,[1 - 2\,b_0\,(y_i - y_r)^2]\,e^{-b_0 r_0^2};$$

$$\overline{\varphi_{3,i}^{(n)}\,\varphi_{4,r}^{(n)}} = C_{uv}\,(x_i - x_r)(y_i - y_r)\,e^{-b_0 r_0^2};$$

$$C_{Hu} = \frac{g}{l_0}\,2\,b_0\,C_{HH};\quad C_{uu} = \left(\frac{g}{l_0}\right)^2 2\,b_0\,C_{HH};\quad C_{uv} = \left(\frac{g}{l_0}\,2\,b_0\right)^2 C_{HH}.$$

Here x,y are the Cartesian coordinates of points, g is the acceleration of free falling, l_0 is the Coriolis parameter.

In the computations it was assumed that $b_0 = 2\cdot10^{-12}\ m^{-1}$.

More detailed information on the modeling of the statistical structure of meteorological fields can be found in [12].

The realization of four-dimensional analysis requires allowance for the asynchronicity of measurements. For a changeover to four-dimensional "space" (three coordinates and time) we used the same procedure as was employed in [4, 5, 7]; specifically, it was assumed that

$$r_0^2 = (x_i - x_r)^2 + (y_i - y_r)^2 + C_T\,(t_1 - t_2)^2.$$

Such an approach considerably simplifies the procedure for solving the problem of the "price" of the inaccuracies unimportant in this stage of the investigations.

Table 1

Evaluation of Numerical Analysis of Fields z, T, u and v

1 Вариант	Использованы данные 2	δ	δ_{max}	r	ρ_c % 3	ρ	σ_K 4	σ_A
			7 Анализ *z* в *дам*					
5 СГЛ	*z*	0,09	0,86	0,907	88,2	0,765	0,31	0,25
	T	0,18	1,55	0,636	70,0	0,400	0,31	0,06
	u, v	0,16	1,05	0,702	72,9	0,458	0,31	0,26
	u	0,18	1,17	0,565	65,8	0,316	0,31	0,20
	v	0,15	1,45	0,543	67,8	0,357	0,31	0,18
	T, u, v	0,15	1,02	0,741	73,7	0,473	0,31	0,26
	z, T, u, v	0,09	0,62	0,932	84,5	0,690	0,31	0,29
6 ИП	*z*	0,81	6,08	0,985	95,0	0,901	6,74	6,85
	T	3,97	32,65	0,650	74,6	0,493	6,74	1,51
	u, v	3,34	19,9	0,733	74,5	0,494	6,74	3,36
	u	3,86	26,3	0,591	68,8	0,375	6,74	2,49
	v	3,93	26,8	0,579	69,1	0,382	6,74	2,32
	T, u, v	3,10	19,0	0,783	77,8	0,556	6,74	3,62
	z, T, u, v	0,89	4,73	0,986	92,5	0,849	6,74	6,62
	z	0,86	6,19	0,985	94,8	0,896	6,74	6,89
			8 Анализ *T* в °C					
5 СГЛ	*z*	0,09	0,46	0,590	69,7	0,393	0,142	0,06
	T	0,04	0,30	0,942	89,5	0,790	0,142	0,110
	u	0,10	0,58	0,350	59,6	0,192	0,142	0,048
	v	0,10	0,53	0,290	58,2	0,164	0,142	0,043
	u, v	0,09	0,51	0,409	62,3	0,246	0,142	0,062
	T, u, v	0,04	0,26	0,935	87,9	0,759	0,142	0,116
	z, T, u, v	0,04	0,26	0,935	87,8	0,756	0,142	0,116
6 ИП	*z*	1,67	7,22	0,637	73,9	0,478	2,797	1,65
	T	0,238	1,45	0,994	97,6	0,952	2,797	2,61
	u	2,06	9,37	0,386	60,1	0,202	2,797	0,598
	v	2,01	10,9	0,408	66,0	0,320	2,797	0,559
	u, v	1,95	9,51	0,498	65,8	0,316	2,797	0,810
	T, u, v	0,251	1,53	0,993	96,6	0,931	2,797	2,68
	z, T, u, v	0,248	1,53	0,994	96,8	0,936	2,797	2,67
	z, T	0,250	1,74	0,992	97,3	0,946	2,797	2,699
			9 Анализ *u* в *м/с*					
6 СГЛ	*z*	0,28	1,78	0,795	76,1	0,522	0,60	0,42
	T	0,41	2,43	0,445	63,7	0,275	0,60	0,09
	u	0,25	2,12	0,847	85,5	0,711	0,60	0,36
	v	0,35	2,08	0,641	72,5	0,451	0,60	0,26
	u, v	0,21	1,52	0,892	85,7	0,713	0,60	0,42
	T, u, v	0,21	1,50	0,892	84,8	0,696	0,60	0,42
	z, T, u, v	0,24	1,54	0,865	77,0	0,540	0,60	0,46
			10 Анализ *v* в *м/с*					
6 СГЛ	*z*	0,28	1,69	0,765	76,8	0,537	0,57	0,40
	T	0,41	2,20	0,367	60,2	0,205	0,57	0,09
	u	0,33	1,69	0,677	72,7	0,453	0,57	0,26
	v	0,25	1,57	0,831	84,6	0,692	0,57	0,35
	u, v	0,21	1,20	0,887	85,5	0,711	0,57	0,41
	T, u, v	0,21	1,21	0,885	85,5	0,710	0,57	0,41
	z, T, u, v	0,24	1,26	0,843	76,3	0,527	0,57	0,44

Continuation of Table 1

Вариант 1	Использованы данные 2	δ	δ_{max}	r	ρ_c % 3	ρ	σ_K 4	σ_A
	9 Анализ u в м/с							
6 ИП	z	4,01	21,37	0,882	83,2	0,663	9,76	6,44
	T	6,76	44,77	0,559	69,1	0,381	9,76	1,07
	u	2,26	12,13	0,961	93,0	0,859	9,76	8,23
	v	6,45	42,78	0,535	68,0	0,360	9,76	2,24
	u, v	2,37	11,03	0,967	93,1	0,862	9,76	7,62
	T, u, v	2,41	11,26	0,966	92,5	0,849	9,76	7,58
	z, T, u, v	3,83	17,8	0,884	77,5	0,549	9,76	6,69
	z, T	3,99	20,9	0,884	83,1	0,662	9,76	6,47
	10 Анализ v в м/с							
6 ИП	z	3,84	14,34	0,874	81,1	0,623	9,14	6,32
	T	6,48	34,45	0,556	69,3	0,386	9,14	1,14
	u	6,13	32,74	0,571	67,6	0,352	9,14	2,25
	v	2,31	13,29	0,951	90,3	0,806	9,14	7,68
	u, v	2,35	11,82	0,961	89,9	0,798	9,14	7,22
	T, u, v	2,36	12,49	0,960	90,4	0,809	9,14	7,21
	z, T, u, v	3,62	13,18	0,881	77,4	0,548	9,14	6,57
	z, T	3,81	14,37	0,875	80,8	0,616	9,14	6,38

KEY:

1. Variant
2. Data used
3. ρ coin(cidence)
4. σ con(trol)
5. Sm(oothing)
6. IF (inertial forecast)
7. Analysis of z in dam
8. Analysis of T in °C
9. Analysis of u in m/sec
10. Analysis of v in m/sec

Method and Content of Numerical Experiments

The basic problem in the numerical experiments was the formulation of an approach to the joint assimilation of data on several meteorological elements on the basis of the optimum interpolation method and an investigation of the possibilities of reproduction of the field of meteorological elements, information on which is lacking, using information on other elements. The basis of the computations was formulas for optimum interpolation of deviations of meteorological elements from their values in the preliminary field represented in the preceding section. The experiments were carried out using the DST-6 archives prepared at the United States National Meteorological Center in connection with work on the program for investigating global atmospheric processes. These archives contain both observational data and the results of analysis by the NMC method.

One of the difficulties arising in checking the quality of the numerical analysis is related to the lack of a standard with which it would be possible to compare the results of the computations. As the standard we used the NMC analysis, which henceforth will be called the "control variant."

The computations were made within the framework of a one-level analysis and use was made of data for the 500-mb surface (temperature T, horizontal velocity components u, v and height z). Numerical experiments were organized in such a way that as a result of the computations it was possible to determine the fields of all the mentioned meteorological elements since the number of elements participating in the analysis ("exerting an influence") can be varied.

The observation network was relatively dense: the distance between the influencing stations and the the point of intersection to be analyzed was 400-600 km.

An important problem is choice of the preliminary field. It is desirable that the deviations of the observed values from the preliminary field be small. In other words, the preliminary field of meteorological elements must correspond quite well to their real values. On a practical basis this is difficult to achieve. Therefore, numerical experiments were carried out for two variants of the preliminary field. In one of them the deviations from the preliminary field were significant, in the second -- small.

In these variants the preliminary field was stipulated in the following way. We will use t_0 to denote the moment in time for which the analysis is computed. In the first case an inertial forecast for 24 hours was used, and specifically, the preliminary field was stipulated on the basis of observations at the time t_0 - 24 hours. We will call this the "IF" variant. In the second case the preliminary field was obtained by smoothing of NMC numerical analysis (variant "Sm").

It was assumed in the computations that the error in measuring the height of the isobaric surface is 1 dam, temperature — 1°C, horizontal velocity components -- 2 m/sec.

Results of Numerical Experiments

As t_0 we used 0000 GMT on 2 February 1976. In order to characterize the deviations of observational data from the preliminary field we use the value $\delta_i^*(F) = |F_i^{(obs)} - F_i^{(pre)}|$, where $F_i^{(obs)}$ and $F_i^{(pre)}$ are the observed and preliminary values of the meteorological element at the point i. We use the notations $\bar{\delta}^*$ and δ^*_{max} -- the mean and maximum δ^* values.

In the "IF" variant the deviations from the preliminary field were extremely significant. For example, for z $\bar{\delta}^* = 4.2$ dam, $\delta^*_{max} = 35.7$ dam there are 13% of the points with values $\delta^* > 8$ dam. The $\bar{\delta}^*$ and δ^*_{max} values are also large for the other meteorological elements. For a temperature $\bar{\delta}^*$ = 2°C, δ^*_{max} = 11°C; for u $\bar{\delta}^*$ = 9.9 m/sec, δ^*_{max} = 47 m/sec; for v δ^* = 6.4 m/sec, δ^*_{max} = 38.9 m/sec.

In the "Sm" variant the corresponding values are smaller, by at least an order of magnitude. For example, for z $\overline{\delta^*}$ = 0.2 dam, δ^*_{max} = 1.7 dam, for T $\overline{\delta^*}$ = 0.1°C, δ^*_{max} = 0.6°C, for u $\overline{\delta^*}$ = 0.4 m/sec, δ^*_{max} = 2.5 m/sec.

Now we will examine the results of the numerical experiments.

The analysis was made for a rectangular regular grid with the distance between points 300 km at 60°N. An evaluation of the results of the computations was made using 1,632 points of intersection in a regular grid situated in Europe, North America and the northern part of the Atlantic.

An evaluation was made by means of a comparison of the computed deviations of meteorological elements from the preliminary field ($F^{(A)}$) and the corresponding deviations in the control variant ($F^{(con)}$). In the evaluations we used a number of characteristics: correlation coefficient r, mean $\overline{\delta}$ and maximum δ_{max} values of the parameter

$$\delta_i = |F_i^{(A)} - F_i^{(con)}| \quad \text{(i is the number of the point),}$$

the distribution of the δ_i values by gradations, ρ_{coin} -- the ratio of the number of points at which there is a coincidence of the deviations $F^{(A)}$ and $F^{(con)}$ to the total number of points, $\rho = \rho_{coin} - \rho_{opp}$, where ρ_{opp} is the number of points with opposite signs of deviations, σ_A and σ_{con} -- the standard deviation for $F^{(A)}$ and $F^{(con)}$ respectively. Evaluations of the results of the numerical experiments for the IP and Sm variants are given in Table 1.

The data in Table 1 show with what accuracy it is possible to carry out a numerical analysis of the heights z of the 500-mb isobaric surface when using different sets of "influencing" meteorological elements. This table shows that some idea concerning the distribution of z can be obtained with definite success using the temperature field at the 500-mb surface. For example, in the IF variant the correlation coefficient r between the computed and control values of the deviations from the preliminary field was 0.65; the signs of the deviations coincided at 75% of the points.

A shortcoming in the restoration of z is that the amplitude of the deviations (see the σ_A and σ_{con} values) is considerably too low. As a result, the errors of the restored field were rather great. Although the $\overline{\delta}$ and δ_{max} values are less than the corresponding ($\overline{\delta^*}$ and δ^*_{max}) values in the initial data, and accordingly, the relative restoration error is less than unity, it is nevertheless about 0.9.

Computation of the z field on the basis of wind data gives somewhat better results. The correlation coefficient was 0.73; the signs coincided at 75% of the points. The amplitude of the computed deviations is closer to the observed value, although the σ_A value is low relative to σ_{con} by approximately a factor of two. The $\overline{\delta}$ and δ_{max} values were less than in the case of use of data only on temperature. It should be noted that computations with joint allowance for u and v gives results which are better than if use is made only of data on u or only on v.

Simultaneous allowance for data on temperature and wind leads to results which are somewhat better than in cases when these elements are taken into account separately. Thus, the correlation coefficient was equal to 0.78 and the signs coincided at 78% of the points. There was some improvement in the other evaluations of quality of the analysis. Similar results were also obtained in the Sm variant.

The conclusion can therefore be drawn that in the absence of data on the heights z the distribution of this meteorological element can be obtained with the above-mentioned accuracy on the basis of the temperature and wind measured in a relatively dense network of points.

Table 1 also gives evaluations of the quality of multivariate analysis for a case when in addition to data on the temperature and wind there are data on the height z. This table specifically gives information for a case when the analysis of z is made using data only on z (variant "z"), and for cases of joint use of data on z and on other meteorological elements. In these computations the values were used in a relatively dense network of points: the z values at four influencing points participated simultaneously in the analysis. These evaluations make it possible to compare the results in cases of a "univariate" analysis (computation of z using data only on z) and a multivariate analysis (in the computations data on other meteorological elements are used together with data on z).

It can be seen from Table 1 that joint allowance for data on z and T did not improve analysis of the z field. In the case of joint processing of data on heights, temperature and wind the quality of analysis of the heights z was somewhat improved in comparison with a univariate analysis. For example, in the Sm variant the correlation coefficient increased from 0.907 to 0.923, the maximum error became 0.62 dam in place of 0.86 dam, and there was an improvement in the ratio σ_A/σ_{con} (0.935 instead of 0.806). However, the percentage of coincidence of signs decreased from 88.2 to 84.5%. The relatively small positive contribution of the additional information is attributable to the fact that data on the main meteorological element (z) were available for a quite dense network of points. This agrees with the conclusion drawn by Schlatter, et al. [12] that allowance for the wind does not give an explicit improvement in the analysis of heights of the isobaric surfaces. The results obtained by Schlatter were for a region with a rather dense network of stations in the United States.

However, the picture changes considerably if there are few stations with data on z. As an illustration of this, Table 2 gives the results of a numerical experiment in the case of a thin network of stations with data on z, and specifically, when only one influencing station with data on z participates in the computation. The first line in Table 2 gives evaluations of the analysis with the use of data on z at one point; the second line -- evaluations of an analysis with the joint use of data on z at one influencing point and data on T, u, v in a dense network (four points with the values of each element). It can be seen that allowance for data on T, u, v within the framework of multivariate analysis led to a definite improvement in the results: the mean error was reduced from 3 to 2 dam, the maximum decreased from 21.3 to 12.2 dam, the correlation coefficient increased from 0.83 to 0.93, etc. The evaluations came close to the evaluations of an analysis with a dense network of points with data on z (see Table 1).

Table 2

Evaluations of Analysis of z in Case of Thin Network With Data on z in IF Variant

Использованы данные о метеоэлементах 1	$\bar{\delta}$ дам 2	δ_{max} дам 2	r	ρ_c % 3	ρ	σ_K 4	σ_A
z	2,96	21,3	0,826	81,3	0,625	6,74	3,65
z, T, u, v	1,99	12,2	0,934	85,4	0,708	6,74	5,09

KEY:

1. Use of data on meteorological elements
2. dam
3. coin
4. con

Now we will proceed to the results of computation of the temperature field. The corresponding evaluations of quality of the analysis are given in Table 1. The data in this table indicate the possibility of using data on heights for determining the temperature field. In the considered case the results are characterized by a correlation coefficient of about 0.6. However, an analysis with the joint use of data on T, z, u, v did not lead to a significant change in the evaluations in comparison with computation based only on temperature data and even somewhat worsened them. This is evidently attributable to the fact that the computations were made for a dense network.

Evaluations of the accuracy in analysis of the wind field are presented in Table 1. This table shows that in the absence of data on the wind the wind field is relatively well restored on the basis of data on the heights of the isobaric surface. For example, in the IF variant the quality of analysis of the velocity component u is characterized by a correlation coefficient r = 0.88; the percentage of points with a coincidence of signs is ρ_{coin} = 83.2%; the mean absolute error is $\bar{\delta}$ = 4 m/sec. The same results were obtained in an analysis of v. The joint use of data on heights and temperature insignificantly improved evaluations of quality of the analysis.

Computations of wind on the basis of data on only this element gives good results in the case of a dense network (in the IF variant r = 0.96; $\overline{\delta}$ = 2.3 m/sec). Joint allowance for data on u and v gives a result somewhat better than when using these components separately. Joint processing of data on z, T, u and v reduced the quality of the wind analysis. This is possibly attributable in part to the fact that when there is a dense network the data on the other elements were excess, and in part to a not very reliable choice of the cross-covariation functions and the values of the measurement errors.

In summarizing what has been said, it should be noted that the results presented above are evidence of a positive effect of a multivariate analysis and can serve as a basis for realizing a scheme for multivariate four-dimensional analysis. In addition, additional work must be done on study of the statistical structure of the deviations of meteorological elements from the preliminary field and on the choice of parameters characterizing the fields of deviations and entering into the computation formulas, on refining the method for joint use of data at different levels of the atmosphere and on evaluation of the role of asynchronicity of observations, etc.

In conclusion the author expresses appreciation to Ye. L. Metelitsa for assistance in making the computations and A. M. Gofen, who kindly furnished a library of programs for work with the DST-6 archives.

BIBLIOGRAPHY

1. Belousov, S. L., Gandin, L. S., Mashkovich, S. A., OBRABOTKA OPERATIVNOY METEOROLOGICHESKOY INFORMATSII S POMOSHCH'YU EVM (Processing of Operational Meteorological Information Using an Electronic Computer), Leningrad, Gidrometeoizdat, 1968.

2. Veyl'. I. G., Kordzakhiya, G. I., Mashkovich, S. A., Sonechkin, D. M., "Dynamic-Statistical Approach to Continuous Assimilation of Asynchronous Data," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 6, 1976.

3. Gandin, L. S., OB"YEKTIVNYY ANALIZ METEOROLOGICHESKIKH POLEY (Objective Analysis of Meteorological Fields), Leningrad, Gidrometeoizdat, 1963.

4. Lugina, K. M., Kagan, R. L., "On the Problem of Spatial-Temporal Analysis of the Pressure Field," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 336, 1974.

5. Gubanova, S. I., Mashkovich, S. A., Metelitsa, Ye. L., "Numerical Analysis of Meteorological Fields Using Satellite Data," METEOROLOGIYA I GIDROLOGIYA, No 1, 1979.

6. STATISTICHESKAYA STRUKTURA METEOROLOGICHESKIKH POLEY (Statistical Structure of Meteorological Fields), edited by L. S. Gandin, et al., Budapest, 1976.

7. Metelitsa, Ye. L., "Four-Dimensional Analysis of Data from Asynchronous Observations," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 197, 1977.

8. Lorenz, A., Rutherford, J., Larsen, G., "The ECMWF Analysis and Data Assimilation Scheme: Analysis of Mass and Wind Fields," ECMWF, TECHN. REP., No 6, 1977.

9. McPherson, R. D., Bergman, K. H., et al., "Global Data Assimilation by Local Optimum Interpolation." 3d CONFERENCE ON NUMERICAL WEATHER PREDICTION, American Meteorol. Soc., April 1977.

10. Rutherford, J. D., "An Operational Three-Dimensional Multivariate Statistical Objective Analysis Scheme," PROC. I.O.S. STUDY GROUP CONFERENCE ON FOUR-DIMENSIONAL DATA ASSIMILATION, Paris, Nov 1975.

11. Schlatter, T. W., "Some Experiments With a Multivariate Statistical Objective Analysis Scheme," MON. WEATHER REV., Vol 103, No 3, 1975.

12. Schlatter, T. W., Branstator, G. W., Thiel, L. G., "Testing a Global Multivariate Statistical Objective Analysis Scheme With Observed Data," MON. WEATHER REV., Vol 104, No 6, 1976.

UDC 551.(509.314+54.543)

POSSIBILITY OF REMOTE SENSING OF THE RELATIVE HEIGHTS OF THE PRINCIPAL ISOBARIC SURFACES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 15-21

[Article by Candidate of Physical and Mathematical Sciences O. M. Pokrovskiy and S. G. Denisov, Leningrad State University and Main Geophysical Observatory, submitted for publication 5 September 1979]

Abstract: The authors propose and validate a scheme for remote sensing of the geopotential field on the basis of the pseudoinversion method. The article examines the problem of choice of the optimum spectral intervals. Optimum measurement schemes are given for the 15-μm CO_2 absorption band applicable to the H_{500}, H_{300}, H_{700} fields. It is shown that in order to derive information concerning variations of the mentioned fields it is necessary to have no more than four measurement channels. The error levels in remote sensing of the heights of the principal isobaric surfaces are given when using a different number of optimum measurement channels. The relative nondependence of the optimum measurement scheme on the level of measurement error and the type of a priori statistical information is clarified.

[Text] Progress in the use of observational data from meteorological satellites is determined to a considerable degree by the effectiveness in obtaining and analyzing quantitative information on the fields of the most important meteorological elements. The problem of remote thermal sensing of the atmosphere and the underlying surface is one of the most timely. At the present time data on relative geopotential are obtained through the intermediate stage of restoration of the temperature field on the basis of the results of remote measurements [6]. In this article we discuss the possibility of constructing a simple computation scheme, making it possible to obtain evaluations of relative geopotential, bypassing the traditional procedure of solution of the inverse problem for determining the vertical distribution of temperature. On the basis of the formulated approach, we will examine the problem of optimum choice of spectral intervals for remote sensing of fluctuations of the geopotential field. The results of computations using the mentioned scheme are given for the 15-μm CO_2 absorption band. Sets of optimum spectral intervals are obtained and the errors of the proposed method are indicated in the case of the most important isobaric surfaces H_{500}, H_{300} and H_{700}.

Mathematical Aspects of Problem

In solving the inverse problem it is common to use a linearized form of the transfer equation, written in terms of deviations from the mean temperature $\Delta T = T - \bar{T}$ and radiation $\Delta L = L - \bar{L}$ values:

$$\Delta L(\nu) = \frac{\partial B_\nu}{\partial T}[\bar{T}(p_s)]\,\tau_{\Delta\nu}(p_s)\,\Delta T(p_s) - \int_0^{\ln p_s} \frac{\partial B_\nu}{\partial T}[T(p)]\,\Delta T\,\frac{\partial \tau_{\Delta\nu}}{\partial \ln p}\,d\ln p. \quad (1)$$

Here $\tau_{\Delta\nu}(p)$ is the atmospheric transmission function for the layer from the upper boundary to the level with the pressure p in the spectral interval with its center at the frequency ν; $B_\nu[T(p)]$ is the Planck function for the emission of an ideally black body at the temperature T(p) for the frequency ν.

Thus, the problem is reduced to a determination of $\Delta T(p)$ using data on $\Delta L(\nu)$. In the presence of a profile of the mean $\bar{T}(p)$ values the problem of determining the geopotential of an isobaric surface with the pressure $\tilde{p}$ is reduced to an evaluation of the corresponding deviations using the formula

$$\Delta H(\tilde{p}) = c\left[\int_{\ln\tilde{p}}^{\ln p_s} \Delta T(p)\,d\ln p + \bar{T}_v(p_s)\,\Delta\ln p_s\right]. \quad (2)$$

Here $\bar{T}_v$ is the mean virtual temperature.

Since the remote sensing method does not make it possible to monitor variations of surface pressure $\Delta\ln p_s$ characterizing the second term in [2], we will examine the problem of evaluating the first term

$$\Delta H^0(\tilde{p}) = c\int_{\ln\tilde{p}}^{\ln p_s} \Delta T(p)\,d\ln p, \quad (3)$$

representing the deviation of the relative geopotential of the isobaric surface with the pressure $\tilde{p}$.

Since (1) and (3) are linear functionals of one and the same function $\Delta T(p)$, it is clear that the $\Delta H^0(\tilde{p})$ value can be directly expressed through $\Delta L(\nu)$, bypassing $\Delta T(p)$. We will examine the necessary transformation, which is accomplished after algebraization of (1) and (3). The replacement of (1) and (3) by approximating expressions containing vectors and matrices leads to the following matrix equations:

$$\Delta L = A \cdot \Delta T, \quad (4)$$

$$\Delta H^0(\tilde{p}) = [r(\tilde{p})]^* \cdot \Delta T \quad (5)$$

(* is the transposition symbol). Here $\Delta L = (\Delta L(\nu_1)\ldots, \Delta L(\nu_m))^*$; $p_n = p_s$, A is the matrix m x n. The vector $r(\tilde{p})$ has the form $r(\tilde{p}) = c \cdot (c_1, \ldots, c_k, 0, \ldots, 0)^*$ under the condition that $\tilde{p} = p_k$, c_i are quadrature coefficients used in approximation of the integral in (3). The perturbed system, describing satellite observations, is rewritten in the form

$$\Delta \tilde{L} = A \cdot \Delta T + \varepsilon. \quad (6)$$

Here ε is the vector of measurement errors. We will assume that ε is a random Gaussian vector with zero mean values of the components and the known covariation matrix K^2_ε. According to [1], the best linear unbiased evaluation (BLUE) $\Delta \hat{H}^0$ for (5) on the basis of a model of measurements (6) is determined using the formula

$$\Delta \hat{H}^0 = \hat{q}^* \cdot \Delta \tilde{L}, \quad (7)$$

where

$$\hat{q} = (I - \bar{K}^+_\varepsilon \cdot K_\varepsilon) \cdot (A^+)^* \cdot r. \quad (8)$$

Here the K_ε matrix is a positive square root of K^2_ε. In addition, $\bar{K}_\varepsilon = K_\varepsilon \cdot (I - A \cdot A^+)$. The BLUE coincides with the evaluation of the least squares (ELS), with which $\tilde{q} = (A^+)^* \cdot r$ then and only then [1] when the following expression is correct

$$\bar{K}^+_\varepsilon \cdot \bar{K}_\varepsilon = \bar{K}^+_\varepsilon \cdot K_\varepsilon. \quad (9)$$

Since $I - A \cdot A^+$ is a projector onto the subspace $N(A^*)$, being the zero-space of the matrix A^*, then the correctness of (9) is ensured by the undegenerate character of the K_ε operator within the $N(A^*)$ limits. It appears that for problems involved in the processing of the results of observations the formulated requirements are usually satisfied. In actuality, the standard assumption that $K^2_\varepsilon = \mathrm{diag}(\sigma^2_1, \ldots, \sigma^2_m)$, $(\sigma^2_i > 0)$ guarantees the undegenerate nature of K^2. In the computations we used the still more frequent assumption that $K^2_\varepsilon = \sigma^2 \cdot I$, which corresponds to a measurement system with a set of equally precise radiation detectors.

In addition, within the framework of the algorithm for optimization of the measurement scheme [3] there is always assurance of choice of a minimum number of linearly independent rows of the A matrix [6]. In the case of a linear nondependence of the A rows the expression $N(A^*) = \{0\}$, which, in turn, transforms (9) into identity, satisfied with any K_ε.

Thus, in examining the group of problems of interest to us BLUE (8) always coincides with the ELS, for which the q vector has the quite simple form

$$\tilde{q} = (A^+)^* \cdot r. \tag{10}$$

The solution of problem (4) has the following general form:

$$\Delta T = A^+ \cdot \Delta L + s. \tag{11}$$

Here s is an arbitrary vector of the linear set N(A). Formula (11) reflects the fact that the vector space ΔT is broken down into the direct sum of the subspaces N(A) and $R(A^*)$. $R(A^*)$ is the transform of the A^* operator. By analogy with (11) it is possible to write an expression for the linear functional ΔH^0 from (5). Since the ELS for the functional of the solution of problem (7) is determined by the choice of the vector q using formula (10), its deviation from the true value can be written in the following way:

$$\Delta H^0 - \Delta \hat{H}^0 = r^* \cdot P \cdot \Delta T - r^* \cdot A^+ \cdot s. \tag{12}$$

In (12) use is made of the fact that $s = P \cdot \Delta T$, where $P = I - A^+ \cdot A$ is the projector onto N(A).

The components of the q vector describe the distribution of information on ΔH^0 in the spectrum. Formula (7) indicates that the variations of relative geopotential are always proportional to variations of some integral spectral characteristic of the radiation.

We will note some peculiarities of the ELS approach. The used evaluations do not require a priori statistical information on the solution. In order to obtain the ELS of fluctuations of the H field there is no need to carry out multistep computations used at the present time in operational practice [6, 7]. The weighting vector q must be computed in advance. The simplicity of formula (7) indicates the possible prospects for constructing a specialized optical system realizing spectral integration of radiation intensity $\Delta \tilde{L}$ with the weight q and providing direct evaluations of fluctuations of the geopotential field.

In the practical realization of the proposed method a highly important problem is that of the optimum choice of a set of spectral intervals for obtaining the best evaluations of the heights of the standard isobaric surfaces. The next part of the study is devoted to a discussion of this problem.

Computing the dispersion (12), taking into account that the components of the ΔT and ε vectors are statistically independent, we obtain

$$\hat{\sigma}^2(\Delta H^0) = r^* \cdot P \cdot K_T^2 \cdot P \cdot r + r^* A^+ \cdot K_\varepsilon^2 \cdot (A^+)^* \cdot r. \qquad (13)$$

Here K_T^2 is the ΔT covariation matrix.

Now we will discuss the terms of the dispersion $\sigma^2(\Delta H^0)$. The first term on the right-hand side of (13) characterizes the mean variations of geopotential caused by fluctuations of the ΔT projection onto the zero space of the A operator. This component of the ΔT fluctuations is such that it contains no information on the $\Delta \tilde{L}$ signal. The second term in (13) is related to the measurement errors. In the case of uncorrelated observation errors $K_\varepsilon^2 = \sigma_\varepsilon^2 \cdot I$ expression (13) assumes the simpler form

$$\hat{\sigma}^2(\Delta H^0) = r^* \cdot P \cdot K_T^2 \cdot P \cdot r + \sigma_\varepsilon^2 \cdot r^* (A^* \cdot A)^+ \cdot r. \qquad (14)$$

Now the problem of optimizing the choice of spectral intervals is naturally related to minimizing of the dispersions of evaluation of geopotential (13) or (14). It is clear that with an increase in the number of measurement channels m the first term on the right-hand side of (13)-(14) decreases (due to a decrease in the dimensionality of zero space of the A operator); the second term at first also decreases and then sharply increases (due to a worsening of conditionality of the matrix $A^* \cdot A$). We note that the "relative weight" of the terms changes in dependence on the level of the errors in initial data σ_ε^2. Thus, it is possible to count on obtaining an optimum with finite m.

Realization of Optimization Method

Since in the proposed approach the usual procedure for solving the inverse problem has been replaced by an algorithm for single computation of the components of the q vector, the center of attention shifts to an examination of the problem of optimization of the measurement scheme. As an illustration of the possibilities of this method we examined the problem of determining the optimum set of spectral intervals in the 15-μm CO_2 absorption band for remote sensing of fluctuations of the relative heights of the isobaric surfaces H_{300}, H_{500}, H_{700}. Computations of the components of the A operator require stipulation of the atmospheric transmission functions. We used computation data furnished through the courtesy of the authors of [5]. These materials corresponded to the spectral region 600-770 cm^{-1} with an interval 0.5 cm^{-1} and a resolution 1 cm^{-1}. The covariation matrix K_T^2 was taken from [8]. The functional (14) was initially optimized using a scheme for successive choice of the spectral intervals [3]. The preliminary stage in the investigation indicated that the optimum number of spectral intervals does not exceed three for each of the considered isobaric surfaces. With a further increase in the number of spectral intervals the dispersion of the evaluation $\hat{\sigma}^2$ increased sharply. Therefore, a real possibility appeared for carrying out optimization by direct trial and error. These computations indicated that both methods (successive and direct trial and error) in most cases lead to identical results.

Principal Characteristics of Optimum Measurement Scheme

Поле 1	Эффективное число каналов зондирования 2	Центры спектральных интервалов, $см^{-1}$ 3	4 Характеристики эффективности зондирования				Компоненты вектора 5 q
			$\hat{\sigma}_1^2$ $м^2$	$\hat{\sigma}_2^2$ $м^2$	$\hat{\sigma}^2/\sigma^2$	$\hat{\sigma}$ м	
H_{500}	2	723	108	2335	0,37	49	21,6
		743	107	1436	0,23	39	10,1 13,6
H_{300}	3	723	254	6297	0,35	81	35,5
		717	552	3530	0,22	64	15,7 21,4
		708	556	3053	0,19	60	18,8 15,7, 3,2
H_{700}	1	723	347	332	0,34	26	8,1

KEY:
1. Field
2. Effective number of sounding channels
3. Centers of spectral intervals, cm^{-1}
4. Characteristics of sounding effectiveness
5. Components of q vector

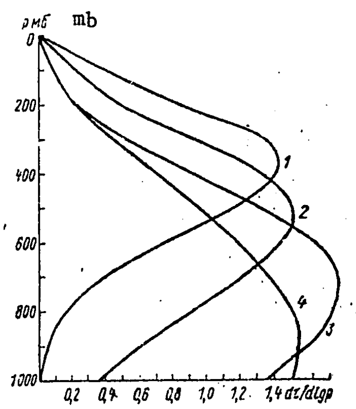

Fig. 1. Weighting functions $d\tau_\nu / d \lg p$ for sounding frequencies: 1) 708 cm^{-1}; 2) 717 cm^{-1}; 3) 723 cm^{-1}; 4) 743 cm^{-1}.

The most important characteristics of the optimum measurement schemes are given in the table. The results indicate that remote sensing of the three most important isobaric surfaces does not require more than four measurement channels centered at ν = 723, 708, 717, 743 cm^{-1}. The channel ν =

723 cm^{-1} is the most important. The multiple correlation coefficient $1 - \hat{\sigma}^2/\sigma^2$ between the ΔL fluctuations in this channel and ΔH^0 always exceeds 60%.

Due to the finite "vertical resolution" of the corresponding weighting functions $\partial \tau_{\Delta\nu}/\partial \ln p$ (see figure) the number of necessary channels increases only with an increase in the thickness of the sensed atmospheric layer. In the sensing of H_{300} and H_{500} the contribution of the second spectral interval to the value of the multiple correlation coefficient is about 15%. The "information weight" of the third channel for H_{300} is still less appreciable and equal to approximately 3%.

Now we will examine the absolute errors of the proposed method. The cited computation results correspond to a level of measurement error constituting 2.5 erg/(cm^2·sec·mean·cm^{-1}). This corresponds to a relative level of measurement error equal to 5%. The $\hat{\sigma}_1^2$ dispersions (first term in (14)), related to fluctuations of the temperature profile ΔT which cannot be monitored during remote sensing, are small in comparison with the $\hat{\sigma}_2^2$ dispersions (second term in (14)), governed by the measurement errors. Hence, from the form of (14) it follows that there is a weak dependence of the method on the type of the a priori covariation matrix K_T^2. An exception is H_{700}. Accordingly, the results of the optimization procedure are determined completely by the behavior of $\hat{\sigma}_2^2$ in dependence on the number of measurement channels. An increase in the number of spectral intervals in comparison with those cited in the table leads to an increase in the $\hat{\sigma}^2$ values.

The errors in determining the H_{500}, H_{300}, H_{700} elements are 40, 60, 25 m respectively. In the case of small measurement errors (1%) it is possible to indicate the following levels of evaluation errors: 22, 37, 18 m.

We note that our computations indicate an absence of any dependence of the optimum measurement scheme on the level of error in initial information σ_ε in the range from 1 to 10%. This circumstance ensures invariance of the q coefficients cited in the table. The practical realization of this approach requires an examination of the problem of optimum spectral resolution, that is, the width of the selected spectral intervals.

Summary

The measurement scheme and the interpolation formulated above differ substantially from the traditional approach assuming a solution of the inverse problem applicable to each subsatellite point. The method which we proposed essentially involves a very simple operation -- computation of the scalar product of vectors with a dimensionality not exceeding 3. This simplification of solution of the problem is fundamental. In this case there is a real possibility of obtaining evaluations of geopotential in an operational regime directly aboard a meteorological satellite. We examined the case of a cloudless atmosphere. In the IR range ordinary difficulties arise

when clouds are present. Accordingly, the advantages of the considered approach should be particularly great when using microwave measurement instruments. In this case the presence of very simple computers in the on-board instrument package can ensure not only the determination of the geopotential fields in the grid, but also the transformation of this information to a more compact form by means of expansion of the fields in a system of orthogonal functions on a sphere or hemisphere and the transfer of the corresponding data for use in numerical forecasting after carrying out initialization. The use of harmonic analysis operations is valid because in the approach which we have proposed the observation equation is scalar and has (in contrast to the initial system (6)) a simple structure. In this case the measured value is equal to the sum of the statistically independent signal and noise with known stochastic characteristics. Therefore, remote observations have no fundamental differences from the aerological sounding data, other than presence of spatial correlation of the errors (noise) [2, 7]. We note that the smoothing of the spatially correlated errors in remote sensing data can be accomplished using adequate filtering procedures [4].

BIBLIOGRAPHY

1. Albert, A., REGRESSIYA, PSEVDOINVERSIYA I REKURRENTNOYE OTSENIVANIYE (Regression, Pseudoinversion and Recurrent Evaluation), Moscow, Nauka, 1977.

2. Denisov, S. G., Pokrovskiy, O. M., "Correction of an Optical Model of the Atmosphere in Solving the Problem of Thermal Sounding," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences, Physics of the Atmosphere and Ocean), Vol 13, No 10, 1977.

3. Pokrovskiy, O. M., "Optimum Conditions for Indirect Sounding of the Atmosphere," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA, Vol 5, No 12, 1969.

4. Pokrovskiy, O. M., "Optimum Statistical Procedures for Spatial-Temporal Assimilation of Meteorological Information," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 7, 1975.

5. Timofeyev, Yu. M., Deler, V., Shpenkukh, D., "Comparison of Computed and Experimental Transmission Functions for CO_2 in the 15-μ-Band," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA, Vol 13, No 6, 1977.

6. Halem, M., Ghil, M., Atlas, R., Susskind, J., "The GISS Sounding Temperature Impact Test," NASA TECHN. MEM. 78063, Goddard Space Flight Center, Md., 1978.

7. Schlatter, T. W., Branstator, G. W., "Errors in Nimbus-6 Temperature Profiles and Their Spatial Correlation," PREPRINT NCAR, Ms. 78/0501 -1, 1978.

8. Spankuch, D., Dohler, W., "Statistische Charakteristik_ der Vertical-profile von Temperature und Ozone und ihre Kreuzkorrelation uber Berlin," GEOD. GEOPHY. VEROFF., B 11, H 19, 1975.

UDC 551.509.6

METHOD FOR DETERMINING THE ICE-FORMING ACTIVITY IN A DIFFUSION CHAMBER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 22-29

[Article by Candidate of Chemical Sciences B. Z. Gorbunov, N. A. Kakutkina, Candidate of Technical Sciences K. P. Kutsenogiy and N. M. Pshenichnikov, Institute of Chemical Kinetics and Combustion, submitted for publication 19 September 1979]

Abstract: It is shown that the usually employed method for taking into account the volume effect during the appearance of ice-forming particles in a diffusion chamber can lead to very great errors in the measured values of the fraction of active particles. Another method is proposed for determining the true ice-forming activity, based on the fact that there can be no volume effect when there is a zero quantity of ice crystals.

[Text] In an investigation of the mechanism of ice formation on foreign particles it is extremely useful to have data on the influence of supersaturation on ice-forming activity. In studying the influence of supersaturation the diffusion chamber method is used. In this method the particles are first sampled from the aerosol flow on a backing and then appear in a diffusion chamber with a known supersaturation. In this procedure the sample is cooled to a stipulated temperature. Then a supersaturation is created over it relative to the ice by heating the ice surface situated nearby and after some time the number of forming ice crystals is counted.

A peculiarity of the diffusion chambers method is that the reagent particles on the backing are situated considerably closer to one another than in a cloud or fog. In this procedure the water vapor arriving from the heated ice surface does not suffice for developing all the ice nuclei [9, 10]. As a result, the measured value of the concentration of ice nuclei is dependent on the number of nuclei in the sample (the so-called vapor depletion, bulk or volume effect) [3, 6-8, 10-11].

In order to clarify what the volume effect is dependent on, Lala and Jiusto [10] carried out model computations of supersaturation in a chamber of the diffusion type. This analysis indicated that in general the supersaturation level in the chamber differs from an equilibrium level, determined by the expression

$$S_w = \frac{P_i\,(T+\Delta T)}{P_w\,(T)}, \tag{1}$$

where P_i is equilibrium pressure of water vapor over a plane surface ice -- source of vapor with a temperature of the upper plate in the chamber $T + \Delta T$, P_w is the equilibrium pressure of vapor over a plane water surface with a temperature of the lower chamber plate with the sample T.

The water vapor, arriving from the upper plate, is expended on the lower plate on the formation and growth of crystals and water droplets. As a result, the effective supersaturation on the lower plate is lower than that determined using formula (1). According to [10], the true supersaturation in the chamber differs from that determined using formula (1) to a greater degree the greater is the concentration of the hygroscopic nuclei and ice crystals in the filter. Thus, the use of formula (1) is possible only with sufficiently small concentrations of condensation nuclei and crystallization levels.

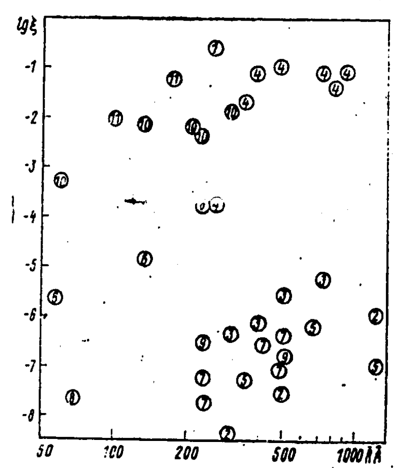

Fig. 1. Fraction of active particles of silver iodide in dependence on their mean radius obtained by different authors in diffusion chambers with T = -16°C and S_w = 100% with different mean radii of particles. 1) [12], 2) [4], 3, 4) [5], 5) [11], 6) [7], 7-9) [13], 10, 11) [12].

In an investigation of artificial aerosols hygroscopic nuclei can be completely dispensed with. However, the forming ice crystals nevertheless will decrease the supersaturation in the chamber. The influence of the depletion effect, related to the growth of ice crystals, can be very great on the measured ice-forming activity. The scale of this influence can be estimated from Fig. 1, which gives the fraction of active particles (ξ) of silver iodide in dependence on the mean size of the particles measured in different diffusion chambers. The scatter of data is eight orders of magnitude ξ. For cloud chambers the scatter of these same data is only one order of magnitude ξ. A scatter of the value by eight orders of magnitude makes it impossible to use diffusion chambers without taking the vapor depletion effect into account. Therefore, it is necessary to have a procedure which makes it possible to take this effect into account in each specific case.

Such a procedure was proposed in a study by Huffman and Vali [8]. The essence of the procedure is that on the basis of several measurements of the concentration of ice nuclei (C) in dependence on the sample volume (V) there is extrapolation to a zero volume, where there can be no depletion effect. An extrapolation law was derived in [8] on the assumption that around each growing ice crystal there is a deactivation region whose extent is not dependent on the number of nuclei in the sample.

In order to be convinced of the correctness of their assumptions, the authors of [8] compared the theoretical and experimental dependences of the concentration of ice nuclei on the air volume passing through the filter. However, the experimental dependence of the concentration of ice nuclei on volume was obtained in a very narrow range of volumes (the volume changed by a factor of four) and, in addition, with such volumes in which the depletion of vapor is still very significant. As will be demonstrated below, this can lead to very great errors in determining the region of deactivation around the crystal, and accordingly, true ice-forming activity.

Thus, the correctness of the method for taking into account the volume effect proposed by the authors of [8] was not experimentally substantiated.

The purpose of this study is an experimental investigation of the effect of vapor depletion and the development of a procedure making possible a correct determination of the ice-forming activity of aerosols in the diffusion chamber.

Experimental Part

A study of the vapor depletion effect was made using silver iodide aerosols. The method for obtaining silver iodide aerosols and determining their characteristics was described in detail in [1]. The aerosol was sampled using a thermoprecipitator [1] on glass with a hydrophobic surface. A hydrophobic surface was created by placing the glass in organosilane [14]. On glass with such a coating there is no condensation right up to supersaturation relative to water S_w = 1.03-1.04.

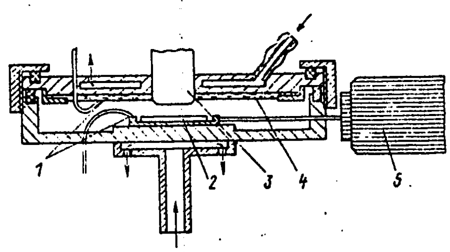

Fig. 2. Diagram of diffusion chamber. 1) thermocouples, 2) glass with sample, 3) microscope objective, 4) ice layer, 5) sample holder

A study of the influence of supersaturation on the probability of ice formation was made in a diffusion chamber which consists of two parallel horizontal plates with a diameter of 80 mm (Fig. 2). The distance between the plates is 5 mm; the lower plate has a projection along which a sample holder with a glass slides. In order to improve heat transfer between the holder and the glass a thin layer of silicone oil is poured between them. A sheet of aluminum foil with a thickness of about 50 μm is attached to the upper plate in the chamber in order to decrease the temperature gradients; a layer of ice is frozen to this plate. The temperature of the ice surface and the glass was monitored using copper-constantan thermocouples with a junction measuring $\approx$ 0.3 mm. The error in measuring temperature is 0.07°C. The chamber was cooled by the vapor of liquid nitrogen independently for the upper and lower plates. The maximum temperature difference along the lower plate was less than the error in determining temperature (0.07°C), and along the upper plate was 0.13°C. The supersaturation in the chamber was determined using formula (1). The formation and growth of ice crystals was observed using a NU-2 (Karl Zeiss) microscope.

The error in determining supersaturation was evaluated on the basis of the accuracy in determining the maximum gradients. This value was about 2%.

The real supersaturation in the chamber can differ from that computed using formula (1) not only due to the temperature gradients, but also as a result of water vapor losses in the chamber. In the absence of ice crystals, these losses can be accounted for by the chamber walls, the glass and the condensation nuclei present in the chamber. Accordingly, prior to the onset of work in the diffusion chamber the absence of "extraneous" losses was checked. This was done by using the dew point, that is, by the regular registry of supersaturation at the time of appearance of water droplets on glass without a hydrophobic covering. This supersaturation must correspond to S_w = 100%. The experiment gave S_w = 100±1% for the dew point. This indicates an absence of extraneous losses and makes it possible to set the supersaturation correctly.

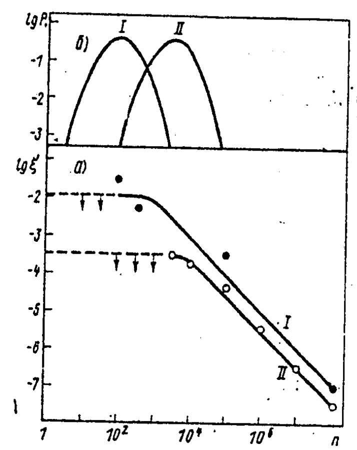

Fig. 3. Dependence of the measured fraction of active particles (a) and probability of formation of last ice crystal with a quantity of particles in the sample n (b) on the number of particles in the sample. I corresponds to $\xi = 10^{-2}$, II corresponds to $\xi = 3 \cdot 10^{-4}$.

The measure of the experimentally observed ice-forming activity of particles (ξ') was the ratio of the total number of forming ice crystals (N_{ice}) to the number of aerosol particles (n) precipitated on the glass (n).

$$\xi' = N_{ice}/n. \qquad (2)$$

Results and Discussion

The depletion of a source of water vapor in the presence of ice crystals has this result: the measured fraction of active particles (ξ') is dependent on the number of particles in the sample. Such dependences were obtained experimentally. Typical dependences are illustrated in Fig. 3a. In order to obtain these dependences we took a number of samples with a different concentration of precipitated particles and for each sample we determined N_{ice} and then $\xi'(n)$. The true ice-forming activity can be determined from the dependence $\xi'(n)$. This could be done most simply by using the procedure proposed by Huffman and Vali [8]: using the segment of the $\xi'(n)$ curve, determine the extent of the deactivation region around the crystal and then extrapolate the curve to n = 0, where the depletion effect cannot exist. For this we rewrite the extrapolation law in terms of ξ and n derived in [8]:

$$\xi' = \xi\left(1 - \frac{\pi r^2}{A}\right)^{\xi' n}. \quad (3)$$

Here A is the total area of the sample, in our case equal to 60 mm^2, r is the deactivation radius.

However, in an attempt to apply this procedure to the experimentally derived dependences $\xi'(n)$ it was found that the extent of the deactivation region and also the true ice-forming activity ξ are highly dependent on from what segment of the ξ'-n curve they are determined. In order to confirm this we will turn to the ξ values cited below, computed using different pairs of points taken on the curve II in Fig. 3a. The coordinates of the four experimental points used were as follows: 1) $n = 3\cdot10^3$, $\xi' = 3.3\cdot10^{-4}$; 2) $n = 10^4$, $\xi' = 2\cdot10^{-4}$; 3) $n = 10^5$, $\xi' = 4\cdot10^{-5}$; 4) $n = 10^6$, $\xi' = 3\cdot10^{-6}$.

True Ice-Forming Activity ξ, Computed from Different Pairs of Experimental Points

No of points	1-2	1-3	1-4	2-3	2-4	3-4
ξ	$7\cdot10^{-4}$	$1.6\cdot10^{-4}$	$3.2\cdot10^{-3}$	10^{-3}	0.79	$1.5\cdot10^{-9}$

As indicated above, the ξ values, computed using different pairs of points on one and the same experimental ξ'-n curve, differ by nine orders of magnitude of the ξ parameter. The ξ value, computed using points 3 and 4, in general contradicts the observed dependence of ξ' on n. In actuality, if $\xi = 1.5\cdot10^{-9}$, with $n = 10^4$ there should be $1.5\cdot10^{-9}\cdot10^4 = 1.5\cdot10^{-5}$ ice crystals, that is, $N_{ice} = 0$. In the experiment, however, two ice crystals appear. Thus, the procedure for taking into account the vapor depletion effect proposed in [8] cannot be used in determining ξ.

Two reasons can be advanced for the unsoundness of the procedure. First, it is possible that the theoretically derived extrapolation law (3) does not correspond to the experimental dependence $\xi'(n)$. The extrapolation law (3) was derived on the assumption that the regions of deactivation of adjacent ice crystals do not intersect, that is

[π = ice]

$$\frac{\pi r^2 N_{л}}{A} \ll 1. \quad (4)$$

Now we will check the satisfaction of this expression for the experimental $\xi'(n)$ curves. For this purpose we will select two pairs of values n and ξ' on the curve II in Fig. 3a, for example, $n = 10^5$, $\xi' = 2.5\cdot10^{-5}$ and $n = 10^6$, $\xi' = 3\cdot10^{-6}$. After substituting these values into (3) we find that the ratio $(\pi r^2/A) = 0.95$. Thus, even with the minimum $N_{ice} = 1$ expression (4) is not satisfied. The second possible reason for the unsoundness of this procedure is in the very character of the dependence of ξ' on n. This can be confirmed by examining the dependence of ξ' on n, cited in Fig. 3a. In the region of large n these curves, corresponding to substantially different ξ^* values, differ very little, by less than a factor of three. [The procedure for determining ξ will be described below.] Therefore, small errors in determining ξ' in this region during extrapolation can lead to great errors in the values. Thus, despite the simplicity and the ease of application of the method for taking into account the depletion effect proposed in [8], the errors arising in its use make its practical employment impossible.

In this connection, in this study we propose another procedure for estimating the true ice-forming activity. It is based on the fact that the depletion effect cannot occur in the absence of ice crystals. The essence of this procedure is as follows. With a gradual decrease in n by one and the same number of times, for example, by a factor of three, there is registry of the minimum number of particles in the sample with which ice crystals are still formed. With a further decrease in n crystals are not formed in the sample during one experiment since due to the small number of particles the probability of appearance of an ice crystal becomes $\ll 1$.

Now we will examine the dependence of ξ' on n in greater detail. We will discriminate two regions of n values: with large n there are ice crystals; with small n there are no ice crystals. The minimum number of aerosol particles precipitated onto the glass with which at least one ice crystal is still observed is denoted n_i, whereas the greatest number of crystals with which crystals are not observed is designated n_{i-1}.

The number of ice crystals observed with n_i by definition is equal to

[Л = ice]

$$N_{\text{л} i} = \xi_i' n_i.$$

If there was no water vapor depletion effect, with n_i a large number of ice crystals could appear, equal to

$$\xi n_i, \text{ that is, } \xi n_i \geqslant N_{\text{ice } i}.$$

In the absence of ice crystals there can be no water vapor depletion and therefore an absence of ice crystals with n_{i-1} means that

$$\xi n_{i-1} < 1.$$

By combining the last two inequalities we obtain an estimate for the true value of the fraction of ice-forming particles:

$$\frac{1}{n_{i-1}} > \xi \geqslant \frac{N_{\text{л} i}}{n_i} = \xi_i'.$$

We will carry out the following reasoning for a more precise estimate of the true ice-forming activity. The fact that the last ice crystal in a series of experiments with a gradual decrease in n is formed with the concentration n_i as a random event gives a probability of its realization which will be denoted P_i. In principle, with a definite probability it could be formed with any other n value, for example, with n_k. The probability of realizing such a possibility will be denoted P_k. The dependence of the probability of formation of the last ice crystal with the concentration n on n is shown in Fig. 3b (the method for computing this dependence is described below). According to this dependence, with some n value the formation of the last ice crystal is most probable. With a change in the true ice-forming activity (ξ) the $\xi'(n)$ curve does not change; there is only a shift parallel to the n-axis (see Fig. 3b). Thus, the search for the ξ value from the dependence of ξ' on n involves finding the ξ value for which the dependence $\xi'(n)$ has the maximum when $n = n_i$.

Now we will proceed to the derivation of specific formulas making it possible to compute the ξ value. The probability of formation of the last ice crystal with the concentration n_i, P_i, according to the formulas of the theory of probabilities, is

$$P_l = \prod_{m=1}^{l-1} \tilde{P}_m \cdot \prod_{m=l}^{\infty} (1 - \tilde{P}_m),$$

where $\tilde{P}_m$ is the probability that with the concentration n_m not one ice crystal appears, and $(1 - \tilde{P}_m)$ is the probability of the appearance of at least one crystal with n_m. The $\tilde{P}_m$ values in the case of absence of the depletion effect can be computed using the Poisson formula

$$W_l = \frac{e^{-\xi n_m} (\xi n_m)^l}{l!},$$

where W_ℓ is the probability of formation of ℓ ice particles with their mean number ξn_m. In the absence of vapor depletion $\tilde{P}_m = W_0 = e^{-\xi n_m}$. In the presence of the depletion effect the Poisson distribution is not satisfied because ice crystals do not appear independently of one another. This complicates the computation of probabilities. However, in the absence of ice crystals there can be no depletion effect. Accordingly, the probability that not a single crystal will be formed is identical both when there is a depletion effect and when this effect is absent and is equal to $e^{-\xi n_m}$. This means that the probability of having at least one crystal with any n_m value also can be determined correctly and is equal to $(1 - e^{-\xi n_m})$. Thus, P_i can be written in the form

$$P_l = \prod_{m=1}^{l=1} e^{-\xi n_m} \prod_{m=l}^{\infty} (1 - e^{-\xi n_m}). \quad (5)$$

The ξ value is determined from the condition

$$\frac{dP_i}{d\xi} = 0. \quad (6)$$

It is impossible to express the ξ value in explicit form from this condition. Therefore, equation (6) was solved numerically. In a general case a solution of equation (6) can be written in the form

$$\xi = f/n_i,$$

where f is a coefficient dependent on the ratio (n_m/n_{m-1}). In experiments each subsequent n value usually differed from the preceding by a factor of three. In this case f = 1.05. Thus, the proposed procedure makes it possible to determine the value of the true ice-forming activity on the basis of the experimental dependence of ξ' on n. Since ξ is determined with a minimum number of ice crystals, the depletion effect in this case should exert no influence.

Now we will evaluate the error in determining the true ice-forming activity by this method. The error is attributable to the fact that with given ξ in principle there is a finite probability of formation of the last ice crystal, not with n_i, but with any other n value (see Fig. 3b); it is true that this probability is less. Each of these possibilities must make a contribution to the error proportional to the deviation from the mean, $\Delta \lg \xi'$, multiplied by the probability of realization of a given possibility F_k. The value of the error can be written in the form

$$\lg\xi = = \lg\bar{\xi} + (P_{i-1}\cdot\Delta\lg\xi' + P_{i-2}\cdot 2\,\Delta\lg\xi'\ldots) - (P_{i+1}\cdot\Delta\lg\xi' + P_{i+2}\cdot 2\,\Delta\lg\xi'\ldots)$$

or more compactly

$$\lg\xi = \lg\bar{\xi} + \sum_{k=i-1}^{1} P_k\,(i-k)\,\Delta\lg\xi' - \sum_{k=i+1}^{\infty} P_k\,(k-i)\,\Delta\lg\xi', \quad (7)$$

where $\Delta \lg \xi'$ is determined by the interval of change in n and is equal to $-\lg n_k/n_{k-1}$.

When obtaining the experimental dependence of ξ' on n each subsequent n value differed from the preceding one by a factor of three, that is

$$\Delta\lg\xi' = -0{,}5.$$

In computing P_k, and also the sums in (7), we took into account only the first three-four terms, since all the subsequent terms were small. As a result of the computations we obtained

$$\lg\xi = \lg\bar{\xi} \pm 0{,}3.$$

In addition, it is necessary to take into account the error in determining the number of particles in the sample, equal to 30%. With this taken into account

$$\lg \xi = \lg \bar{\xi} \pm 0{,}4.$$

Such an error value allows a scatter in ξ values of the most by a factor of 7, which agrees well with the experimentally observed scatter. We note that the described procedure for determining the true ice-forming activity was used only with $\xi < 10^{-1}$. With large ξ values it was impossible by decreasing n to attain an absence of ice crystals in the sample. In this case the ξ value was determined from the plateau region in the dependence of ξ' on n. The knee in the curve and formation of a plateau were attained with a large number of ice crystals (10-50 on a glass with an area of 60 mm^2), which is measured quite precisely. With small ξ values the vapor depletion effect is far stronger; no plateau region was reached in the dependence of ξ' on n because the number of ice crystals corresponding to the reaching of the plateau was less than 1 (see Fig. 3a). For this reason the procedure described above was employed for determining ξ.

BIBLIOGRAPHY

1. Baklanov, A. M., Gol'dman, B. M., Gorbunov, B. Z., Kutsenogiy, K. P., Makarov, V. I., Sakharov, V. M., "New Apparatus for Investigating the Ice-Forming Activity of Aerosols," IZV. SO AN SSSR, SERIYA KHIM. (News of the Siberian Department USSR Academy of Sciences, Chemical Series), Vol 4, No 9, 1976.

2. Gorbunov, B. Z., Kutsenogiy, K. P., "Influence of Dispersion of Aerosols on Their Ice-Forming Activity," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 372, 1976.

3. Bigg, E. K., Mossop, S. C., Thorndike, N. S. C., "The Measurements of Ice Nucleus Concentration by Means of Millipore Filters," J. APPL. METEOROL., Vol 2, No 2, 1963.

4. Cooper, A., "Ice Nucleus Measurements Using a Stober Centrifuge," THE THIRD INTERN. WORKSHOP ON ICE NUCLEUS MEASUREMENTS, Laramie, Wyoming, University of Wyoming, 1976.

5. Gerber, H. E., "Activity and Size of Aggregate Thermal AgI Particles," THE THIRD INTERN. WORKSHOP ON ICE NUCLEUS MEASUREMENTS, Laramie, Wyoming, University of Wyoming, 1976.

6. Gravenhorst, G., Georgii, H. W., Grosch, M., Meyer, D., "A Low-Pressure Diffusion Chamber for Ice Nuclei Detection," PROCEEDINGS EIGHTH INTERN. CONF. ON NUCLEATION, Leningrad, Gidrometeoizdat, 1975.

7. Huffman, P. J., "Supersaturation Dependence of Ice Nucleation by Deposition of Silver Iodide and Natural Aerosols," REPORT N. AR 108, Laramie, Wyoming. College of Engineering. University of Wyoming, 1973.

8. Huffman, P. J., Vali, G. J., "The Effect of Vapor Depletion on Ice Nuclei Measurements With Membrane Filters," J. APPL. METEOROL., Vol 12, No 6, 1973.

9. King, W. D., "Vapor Depletion in Processing Membrane Filters: The Effect of Chamber Parameters," J. APPL. METEOROL., Vol 17, No 10, 1978.

10. Lala, G. G., Jiusto, J. E., "Numerical Estimates of Humidity in a Membrane Filter Ice Nucleus Chamber," J. APPL. METEOROL., Vol 11, No 6, 1972.

11. Meyer, D., Gravenhorst, G., "A Low Pressure Diffusion Chamber," THIRD INTERN. WORKSHOP ON ICE NUCLEUS MEASUREMENTS, Laramie, Wyoming, University of Wyoming, 1976.

12. THE SECOND INTERN. WORKSHOP ON CONDENSATION AND ICE NUCLEI, Fort Collins, Colorado, Colorado State University, 1971.

13. THE THIRD INTERN. WORKSHOP ON ICE NUCLEUS MEASUREMENTS, Laramie, Wyoming, University of Wyoming, 1976.

14. Zettlemoyer, A. C., Hsing, H. H., "Water on Organo-Silane Treated Silica Surfaces," J. COLLOID INTERFACE SCI., Vol 58, No 2, 1977.

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RESULTS OF COMPUTATION OF DIURNAL TEMPERATURE VARIATION DURING CLOUDLESS WEATHER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 30-36

[Article by M. Alautdinov, USSR Hydrometeorological Scientific Research Center, submitted for publication 13 November 1979]

Abstract: The author presents the results of numerical modeling of the diurnal variation of temperature in the free atmosphere, at the earth's surface and in the active soil layer on the basis of solution of the two-dimensional problem of deep convection in the atmosphere and the equations for heat conductivity in the soil.

[Text] A numerical modeling of the diurnal variation of temperature was carried out for the purpose of perfecting an algorithm for computing radiation heat influxes in a local weather forecasting model. This problem is a good test for checking a model in which there is simultaneous allowance for the processes of convective, turbulent and radiative heat exchange.

A great many studies have been devoted to the modeling of the diurnal variation of meteorological elements; the first of these was carried out by Dorodnitsyn [7]. The further development of investigations on the theory of diurnal variation of meteorological elements is reflected in [3, 5, 6, 11, 12, 14, 15], in which the authors proposed more perfect methods for taking turbulent exchange in the atmospheric boundary layer into account, as well as moisture exchange between the atmosphere and the active soil layer and computation of radiative heat exchange.

The processes of convective exchange in the entire thickness of the troposphere were not taken into account in the problem of diurnal variation of meteorological elements. However, under definite conditions the convective currents substantially redistribute the cloud cover and humidity fields, which exerts a considerable influence on radiative transfer in the atmosphere and the diurnal variation of meteorological elements.

In order to take into account directly the processes of convective exchange in the problem of diurnal variation of meteorological elements, the authors of [2] proposed a model by means of which it is possible to carry out computations of mesoscale movements in the entire thickness of the troposphere, thereby taking into account such important factors as the temporal redistribution of temperature, humidity and cloud liquid-water content. Due to the fact that the physical model and the algorithm for its numerical solution were set forth in detail in [2], here we will mention only its principal points.

A study was made of a plane layer of the atmosphere with a thickness H = 10 km and the active soil layer with a depth H_{soil} = 1.2 m, for which the equations of deep convection are solved numerically (in the layer from H to the ground surface) and the thermal conductivity equation (from the ground surface to H_{soil}). The coefficient of vertical exchange k_{ver} is considered to be a known function of altitude and the coefficient of horizontal exchange k_{hor} is assumed to be constant and equal to the corresponding k_{ver} at each level. It is assumed that heat transfer in the soil occurs only under the influence of molecular heat exchange and the heat exchange coefficient in the soil is constant.

The full variant of the model takes into account the processes of moisture transfer in the atmosphere, but in the first stage of model adjustment it was deemed desirable to carry out a series of numerical experiments with a constant humidity field in an atmosphere at rest in order to be able to analyze the patterns of the modeled temperature variation in the simpler case of a cloudless atmosphere.

The initial system of equations of deep convection, with radiation heat influxes taken into account, is written in dimensionless form using the following scales:

$$H,\ \Delta T,\ \Delta\tilde{t}=\left[H\Big/\left(g\frac{\Delta T}{\overline{T}}\right)\right]^{1/2},\ \rho_0,$$
$$\varkappa_0=H^2/\Delta\tilde{t},\quad V=H/\Delta\tilde{t},\quad P=\rho_0 H^2/\Delta\tilde{t}^2. \qquad (1)$$

Here H is the thickness of the convective layer, $\overline{T}$ is mean temperature of this layer, ρ_0 is density at the lower boundary, g is the acceleration of free falling, ΔT is the temperature scale.

With (1) taken into account, the system of dimensionless equations assumes the form

$$\frac{dv}{dt}=-\frac{1}{s}\frac{\partial p}{\partial y}+\frac{k_r}{s}\frac{\partial^2 v}{\partial y^2}+\frac{\partial}{\partial z}\left(\frac{k_n}{s}\frac{\partial v}{\partial z}\right), \qquad (2)$$

$$\frac{dw}{dt}=-\frac{1}{s}\frac{\partial p}{\partial z}+T+\frac{k_r}{s}\frac{\partial^2 w}{\partial y^2}+\frac{\partial}{\partial z}\left(\frac{k_n}{s}\frac{\partial w}{\partial z}\right), \qquad (3)$$

$$\frac{\partial (sv)}{\partial y}+\frac{\partial (sw)}{\partial z}=0, \qquad (4)$$

$$\frac{dT}{dt}=-\frac{H}{\Delta T}\left(\frac{\partial\overline{T}}{\partial z}+\gamma_a\right)w+\frac{k_r}{s}\frac{\partial^2 T}{\partial y^2}+\frac{\partial}{\partial z}\left(\frac{k_n}{s}\frac{\partial T}{\partial z}\right)+\frac{\Delta\tilde{t}}{\Delta T}\varepsilon_p, \qquad (5)$$

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Here v, w are the horizontal and vertical velocity components, T, P are the temperature and pressure deviations from their statistical values $\bar{T}$ and $\bar{P}$, $s = \bar{\rho}(z)/\rho_0$ is a dimensionless parameter characterizing the change in statistical density $\bar{\rho}$ with altitude, γ_a is the dry adiabatic temperature gradient, $\partial \bar{T}/\partial z$ is the vertical gradient of background temperature,

$$\frac{d}{dt} = \frac{\partial}{\partial t} + v\frac{\partial}{\partial y} + w\frac{\partial}{\partial z},$$

ε_p is the radiation heat influx, computed using the formula

$$\varepsilon_p = \frac{1}{\bar{\rho} c_p}\frac{\partial R_б}{\partial z}, \qquad (6)$$

where c_v is the specific heat capacity of air at a constant pressure, R_b is the radiation balance, equal to the difference between the descending and ascending radiation fluxes at each level.

Computations of the radiation fluxes and heat fluxes are made separately in the visible (0.4-0.75μm), near-IR (IR) (0.76-4μm) and far-IR (> 4μm) parts of the spectrum using the method proposed in [9, 10, 13]. The algorithm for computing the radiation fluxes and heat influxes is set forth in detail in [2].

System (2)-(5) is solved under the following initial conditions:

$$T(0, y, z) = \bar{T}(z),$$
$$q(0, y, z) = \bar{q}(z), \qquad (7)$$
$$v(0, y, z) = w(0, y, z) = p'(0, y, z) = 0.$$

The conditions of periodicity of all the functions are applied at the lateral boundaries

$$f(t, y_0, z) = f(t, y_N, z). \qquad (8)$$

At the upper boundary and at the earth's surface (Z_0) the attachment conditions are applied

$$v = w = 0 \text{ with } z = H \text{ and } z = Z_0. \qquad (9)$$

The upper and lower boundary are assumed to be ideally conductive of heat:

$$T = 0 \text{ with } z = H \text{ and } z = H_{surf}. \qquad (10)$$

At the earth's surface use is made of the temperature continuity and heat flux conditions.

For numerical solution of the system of equations (2)-(5) with the initial and boundary conditions (7)-(10) use is made of a model with the introduction of artificial compressibility [16], used by many authors [4, 8] in solving the problems of a viscous incompressible fluid. The applicability of this method for solving problems of deep convection was validated in [1].

The computations were made on a grid of 23 x 57 points of intersection in the vertical and horizontal directions. Along the horizontal the dimensional grid interval was constant and equal to 1 km. Along the vertical the grid interval decreases from top to bottom in the lower kilometer layer. The maximum grid interval in the free atmosphere is 1 km; the minimum is 0.1 m (in the soil). The authors of [2] carried out diagnostic computations of the radiation fluxes in the long-wave part of the spectrum, which were compared with measurement data. Comparison of the computed and actual radiation fluxes revealed their satisfactory correspondence.

After the "blocks" for computing radiation [2] and convective currents [1] were adjusted, it was possible to carry out computations using the full system of equations (2)-(5). When carrying out computations definite difficulties arose in a finite-difference representation of the radiation heat fluxes at the earth's surface. Numerical experiments indicated that the use of a rather rough computation model for computing the divergence of radiation fluxes leads to a considerable error due to the fact that the absorption of radiation occurs in relatively thin soil layers and the radiation heat influxes are very sensitive to the thickness of the absorption and radiation layers. An example of the sensitivity of the diurnal variation of temperature to changes in the depth of the emitting layer is given in Fig. 1. It is easy to note that in the field of extremal values the temperature differences at the earth's surface attain 4-5°C, and at the 2-m level -- 3-4°C.

As a result of a series of numerical experiments it was established that there is a good correspondence between the actual and modeled temperature variation when the thickness of the emitting layer is 10 cm and the thickness of the absorption layer for the visible and near-IR radiation is 15 cm. Naturally, in nature the thickness of the effective absorbing layers varies in a broad range: from several meters for the vegetation cover to millimeters for an even dense surface and therefore the adopted parameterization characterizes some averaged state of the underlying surface. Thereafter all the computations were made with the above-mentioned values of the absorption layers.

We carried out four numerical experiments with modeling of the diurnal variation of temperature, each of which occupied the period 1-3 days. As was indicated above, the computations were made in an atmosphere at rest with a constant background specific humidity and therefore for computations and comparisons of the results of computations and observations we selected cases of anticyclonic synoptic situations, that is, cases when cloud cover was absent and there were no advective temperature changes at the earth's surface.

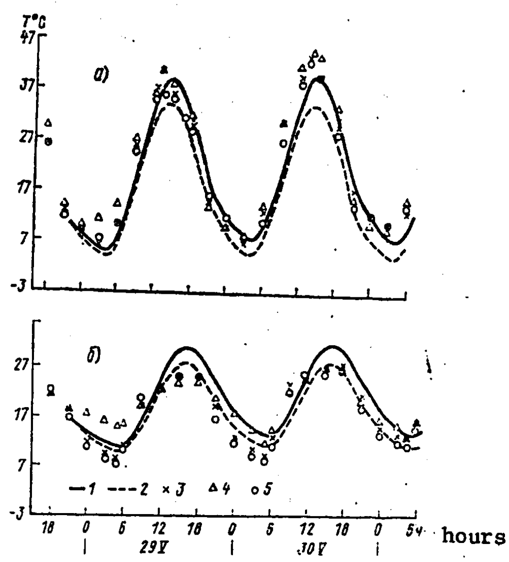

Fig. 1. Diurnal variation of temperature at underlying surface and at the level 2 m. 1971. 1) h_i = 10 cm, 2) h_i = 7.5 cm, 3) Agricultural Academy imeni Timiryazev, 4) Moscow State University, 5) All-Union Exhibition of Achievements in the National Economy

For comparison of computations with observations we used data from radiosonde measurements of the atmosphere at Dolgoprudnaya station and observations at the level 2 m, at the surface and in the soil at the stations of the All-Union Exhibition of Achievements in the National Economy, Moscow State University and the Agricultural Academy imeni Timiryazev.

We analyzed curves of the diurnal variation of temperature at the 2-m level, at the underlying surface, in the soil and at the standard isobaric surfaces in the free atmosphere. Naturally, in the course of computations, in addition to temperature data, information was received on convective currents, but here we will discuss only an analysis of the temperature field because the characteristics of small-scale currents cannot be compared with actual data. It can only be noted that in all the selected cases there was a stable stratification of the atmosphere in the lower kilometer layer of the atmosphere, as a result of which the intensity of the convective currents did not exceed 0.5 cm/sec and pressure fluctuations did not exceed several tenths of a millibar.

An example of the diurnal variation of temperature at the earth's surface is represented in Fig. 1a, where in addition to the results of the computations (solid curve) data are given for observations at three stations. It is easy to note that the computed temperature agrees fairly well with the actual temperature. The deviations of the computed values from the actual values are commensurable with deviations between observations at different stations. For a more complete quantitative evaluation we computed the mean error in the computations relative to the curve constructed by averaging the results of observations at three stations. At the hours of maximum heating it is -0.8°C, whereas at the hours of maximum cooling it is -1.1°C. Thus, the computed temperature is somewhat below the actual temperature. In addition to the mean error we computed the standard deviations of the computations and measurements at individual stations from the mean curve constructed by the method described above. The values of the standard deviations σ are given in the table. It can be seen from the data given in the table that at the hours of maximum heating σ for the computed temperature is commensurable with σ for individual stations. In the morning hours the σ for computations exceeds by a factor of approximately 2 the σ of observations.

Standard Deviations of Temperature from Mean Temperature Computed and Observed at Individual Stations

Уровень и время 1		Академия им. Тимирязева 2	МГУ 3	ВДНХ 4	Среднее 5	Расчет 6
7 Почва	1	0,87	1,12	0,85	1,03	2,13
	2	1,45	2,36	2,01	2,92	2,57
2 м	1	0,65	1,40	1,03	1,43	2,33
	2	0,37	0,23	0,25	0,36	3,92

KEY:
1. Level and time
2. Academy imeni Timiryazev
3. Moscow State University
4. All-Union Exhibition of Achievements in the National Economy
5. Mean
6. Computed
7. Soil

Notes: 1) the mean square error at the hours of maximum cooling, 2) mean square error at hours of maximum heating

The curves of the diurnal variation of temperature at the 2-m level are given in Fig. 1b. It is easy to note that the computed temperature values are systematically exaggerated during the daytime hours: the mean error at midday is 3.9°C. At nighttime it decreases and is 0.5°C. The standard deviations, computed the same as for the earth's surface, are given in the table. Particularly great deviations are observed at midday; they exceed σ by an order of magnitude for observations at individual stations. This is evidently the result of a rather rough parameterization of turbulent exchange in the model. Plans call for the improvement of this block in the future.

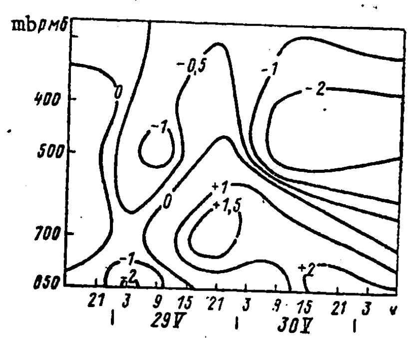

Fig. 2. Isopleths of deviations of computed temperature from actual temperature (°C) in free atmosphere (Dolgoprudnaya station, 1971).

An example of deviations of actual temperature from the computed temperature in the free atmosphere is given in Fig. 2. On 29 May 1971 the results of measurements revealed the existence of a diurnal variation of temperature, whereas on 30 May it was disrupted in the layer above 500 mb by the advection of cold and therefore as a comparison it is desirable to examine only the left part of the figure. It can be concluded from the nature of distribution of the deviations that the computed diurnal temperature wave has a somewhat lesser amplitude than the actual wave, but the maximum deviations do not exceed 2°C. The mean characteristics of the deviations of computed temperatures from the actual temperatures could not be determined because the actual data include the effects of advection and it is difficult to exclude these with a sufficient degree of accuracy.

Analysis of the thermoisopleths and comparison of the results of computations with the actual temperature distribution in the upper meter soil layer indicated that the propagation of the computed thermal wave in the soil coincides well in phase with the actual distribution. The greatest deviations of computed temperature from the mean for three stations are observed in the evening hours (about 2100 hours) at a depth of 10 cm, where they attain +5.4°C. At the same time it must be noted that the maximum differences between measurements at individual stations and the mean value in this case are +2.6°C, and the maximum differences between measurements at stations attain 4.5°. Thus, the differences between the computed and actual temperature values at this level are approximately of the same order of magnitude as the scatter between observations at different stations. At a depth of 20 cm the differences between the computed and actual temperatures do not exceed 1.6°C. However, it should be noted that in the model there is a more rapid accumulation of heat in the soil than under real conditions, which is noted particularly clearly when making computations for several days. In this connection it appears desirable to carry out a further improvement in the algorithm for heat transfer in the soil.

These numerical experiments make it possible to formulate the following conclusions.

1. The formulated model in general satisfactorily reproduces the diurnal variation of temperature under the conditions of a cloudless atmosphere.

2. The computed temperature is systematically higher at the 2 m level, as a result of which it is necessary to improve the processes of parameterization of turbulent exchange processes in the atmospheric surface layer.

In the future plans call for carrying out a series of numerical experiments taking into account the processes of moisture transfer and cloud formation in the atmosphere.

In conclusion I express sincere appreciation to N. F. Vel'tishchev, who gave great assistance in the writing of this article.

BIBLIOGRAPHY

1. Alautdinov, M., "Numerical Modeling of Deep Convective Processes," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 10, 1979.

2. Alautdinov, M., Vel'tishchev, N. F., "Numerical Model of Diurnal Variation of Meteorological Elements," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 219, 1979.

3. Berlyand, M. Ye., "Diurnal Variation of Temperature, Turbulent Exchange and the Radiation Balance," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 48(110), 1954.

4. Vel'tishchev, N. F., Zhelnin, A. A., "Numerical Model of Convection in a Flow With Vertical Shear," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 110, 1973.

5. Gavrilov, A. S., Gutman, L. N., Lykosov, V. N., "Nonstationary Problem of the Planetary Boundary Layer of the Atmosphere With Allowance for Radiative Heat Exchange," TRUDY ZSRNIGMI (Transactions of the West Siberian Regional Scientific Research Hydrometeorological Institute), No 11, 1974.

6. Galushko, V. V., Yevteyev, A. P., Ordanovich, A. Ye., "One Method for Computing the Diurnal Variation of Temperature in the Atmospheric Boundary Layer," TRUDY IEM (Transactions of the Institute of Experimental Meteorology), No 6(44), 1974.

7. Dorodnitsyn, A. A., "On the Theory of the Diurnal Variation of Temperature in the Mixing Layer," DOKLADY AKADEMII NAUK SSSR (Reports of the USSR Academy of Sciences), Vol XXX, No 5, 1941.

8. Zhelnin, A. A., "Some Results of Numerical Modeling of Convection in an Unstably Stratified Flow with Shear," TRUDY GIDROMETTSENTRA SSSR, No 148, 1974.

9. Krasnokutskaya, L. D., Sushkevich, T. A., "Analytical Representation of Integral Functions of Transmission of Clouds," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences, Physics of the Atmosphere and Ocean), Vol 13, No 5, 1977.

10. Krasnokutskaya, L. D., Feygel'son, Ye. M., "Computation of Fluxes of IR Solar Radiation in the Cloudy Atmosphere," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA, Vol 9, No 10, 1973.

11. Speranskiy, L. S., Kostrikov, A. A., Pushistov, P. Yu., "Local Prediction of Temperature and Wind in the Atmospheric Surface Layer Using a Model of the Planetary Boundary Layer," TRUDY ZSRNIGMI, No 29, 1978.

12. Speranskiy, L. S., Pushistov, P. Yu., Gutman, L. N., "Hydrodynamic Models of Local Weather Forecasting," METEOROLOGIYA I GIDROLOGIYA, No 2, 1977.

13. Feygel'son, Ye. M., LUCHISTYY TEPLOOBMEN I OBLAKA (Radiant Heat Exchange and Clouds), Leningrad, Gidrometeoizdat, 1970.

14. Shvets, M. Ye., "Diurnal Variation of Temperature and Radiant Heat Exchange," IZV. AN SSSR, SERIYA GEOGR. I GEOFIZ. (News of the USSR Academy of Sciences, Series on Geography and Geophysics), No 4, 1943.

15. Yudin, M. I., "Diurnal Variation of Air Temperature and Heat Exchange," IZV. AN SSSR, SERIYA GEOGRAF. I GEOFIZ., Vol 12, No 4, 1948.

16. Chorin, A., "A Numerical Solution of the Navier-Stokes Equations," MATHEM. COMPUT., Vol 22, No 104, 1968.

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INFLUENCE OF A LARGE CITY ON AIR TEMPERATURE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 37-41

[Article by Professor V. N. Parshin, USSR Hydrometeorological Scientific Research Center, submitted for publication 14 December 1979]

Abstract: In the example of Moscow the author demonstrates the influence of a large city as it develops and as thermal effluent increases on the mean annual air temperature. The article also examines the problem of reducing air temperature data to a uniform series, reduced to the conditions of present-day Moscow. Recommendations are given on determining the different probability of mean annual air temperature.

[Text] A large city unquestionably increases the ambient temperature and this occurs primarily due to the thermal effluent of industrial enterprises, operation of vehicles, thermal communications, heating of buildings and asphalt pavements under the influence of direct solar radiation. However, a quantitative evaluation of this phenomenon has not been made. We will attempt to clarify this problem in the example of Moscow, in particular, for mean annual air temperature. The problem was solved by a comparison of long-term data for the meteorological station of the TSKhA (Agricultural Academy imeni Timiryazev) in Moscow and data for the meteorological stations Mozhaysk, Klin, Serpukhov and Cherusti, situated around Moscow in a distance of 100-150 km (Fig. 1). Air temperature observations at the TSKhA meteorological station have been made for the last 100 years and at the mentioned meteorological stations around Moscow -- during the last 45-50 years. Within the city, in addition to the TSKhA control meteorological station, there are three other meteorological stations situated in different parts of the city: at the All-Union Exhibition of Achievements in the National Economy, at Moscow State University and at the center of the city in the neighborhood of Balchug. The period of observations at these stations is 25-30 years. The mean annual air temperatures at the meteorological stations at the TSKhA, the All-Union Exhibition of Achievements in the National Economy and Moscow State University are completely identical, but at Balchug meteorological station the temperature is somewhat higher than at the remaining three stations. This is attributable to the fact that Balchug meteorological station is situated in the immediate neighborhood of the thermal electric power station and the canal into which the thermal power station discharges warm water, which does not freeze even when temperatures are considerably below zero. Therefore, Balchug meteorological station in general is not representative for the city, but reflects only the microclimate of the particular small region. Thus, the TSKhA meteorological station with a 100-year series of observations in actuality can be adopted for characterizing the mean annual air temperatures for the city as a whole. A comparison of the mean annual air temperatures for five-year periods for the joint period of observations for the TSKhA meteorological station and the meteorological stations situated around Moscow at a distance 100-150 km is given in Table 1. The air temperature for the meteorological stations around Moscow is given as averaged for the four stations.

Fig. 1. Diagrammatic map of Moskovskaya Oblast.

Table 1

Mean Annual Air Temperature (°C) for Five-Year Periods

Пятилетия 1	Москва 2	Можайск, Клин, Серпухов, Черусти (средняя) 3	Разность 4
1926—1930	3,5	3,4	0,1
1931—1935	4,3	4,1	0,2
1936—1940	5,0	4,8	0,2
1941—1945	3,4	3,2	0,2
1946—1950	4,6	4,3	0,3
1951—1955	4,3	4,0	0,3
1956—1960	4,6	4,1	0,5
1961—1965	4,7	4,1	0,6
1966—1970	4,6	3,9	0,7
1971—1975	5,8	5,0	0,8
1976—1978	4,0	3,1	0,9

KEY:
1) Five-year periods
2) Moscow
3) Mozhaysk, Klin, Serpukhov, Cherusti (mean)
4) Difference

Table 1 shows that the excess of mean annual temperature in Moscow over the surrounding stations is continuously increasing and during recent years has attained 0.8-0.9°C. This is a result of intensive development of operations in the capital, the increase in transport, volume of production and population. For example, in Moscow from 1913 through the present time the volume of production has increased by a factor of 215 and the population has increased from 1.6 million to 7.9 million [2].

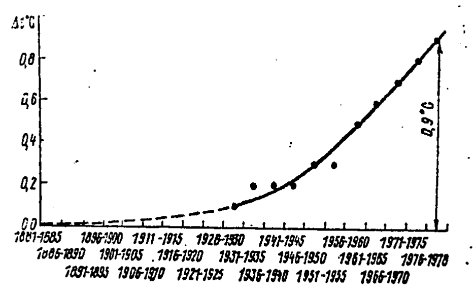

Fig. 2. Excess of mean annual air temperature at Moscow in comparison with data for meteorological stations at a distance of 100-150 km.

Table 2

Values of Corrections (°C) to Observed Mean Annual Air Temperatures at Moscow for Reduction of Data to Conditions of Modern City

Пятилетия 1	Поправка в гр. 2	Пятилетия 1	Поправка в гр. 2
1881—1885	0,90	1931—1935	0,70
1886—1890	0,90	1936—1940	0,70
1891—1895	0,85	1941—1945	0,65
1896—1900	0,85	1946—1950	0,60
1901—1905	0,85	1951—1955	0,50
1906—1910	0,80	1956—1960	0,40
1911—1915	0,80	1961—1965	0,30
1916—1920	0,75	1966—1970	0,20
1921—1925	0,75	1971—1975	0,10
1926—1930	0,75	1976—1978	0,00

KEY:
1. Five-year periods
2. Group correction

Table 3

Long-Term Characteristics of Mean Annual Air Temperature for Modern Moscow

Maximum in 100 years	Guaranteed probability, % 2	5	10	25	50	75	90	95	98	Minimum in 100 years
6.9 1938	6.8	6.2	6.1	5.3	4.6	4.0	3.4	3.0	2.7	2.4 1941

Thus, we confirmed that the influence of a large city on the temperature of its ambient air is extremely significant. Now the question arises: how is it possible to characterize the norm of mean annual air temperature at

Moscow, the anomalousness and frequency of recurrence of temperature over a long-term period? Indeed, for this it is necessary to have a long-term period of observations for a modern city, and this is unavailable. The 100-year period of observations contains nonuniform data due to the different influence of the city as it developed. We carried out the reduction of long-term observational data on air temperature at Moscow to a uniform series using the curve represented in Fig. 2, which was constructed using the data in Table 1. This curve shows the excess of mean annual air temperature at Moscow in comparison with the stations surrounding it in a chronological sequence. The lower part of the curve has been extrapolated to the zero value, that is, it is evident that 100 years ago there were no differences in air temperatures at Moscow and at the stations surrounding it.

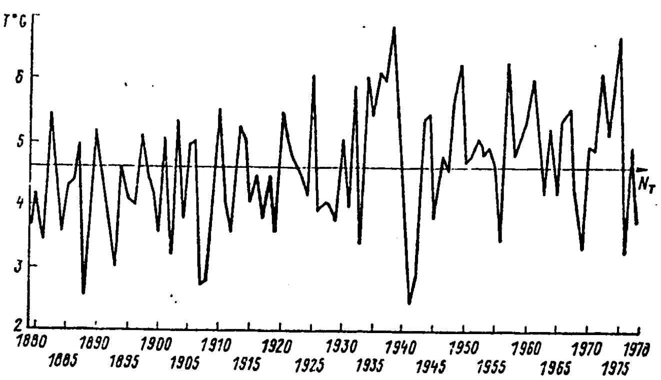

Fig. 3. Variation of mean annual air temperature at Moscow (the data are reduced to the conditions of the modern city).

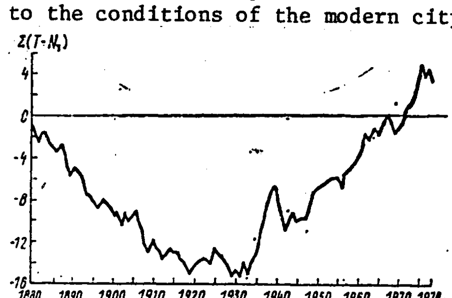

Fig. 4. Variation of the integral value of deviations of mean annual air temperature at Moscow from the norm (the data are reduced to the conditions of the modern city).

The reduction of observations of air temperature at Moscow to the conditions of the modern city and thus obtaining a comparable series of observations was accomplished in the following form:

$$T = t + (0{,}9 - \Delta t),$$

where T is the mean annual air temperature, reduced to the conditions of modern Moscow; t is the observed mean annual air temperature; $(0.9 - \Delta t)$ is the correction for the observed temperature as a result of the influence of the city, for which Δt is determined from the graph in Fig. 2.

The value of the corrections for five-year periods are given in Table 2.

After the 100-year series of observations for Moscow was reduced to conditions of the modern city it was possible to determine the mean long-term value and the values of different frequency of recurrence of the mean annual air temperature, which are given in Table 3.

The norm of the mean annual air temperature for a 100-year series of observations, reduced to the conditions of present-day Moscow, is 4.6°C. If we simply take the mean value and the 100-year series of observations, it is 4.0°C, and the maximum and minimum values are 6.7°C in 1975 and 1.7°C in 1888 respectively.

Now, when a matched series of observations has been obtained, it is possible to analyze the variation of the mean annual air temperature in Moscow in a chronological series. The variation in mean annual temperature for the 100-year observation period is given in Fig. 3, from which it can be seen that during the first 50 years the temperature was somewhat lower than during the subsequent 50 years and the amplitude of air temperature in the second part of the period increased considerably. In order to represent these characteristics more graphically, in Fig. 4 we have shown the variation of the integral value of the deviations from the norm. The figure rather clearly shows two periods -- cold until 1932 and warm since 1932. During the cold period the sum of the deviations from the norm was -15.4°C, that is, on the average during these 53 years the mean annual temperature was below the norm by approximately 0.3°C. During the warm period from 1933 through 1978 the total deviation of the mean annual temperature from the norm was +18.8°C or as an average for the 47 years the temperature was above the norm by approximately 0.4°C. If the mean temperature is computed for the mentioned cold and warm periods it will be 4.3° and 5.1°C respectively and the mean for 100 years, as already noted, will be 4.6°C.

It is difficult to say what the variation of the mean annual temperature in Moscow will be in the future. It can only be noted that the last three years (1976-1978) were relatively cold. It is also difficult to say with assurance whether this is the beginning of a replacement of a warm period by a cold period. Accordingly, it is impossible to agree with the recently appearing recommendations on determining the air temperature norm on the basis of data for the last 30-40 years. We will assume that the temperature norm and the long-term air temperature characteristics must be determined on the basis of the entire long-term series of observations of not less than 80-100 years, but for large cities it is necessary to introduce a corresponding correction, as was done, for example, in this article.

It must also be noted that with different kinds of computations and conclusions concerning the change in climate use is made for the most part of long series of observations of air temperature such as are available, primarily, for meteorological stations situated in the large cities. And here it is particularly important to take into account the influence of a large city on air temperature, particularly since the warmings or coolings of cliate in different regions or at a global scale cited in the literature only amount to tenths of a degree.

The second peculiarity of the temperature variation with time, as we have already noted, is its great variability in the second half of the hundred-year observation period, as is confirmed by the standard deviations (σ). Whereas for the period 1879-1931 σ = 0.8°C, for the period 1932-1978 σ = 1.2°C.

Above we have discussed the mean annual air temperature. Similarly we examined data on the mean air temperature during the cold and warm periods, during the coldest month -- January and the hottest month -- July. In all cases the conclusions drawn were the same as for the mean annual temperature. This is completely understandable because the influence of a large city on air temperature is constant and is not dependent on season of the year. The only difference is the heating of buildings during the cold season, which during the warm period is evidently compensated by the stronger influence of heating of the surface of the buildings and asphalt pavements by direct solar radiation. Thus, the corrections cited in Table 2 for Moscow can be used for the purpose of reducing the series of observations to the conditions of modern Moscow and obtaining the long-term characteristics and the values of different frequency of recurrence for mean air temperatures from a month to a year.

In conclusion we will express the established effect of the city on air temperature by the quantity of thermal energy. The computations made below have an approximate character and make no pretense at a high accuracy and are intended only to show the order of magnitude. The territory of the city is now 878.6 km^2 [2]. We will assume the air layer to be equal to the boundary layer of the atmosphere, that is, 1 km; we will assume that at the upper boundary of this layer the influence of the city on air temperature disappears and at the ground it is equal to 0.9°C. Proceeding on this basis and assuming the corresponding density and heat capacity values for air we find that for heating the indicated air volume over the city it is necessary to have $3.94 \cdot 10^{14}$ J. Since we are operating with the mean diurnal air temperatures, the thermal energy will be $4.6 \cdot 10^3$ MW.

It is interesting to compare these data with the results of computations of the production of thermal energy made by American scientists [1]. According to data published by Lees, in the Los Angeles region the production of thermal energy, scaled to an area of 1,000 km^2, is about $7 \cdot 10^3$ MW.

Thus, the results of our computations and those of American scientists have an identical order of magnitude. For a real idea concerning the determined values we note that the power of the Volga Hydroelectric Power Station imeni Lenin is $2.3 \cdot 10^3$ MW.

BIBLIOGRAPHY

1. VLIYANIYE CHELOVEKA NA GLOBAL'NYYE KLIMATICHESKIYE USLOVIYA (Man's Influence on Global Climatic Conditions), Leningrad, Gidrometeoizdat, 1972.

2. MOSKVA V TSIFRAKH: STATISTICHESKIY YEZHEGODNIK (Moscow in Figures: Statistical Yearbook), 1978, Moscow, Statistika, 1978.

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CONDITIONS FOR THE FORMATION AND FALLING OF ABUNDANT SHOWER PRECIPITATION IN EASTERN TRANSCAUCASIA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 42-48

[Article by Candidate of Geographical Sciences M. A. Dzhabbarov, Geography Institute Azerbaydzhan Academy of Sciences, submitted for publication 27 August 1979]

Abstract: The article discusses the characteristics of the territorial distribution of intensive abundant shower precipitation in the Azerbaydzhan SSR. For the first time the author has computed the mean daily quantity of precipitation by gradations, the mean of the maximum intensities of shower precipitation and the duration of these showers for characteristic stations. Regionalization was carried out with respect to the maximum intensity of shower precipitation. It was possible to determine the structures of high-altitude and surface pressure fields and the quantitative indices of meteorological elements causing the falling of abundant shower precipitation.

[Text] In individual regions of Transcaucasia it is common for heavy shower precipitation to fall, causing strong mudflows in river basins, causing considerable material loss to agriculture and population. Despite individual investigations of such showers [1-4], the meteorological conditions for their falling in general in the territory of the Azerbaydzhan SSR have not been adequately studied. For investigating this we selected those cases when the diurnal quantity of precipitation was $\geqslant$ 70 mm with an intensity of showers $\geqslant$ 1.5-2.0 mm/min. During the period 1950-1977 we selected 109 cases of abundant precipitation in accordance with the adopted criteria.

We note that despite the lesser territory, the range of annual sums of precipitation is rather great and is characterized by a great nonuniformity in distribution. These mean annual sums vary from values less than 200 mm to 1,700 mm or more. The greatest annual precipitation (1,300-1,800 mm) is noted on the southern slope of the Greater Caucasus (Alibek -- 1,394 mm) and in the foothill areas of the Talysh (Bursulum -- 1,838 mm). In the Lesser Caucasus, in the Nakhichevanskaya ASSR, the annual precipitation does not exceed 800-1,000 m, and in the Kuro-Araksinskaya Lowland decreases to 200-300 mm. The zone of maximum precipitation is at an elevation 2,800-3,000 m (at Talysh -- 800-1,200 m). In the annual variation the maximum falls in May-June and September-October, and the minimum in January and August. Sixty-seventy percent of the annual precipitation in the investigated region falls from April through September and has a shower character. The diurnal quantity of precipitation during the considered period often is maximum on the southern slopes of the Greater Caucasus (4-14 cases) and in the Talysh region (3-9 cases); it is relatively less in the Lesser Caucasus (2-3 cases). In lowland regions the diurnal precipitation sums rarely exceed 80-90 mm, whereas in the mountains they frequently attain 200-350 mm (Alibek -- 188 mm, Bilyasar -- 334 mm).

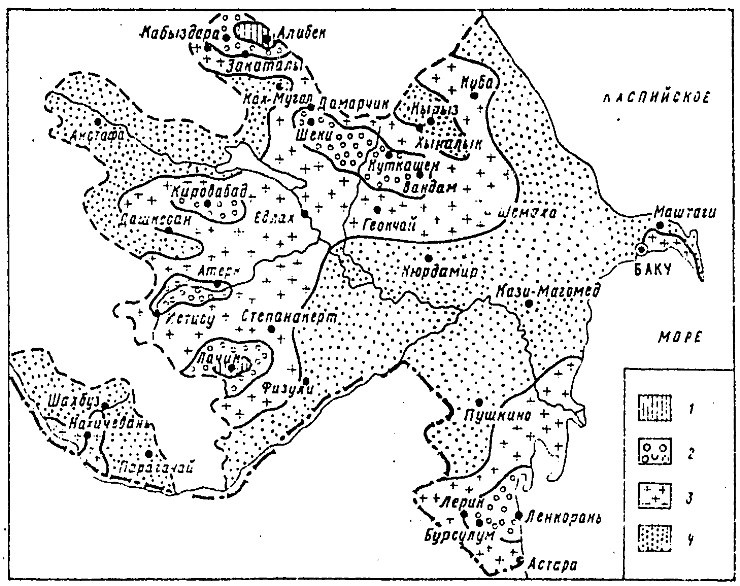


Fig. 1. Map of regions of maximum intensity of shower precipitation. 1) 6-11 mm/min, 2) 4-6 mm/min, 3) 2-4 mm/min, 4) 0.5-2 mm/min.

The mean daily quantity of such precipitation, for the first time computed by the author for different stations in Eastern Transcaucasia, is given in Table 1. It follows from this table that abundant precipitation during individual years with a gradation 70-100 mm/day falls in all mountain regions of the Azerbaydzhan SSR, and with a gradation 131-160 mm/day or more -- only on the southern slopes of the Greater Caucasus and the foothills of the Talysh Mountains. An example is the abundant precipitation observed on 16 September 1962 at Talysh, on 8 June 1963 in all mountain regions, on 16 August 1955, on 19 August 1964, 16 July 1973 on the southern slope of the Greater Caucasus, etc. In individual regions of the republic the maximum intensity of showers varies in a wide range. For example, the maximum intensity of showers (Table 2) on the southern slope of the Greater Caucasus (Alibek -- 10.7 mm/min), in the Lesser Caucasus (Lachin -- 9.4 mm/min) and in the Talysh (Bursulum -- 5.1 mm/min) attains 4-11 mm/min, whereas in adjacent regions of the Armenian SSR (Kirovsk -- 5.5 mm/min) and the Dagestanskaya ASSR (Khalavyurt -- 2.2 mm/min) it does not exceed 3.5-5.5 mm/min.

A high intensity of showers (1.5-2.0 mm/min) is observed in the Priaraksinskaya Lowland of the Nakhichevanskaya ASSR. On the northeastern slope of the Greater Caucasus it is 2.5-3.5 mm/min and is noted over mountainous sectors, which is important to take into account when preparing a weather forecast. In the lowland and foothill regions of the republic it is 0.9-2.5 mm/min (Fig. 1).

In the Azerbaydzhan SSR the mean maximum shower intensities, computed for the first time, vary in the range from 0.5 to 4.5 mm/min. The highest intensity of showers is on the southern slopes of the Greater Caucasus (9-11 mm/min) is observed at an elevation of 1,800-2,300 m, on the northeastern slopes (2-3.5 mm/min) -- at elevations 400-700 m and 1,900-2,000 m, on the northern slopes of the Lesser Caucasus (4-9.5 mm/min) -- at an elevation 1,000-1,700 m, in the Talysh (2-5 mm/min) -- at an elevation of 700-1,200 m, and in the Nakhichevanskaya ASSR (1.5-2.0 mm/min) -- elevations 800-900 and 1,500-1,700 m.

Showers with a mean intensity 3-5 mm/min or more are usually not very prolonged -- a maximum of 30-60 min, but most frequently 5-15 minutes, after which their intensity decreases to 0.5-1.5 mm/min (Table 3).

An analysis of radiosonde observations in the regions Mashtagi, Lenkoran' and Tbilisi during the years 1950-1977 were determined using the quantitative criteria of the principal meteorological elements. It was found that in all cases of the falling of heavy abundant precipitation in the Azerbaydzhan SSR ($>$ 70 mm/day) the air temperature over Transcaucasia is 18-24°C at the earth's surface. It varies insignificantly to an altitude of 1,000-1,200 m, aloft it decreases sharply to 8-15°C at 1,500-2,500 m and to -5, -15°C at3,500-5,500 m. In general, the penetration of cold air from the north and northwest in the territory of the Azerbaydzhan SSR leads to a decrease in air tempe ature in 1-1.5 days on the average by 8-12°C, and sometimes by 10-14°C. Relative air humidity on a day of abundant precipitation is 80-90% at the earth's surface, 60-85% at 1,400-1,600 m and 75-87% at 3,000-3,500 m, that is, there is a quite high relative humidity in the entire layer of the troposphere. In particular, over the Talysh an increase in relative humidity by 12-15% is observed at 2,000-2,500 m in comparison with the lower layer. The mean specific humidity values in the lower troposphere on a day with precipitation vary in the range from 8.5 to 12.9 g/kg and gradually decreasing, constitute 2.0-4.7 g/kg in the middle layers [5]. Frontal precipitation falls with a specific humidity $\geqslant 7$ g/kg and a vertical gradient $\geqslant 0.6°C/100$ m [8]. With the intrusion of cold air from the west, across the Black Sea, the relative and specific humidities are always high and showers are intensive (especially in the mountains on the southern slope of the Greater Caucasus).

Table 1

Mean Daily and Maximum Quantity of Abundant (more than 70 mm) Precipitation mm/day

Станция 1	Максимум 2	Среднее 3	4 Градации, мм/сут			
			70—100	101—130	131—160	>160
5 Кабыздара	176,5	99,9	79,9	123,3	143,6	176,5
6 Закаталы	172,7	98,4	84,0	115,5	—	166,6
7 Алибек	198,2	138,5	83,2	114,4	136,3	188,2
8 Бурсюлум	334,2	153,7	80,4	115,9	145,9	194,6
9 Билясар	353,9	108,8	84,3	112,1	155,1	269,4
10 Лерик	263,2	130,7	74,1	115,6	154,4	263,2
11 Ках-Мугал	147,0	93,6	80,0	—	138,7	—
12 Кутканен	129,0	78,2	76,2	104,6	—	—
13 Вандам	105,7	86,6	81,5	105,7	—	—

KEY:

1. Station
2. Maximum
3. Mean
4. Gradations, mm/day
5. Kabyzdara
6. Zakataly
7. Alibek
8. Bursyulum
9. Bilyasar
10. Lerik
11. Kakh-Mugal
12. Kutkashen
13. Vandam

In the overwhelming number of cases on days with abundant precipitation the winds at 2.5-3 km in Transcaucasia are replaced by southwesterly and westerly winds (75-85%), below which there is a predominance of northerly and northwesterly. Over the Talysh, with winds of easterly and northeasterly direction, at 1.5-3.0 the relative humidity attains 100% and the quantity of precipitation during the day exceeds 100 mm. This is attributable to the closeness of the Caspian Sea, which enriches the air masses passing over its surface by water vapor, and the presence of the Talysh Mountains, which favor the abundant falling of precipitation. With the penetration of cold air into the Azerbaydzhan SSR the winds in the surface layer, under the influence of local orography, occupy southerly and southwesterly directions on the southern slopes of the Greater Caucasus, northeasterly and easterly in the Lesser Caucasus and Talysh. In the Kura-Araksinskaya Lowland the winds for the most part have southeasterly, easterly and northwesterly directions.

Table 2

Intensity of Shower Precipitation, mm/min

Station	Elevation, m	Maximum	Mean of absolute maxima
Alibek	1750	10.7	4.46
Zakataly	487	3.4	2.88
Damarchik	1170	6.5	3.59
Akhchay	1000	6.8	0.07
Kutkashen	679	6.0	3.35
Kuba	550	2.4	2.24
Kyryz	2070	3.2	2.78
Khynalyk	2048	0.8	0.57
Akstafa	331	0.4	0.32
Kirovabad	312	4.4	2.80
Aterk	1043	4.0	2.36
Istisu	2294	4.0	3.01
Lachin	1151	9.4	3.08
Dashkesan	1655	3.7	2.23
Geygel, shamkh.	2475	1.0	0.43
Geokchay	107	3.8	2.08
Mashtagi	27	2.5	1.78
Lenkoran'	20	5.0	3.58
Bursulum	778	5.1	3.86
Nakhichevan'	975	2.1	1.97
Paragachay	2300	0.5	0.37
Shakhbuz	1199	0.5	0.41

It is important to note that during abundant shower precipitation over the Talysh, judging from radiosonde data, above 2.0-2.5 km there is a predominance of strong southwesterly and westerly winds and the propagation of cold northeasterly winds into the depths of the region is restricted by the elevations of the mountain range. Accordingly, the forced rising of moist shower clouds occurs in the foothill zone of the Talysh, where abundant precipitation falls, and not over the high mountains, both in the Greater and in the Lesser Caucasus. In regions situated at a higher level, the quantity and intensity of precipitation sharply decrease. In general, 1-1.5 days prior to the falling of abundant shower precipitation the mean temperature aloft is several degrees higher and there are winds of a southwesterly and westerly direction. A shifting of the prevailing wind direction by 180° and a marked decrease in air temperature occurs 10-12 hours prior to the formation of heavy shower clouds.

An analysis of the pressure pattern charts indicated that abundant shower precipitation arises when there are meridional transformations of the thermopressure field in the troposphere, when a trough or a cyclone with cold centers are formed over the Black Sea and Asia Minor aloft (Fig. 2).

Table 3

Intensity of Special Cases of Showers in Different Regions, mm/min

Дата 1	Максим. интенсивность 2	3 Продолжительность, мин					
		5	10	15	20	30	40
4 Степанакерт — 827 м							
5 VI 1955	3,43	3,25	2,39	1,75	1,36	0,93	0,71
5 Шуша — 1358 м							
8 VI 1936	4,00	1,83	1,23	1,30	1,30	0,70	0,58
6 Куба — 550 м							
18 V 1935	2,10	1,68	1,35	1,09	0,98	—	—
7 Ленкорань — 12 м							
16 IX 1942	2,18	2,00	2,00	2,00	1,84	1,73	1,80
8 Алибек — 1750 м							
16—17 VIII 1959	10,7	4,10	3,37	2,84	2,16	1,50	1,17
9 Закаталы — 487 м							
7—8 VII 1951	4,80	3,81	2,20	1,77	1,59	1,33	1,12
10 Дамарчик — 1170 м							
30 VI 1953	6,50	2,62	2,02	1,60	1,26	0,85	—
11 Куткашен — 679 м							
18 IX 1957	3,40	1,85	2,02	1,78	1,51	1,06	0,90
12 Белоканы — 410 м							
30 IX 1968	6,20	1,64	0,95	0,60	0,50	—	—

KEY:
1. Date
2. Maximum intensity
3. Duration, minutes
4. Stepanakert
5. Shusha
6. Kuba
7. Lenkoran'
8. Alibek
9. Zakataly
10. Damarchik
11. Kutkashen
12. Belokany

Powerful advection of cold in the Asia Minor region favors an intensification of the high-altitude frontal zone and the development of a cyclone here, with its subsequent movement in the direction of the Caucasus. At this time over central and western Europe there is a well-developed high ridge with surface high-pressure centers over the Baltic Sea region and the European USSR. There is powerful heat advection in the west and at the center of Europe. The axis of the high-altitude frontal zone passes through Moscow, Bucharest and Athens and bends toward Transcaucasia. Thus, as a result of meridional transformation of the thermopressure field and circulation over Europe, the eastern part of the Mediterranean Sea and Asia Minor there is a meeting of cold northwesterly and warm southwesterly air masses, a surface cyclone develops and shower precipitation forms in Transcaucasia.

B = high
H = low

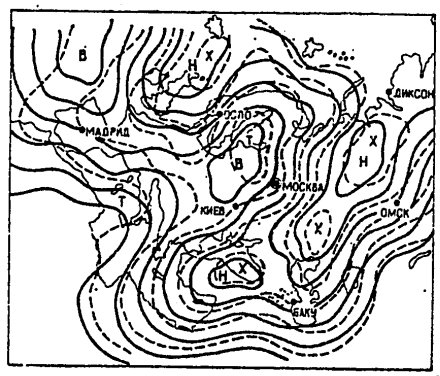
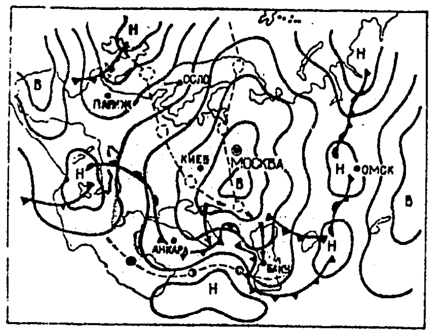


Fig. 2. Thermopressure field in the middle troposphere prior to penetration of cold air into Eastern Transcaucasia and the falling of shower precipitation.

In an analysis of the meteorological and aerosynoptic materials it was established that over the studied territory in the overwhelming majority of cases (92%) the falling of abundant shower precipitation was associated with the passage of cold fronts. In the case of movement of precipitation-forming processes from the west across the Black Sea and Georgia abundant shower precipitation occurs more frequently in the western regions of the Azerbaydzhan SSR (45%), whereas with their passage from the east, across the Caspian Sea, they are frequent in the eastern regions of the republic (28%). With the simultaneous penetration of cold air from the two directions (18%) precipitation falls everywhere (Fig. 3).

Analyses of the materials show that with movement of cold fronts across the Kura-Araksinskaya Lowland there is an intensive upward forcing of the pre-frontal moist warm air along the slopes of the surrounding Greater and Lesser Caucasus. Numerous lateral ranges somewhat slow the movement of the surface front and cold air behind the front is propagated aloft. Individual branches of the cold front, bending around the mountain ranges, are directed upward along the river valleys, causing a sharp decrease in air temperature with local elevation. This results in creation of favorable conditions for forming of thick cumulonimbus clouds and the falling of intense abundant shower precipitation. It falls for the most part when there is a great instability and high moisture content of the air masses in the frontal zone and when orographic factors are operative.



B = high
H = low

Fig. 3. Surface synoptic situation with the penetration of cold air into the Eastern Caucasus and the falling of abundant shower precipitation.

In addition to cold intrusions, intensive shower precipitation also falls with the arrival of southerly cyclones (7%). Southerly cyclones, usually arising over the eastern part of the Mediterranean Sea, move eastward across Asia Minor to the south of the Caspian. In such cases there is a rear intrusion (for the most part from the east) of cold air into the investigated region with the falling of heavy shower precipitation, the daily quantity of which does not exceed 80-90 mm, and the intensity is 1.5-2.5 mm/min or more. Less frequently shower precipitation falls with the development of local (air-mass) atmospheric processes (2%), also associated with meridional synoptic processes.

Thus, under the conditions prevailing in the Azerbaydzhan SSR heavy showers usually fall with the intrusion of cold air masses behind cold fronts with a more meridional transformed pressure field. The forming of a high-altitude trough or the individual center of a cyclone with cold foci over Asia Minor, a great instability and high moisture content of the air masses in the frontal zone are important factors for the falling of intensive shower precipitation. An important role is also played by the complex orography of terrain in the republic, exerting a mechanical effect on the dynamics of circulation processes and on the development of powerful vertical flows over the mountainous part of the basins of individual rivers. The Black Sea and the Caspian Sea play a leading role in the moistening of air and the falling of precipitation.

BIBLIOGRAPHY

1. Aleksandryan, G. A., ATMOSFERNYYE OSADKI V ARMYANSKOY SSR (Atmospheric Precipitation in the Armenian SSR), 1971.

2. Gabriyelyan, G. A., Khachaturyan, A. G., "The Ararat Basin as a Factor in Mudflow Formation," IZV. AN ARM. SSR, NAUKI O ZEMLE (News of the Academy of Sciences Armenian SSR. Earth Sciences), Vol 17, No 1, 1964.

3. Gogishvili, K. S., ISSLEDOVANIYA TSIRKULYATSIONNYKH FAKTOROV GENEZISA KLIMATA GRUZII (Investigations of Circulatory Factors in the Genesis of the Climate of Georgia), 1974.

4. Guniya, S. U., Kharchilava, F. T., AEROSINOPTICHESKIYE USLOVIYA LIVNEVYKH OSADKOV V ZAKAVKAZ'YE I RAZRABOTKA METODIKI IKH PROGNOZIROVANIYA (Aerosynoptic Conditions for Shower Precipitation in Transcaucasia and Development of a Method for its Prediction), 1959.

5. Dzhabbarov, M. A., "On the Problem of the Role of Atmospheric Stratification (Temperature and Air Humidity) in the Formation of Precipitation in the Azerbaydzhan Part of the Southern Slope of the Greater Caucasus," IZV. AN AZERB. SSR, SERIYA NAUK O ZEMLE (News of the Academy of Sciences Azerbaydzhan SSR, Series on the Earth Sciences), No 6, 1974.

6. Madatzade, A. A., Shikhlinskiy, E. M., KLIMAT AZERBAYDZHANA (Climate of Azerbaydzhan), 1968.

7. Pogosyan, Kh. P., Gakhramanov, G. A., "Vertical Distribution of Atmospheric Precipitation in Transcaucasia," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 7, 1967.

8. Sulakvelidze, G. K., Glushkova, N. I., Fedchenko, L. M., PROGNOZ GRADA, GROZ I LIVNEVYKH OSADKOV (Prediction of Hail, Thunderstorms and Shower Precipitation), 1970.

UDC 551.(510.7:515.12)(263)

DISTRIBUTION OF SOME MINOR IMPURITIES IN THE TROPICAL ZONE OF THE ATLANTIC OCEAN

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 49-53

[Article by V. V. Belevich and V. I. Medinets, Odessa Division of the State Oceanographic Institute, submitted for publication 21 September 1979]

Abstract: A study was made of the latitudinal distribution of radon, aerosol, water vapor, aerosol and direct solar radiation reaching the ocean surface, determined on the basis of data from the 27th expeditionary voyage of the scientific-research weather ship "Musson" in the spring of 1978. It was established that the principal factors determining the distribution of the investigated characteristics of the near-water layer of the atmosphere in the tropical Atlantic were the Northeast Trades and the ICZ. In the Trades zone the attenuation of direct solar radiation by aerosol can exceed by a factor of four its attenuation by water vapor. A close correlation is established between the aerosol content in the near-water layer of the atmosphere and aerosol attenuation of direct solar radiation in the region of the Northeast Trades.

[Text] The influence of aerosol on the optical characteristics of the atmosphere, and accordingly on the receipts of solar heat at the surface, in general has been established, although the quantitative values of these correlations have not yet been adequately investigated over the ocean due to the excessively small number of observations. The most complete generalization of the studies examining the influence of aerosol on the receipts of solar radiation at the ocean surface has been made at the Main Geophysical Observatory using data from the "TROPEKS-72" and GATE expeditions [2, 3]. A further study of the quantitative dependences of incoming solar radiation on aerosol is of unquestionable interest and therefore we will examine some aspects of this problem in the example of the expedition on the 27th voyage of the scientific-research weather ship "Musson" in the spring of 1978. On this voyage two meridional profiles were run:

along 30-25.5°W (from 35°N to 5°S) and along 23.5°W (from 5°S to 27°N).

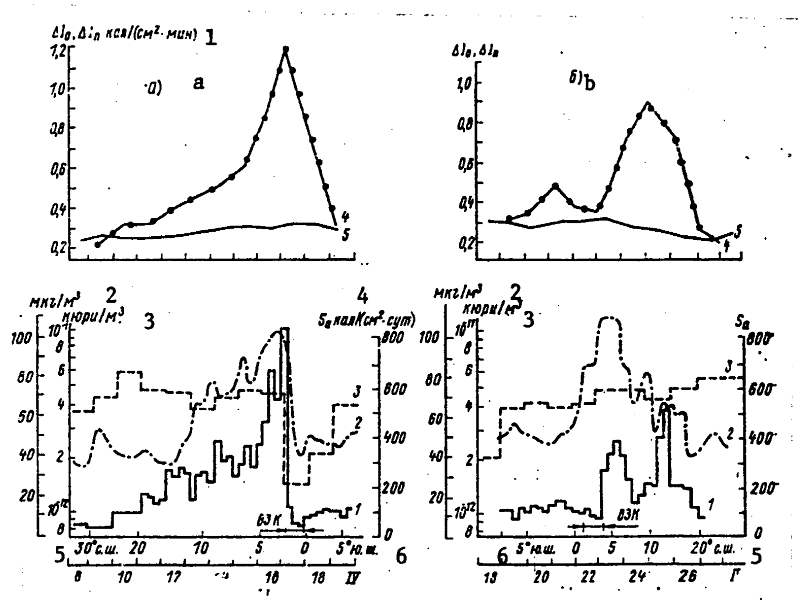


Fig. 1. Distribution of aerosol (1), radon (2) and absorbed radiation (3), and attenuation of direct solar radiation by aerosols (4) and water vapor (5). a) on profile along 30°W (35-5°N) and 25.5°W (5°N-5°S); b) on profile along 23.5° (5°S-27°N).

KEY:

1. cal/(cm^2·min)
2. μg/m^3
3. curie/m^3
4. cal/(cm^2·day)
5. N
6. S
7. ICZ

It is known from the data in the literature that in the Trades region of the Atlantic there is an increased aerosol concentration, especially significant in the latitude zone 10-22°N [2-4, 7], related to the transport of sand dust from the African continent. It has been established by investigations of recent years that a considerable quantity of aerosol of continental origin is also observed at the equator [1, 4, 5].

In order to clarify the influence of aerosol on some atmospheric characteristics on the described voyage on the mentioned meridional profiles specialists made measurements of the weight concentration of aerosol (inorganic dust) in the near-water layer (four times a day, exposure time --

6 hours) and direct solar radiation and carried out continuous registry of natural radioactivity, and also total and reflected solar radiation.

The sampling of atmospheric aerosol was with a filter-ventilation apparatus using FPP-15-1.5 filter fabric. Using the known weight of the filter after reduction to ash and the volume of the investigated air it was possible to ascertain the weight concentration of aerosol.

The radon content in the near-water air layer was determined using an apparatus for the continuous registry of natural radioactivity, described in [6]. Data on its distribution, together with the results of standard meteorological observations and cloud cover photographs from a satellite, were used in identifying the boundaries of the ICZ.

Direct solar radiation was measured hourly with a clear sky near the sun by means of an actinometer and the total and reflected radiation, determined with a pyranometer and albedometer respectively, were registered on the tape of an automatic electronic potentiometer of the KSP-4 type. The absorbed radiation was found as the difference between the total and reflected radiation.

The attenuation of direct solar radiation by aerosol, with reduction to an atmospheric optical mass m = 2, was computed using the formula [4]

$$\Delta I_a = I_0^{\prime} - I - \Delta I_n, \quad (1)$$

where I_0 is direct solar radiation less molecular attenuation in an atmosphere with m = 2 (assumed equal to 1.6 cal/(cm^2·min) [4]), I is the measured intensity of solar radiation, reduced to m = 2 and the mean distance between the earth and sun, received on a perpendicular surface (cal/(cm^2·min)), ΔI_n is the absorption of direct solar radiation by water vapor, related to the content of the latter in a vertical column of the atmosphere by the approximate MacDonald dependence [4, 9], satisfying the accuracy of the computations made,

$$\Delta I_n = 0{,}149\,(2\,w)^{0{,}3}. \quad (2)$$

The w parameter, expressed in g/cm^2, was computed using aerological sounding data for 0930 GMT for a vertical column of the atmosphere 10 km [10].

The spatial-temporal distribution of the investigated characteristics is illustrated in the figure.

In April 1979 the weather conditions in the tropical Atlantic were determined by the subtropical highs. There was an intensification or weakening of the Northeast Trades and a change in the wind regime in the work area in dependence on the position of the Azores High. On 10 April (24°N) the ship entered the zone of the Northeast Trades. During the period 17-23 April the scientific-research weather ship "Musson" was situated in the equatorial pressure trough; on the first and last days of the mentioned period it intersected the ICZ. During the run along 25.5°W the ICZ was situated between 1.5 and 0.5°N and was well developed. During movement of the ship northward along 23.5°W the ICZ was blurred and was traced between 2 and 4°N, that is, it occupied a more northerly position than during movement toward the south.

When running the profile along 30-25.5°W the content of radon and aerosol gradually increased from $2.0 \cdot 10^{-12}$ curie/m^3 and 12 μg/m^3 (20°N) to $10 \cdot 10^{-12}$ curie/m^3 and 105 μg/m^3 (3°N) respectively. A marked decrease in the concentration of radon and aerosol was observed between 2 and 1°N (17 April). This was probably caused by a change in the direction of transport of air masses (wind shear at an altitude of 2-3 km [5] from northeast to southeast), and also an increased purification of the near-water air layer by the shower precipitation and cloud cover observed in the ICZ, being responsible for the loss of aerosol in the lower layers of the atmosphere [11].

As indicated by an analysis of the experimental data (see figure), to the south of the ICZ the radon and aerosol content changed insignificantly. The maximum in the radon distribution ($12 \cdot 10^{-12}$ curie/m^3) during the ship's movement to the north along the profile 23.5°W was observed to the north of the ICZ (4-5°N). With advance northward its content decreased monotonically to $2.0 \cdot 10^{-12}$ curie/m^3, in general duplicating the distribution observed during movement toward the south.

The pattern of distribution of aerosol in the near-water air layer along the meridian 23.5° differs considerably from that obtained during the ship's southward movement along the meridians 30-25.5°W.

Two maxima were observed: at 4-6°N (47 μg/m^3) and at 15°N (60 μg/m^3) and there was a minimum in the region 8-10°N (15 μg/m^3).

The correlation coefficient between the radon and aerosol concentrations in the Trades zone is 0.60, which can indicate transport from a single source (African continent). In our opinion, the different physical properties of the investigated substances determine their different behavior in the atmosphere.

The quantity of vapor in a column of the atmosphere which we computed and its change in the equatorial zone (10°N-5°S) in general agree with the data in [10].

The aerosol attenuation of direct solar radiation ΔI_a and its absorption by water vapor ΔI_n during the movement of the ship to the south also gradually increased and caused a decrease of absorbed radiation; ΔI_n increased considerably more slowly than ΔI_a. For example, whereas at 30°N these values were approximately identical, at 5°N the ΔI_a value more than doubles, whereas ΔI_n increases by only 17%. Accordingly, in the southern part of the Trades zone direct solar radiation was attenuated primarily by aerosol. The maximum attenuation of direct solar radiation by aerosol (to 1.2 cal/(cm^2·min)) was observed in the region 2.5°N before the ICZ, specifically in the transition zone in which there is a predominance of descending compensatory movements [8]. A maximum aerosol concentration in the near-water air layer (105μg/m^3) was also noted in this same source. It should be noted that the prevailing wind direction at 2-3 km remained northeasterly, that is, the air masses were transported from the continent. When running the profile along 23.5°W the maximum ΔI_a value was already noted near 10°N (0.9 cal/(cm^2·min), evidence of a great variability and dynamicity of processes of aerosol transport from the continent to the ocean.

The attenuation of direct solar radiation by water vapor ΔI_n when making the run along 23.5°W had a distribution which in general was the same as when moving from north to south. Along the mentioned profiles the relationships between ΔI_a and ΔI_n changed virtually identically with latitude.

The absorbed radiation along the profile with southward movement in the Trades zone varied in the range 500-640 cal/(cm^2·day), considerably reduced (to 200 cal/(cm^2·day)) by thick cloud cover of the well-developed ICZ.

Along the profile 23.5°W the level of absorbed radiation remained virtually constant (540-650 cal/(cm^2·day)), not decreasing in the ICZ, whose cloud cover was blurred.

An investigation of the correlation between the aerosol distributions in the near-water air layer and aerosol attenuation of solar radiation indicated that in the Trades zone the correlation coefficient between them is 0.91, whereas in the ICZ and to the south there was no significant correlation (correlation coefficients 0.11 and 0.08 respectively). This is evidence that observations of the aerosol content in the near-water air layer of the Trades zone give information on the aerosol content in the entire thickness of the atmosphere if it is assumed that the ΔI_n value is proportional to the total aerosol content in a vertical column of the atmosphere.

The role of aerosol attenuation of solar radiation in the Trades zone will be illustrated in the following example: 25 April (12°N) the ΔI_n value was 0.14 I_0 and $\Delta I_a = 0.58\ I_0$. The direct solar radiation reaching the ocean surface was only 28% of I_0.

In conclusion we note the following.

The principal factors governing the distribution of the investigated characteristics of the near-water layer of the atmosphere in the tropical Atlantic were the Northeast Trades and the ICZ.

The direct solar radiation in the zone 5-20°N is primarily dependent on the atmospheric aerosol concentration.

The close correlation between the aerosol content in the near-water air layer and aerosol attenuation in the Trades zone is evidence that the distribution of aerosol content in the near-water layer characterizes its content in the entire thickness of the atmosphere.

BIBLIOGRAPHY

1. Kapustin, V. N., Pirogov, S. M., "Aerosol in the Near-Water Layer of the Equatorial Zone of the Atlantic Ocean," TROPEKS-74 (Tropeks-74), Leningrad, Gidrometeoizdat, 1976.

2. Kondrat'yev, K. Ya., KLIMAT I AEROZOL' (Climate and Aerosol), TRUDY GGO (Transactions of the Main Geophysical Observatory), No 381, 1976.

3. Kondrat'yev, K. Ya., et al., "Aerosol in the GATE Region and its Radiation Properties," TRUDY GGO, No 381, 1976.

4. Laktionov, A. G., Gudimenko, A. V., Kopchenov, V. M., Semko, N. N., "Some Characteristics of Aerosol in the Tropical Zone of the Atlantic Ocean," TROPEKS-72 (Tropeks-72), Gidrometeoizdat, 1974.

5. Laktionov, A. G., et al., "Correlation of Optical and Aerosol Characteristics of the Atmosphere in the Eastern Equatorial Atlantic," TROPEKS-74, Vol 1, Leningrad, Gidrometeoizdat, 1976.

6. Medinets, V. I., Tarnopol'skiy, L. G., "Determination of the Boundaries of the ICZ Using the Radon Concentration," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 2, 1978.

7. Orlov, A. P., et al., "Atmospheric Radiation in the Spectral Region 9-14 μm in the Equatorial Zone of the Atlantic Ocean," TROPEKS-74, Leningrad, Gidrometeoizdat, 1976.

8. Petrosyants, M. A., Slaby, S., Snitkovskiy, A. I., Fal'kovich, A. I., "Air Circulation in the Tropical Tropopause Along the Meridian 23°30' W," TROPEKS-74, Leningrad, Gidrometeoizdat, 1976.

9. Sivkov, S. I., METODY RASCHETA KHARAKTERISTIK SOLNECHNOY RADIATSII (Methods for Computing the Characteristics of Solar Radiation), Leningrad, Gidrometeoizdat, 1968.

10. Snopkov, V. G., "Total Atmospheric Moisture Content in the Tropical Zone of the Atlantic Ocean Using Aerological Sounding Data from the 13th Voyage of the SRS 'Akademik Kurchatov'," TROPEKS-72, Leningrad, Gidrometeoizdat, 1974.

11. Hogan, A. W., "Aerosols of the Trade Wind Region," J. APPL. METEOROL., Vol 15, No 6, 1976.

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PROPAGATION OF A MONSOON OVER EAST ASIA AND THE DEGREE OF ITS STABILITY

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[Article by Candidate of Geographical Sciences N. I. Lisogurskiy and A. Z. Petrichev, Far Eastern Scientific Research Hydrometeorological Institute, submitted for publication 1 October 1979]

Abstract: On the basis of observational data from 393 stations, using the S. P. Khromov method, the authors constructed a map of the propagation of monsoons in East Asia. The degree of their stability is demonstrated. It was found that the monsoon region of East Asia breaks down into zonal parts and the position of the monsoon "divides" corresponds to the position of the climatological fronts. It is shown that the stability of middle-latitude monsoons is no less than the stability of subtropical monsoons.

[Text] The enormous influence which monsoons exert on the formation of climate over extensive regions of the earth is well known. It is therefore easy to understand the interest which scientists have in this form of atmospheric circulation. A great number of investigations has been devoted to the subject of monsoons, but until now there have been different definitions of the term "monsoon" itself and there is no unanimity on matters relating to the reasons for genesis and development of the regions of propagation of monsoons over the earth.

At the present time the definition of a monsoon proposed by S. P. Khromov in 1950 and made more precise by him in 1956 [8, 9] is the most recognized by meteorologists. According to this definition, a monsoon is "such a regime of general circulation of the atmosphere in a large geographical region in which winds of one direction (quadrant, octant) in each place in this region sharply predominate over the others and the prevailing direction of the wind changes to the opposite or nearly opposite direction from winter to summer and from summer to winter." Opposite directions are those between which the angle is 120° or more and sharply prevailing directions are those whose frequency of recurrence is 40% or more. Although such a definition has a purely meteorological character and gives no idea concerning the genesis of monsoons it makes it possible to distinguish monsoonal flows from the total number of atmospheric phenomena and give them quantitative characteristics.

Using these criteria, S. P. Khromov, on the map which he constructed, showed the regions of the earth in which monsoons occur, as well as regions with a "monsoon tendency" (mean frequency of recurrence of the prevailing direction less than 40%). Some of this map, the part for East Asia, is reproduced as Fig. 1. On the basis of his investigations S. P. Khromov drew the conclusion that monsoonal regions are grouped into zones drawn out in a latitudinal direction, which is caused by seasonal movements and evolution of atmospheric centers of action. He differentiated the following monsoonal zones: tropical -- between 20° north and south latitude, subtropical -- between 30 and 40° latitude in both hemispheres, zone of monsoons in the temperate latitudes in the northern hemisphere -- between 50-60° latitude, and also the polar zone -- near the 70th parallel in the northern hemisphere.

The zonal distribution of monsoonal regions on the S. P. Khromov map is disrupted only in East Asia, where this zone is a continuous meridional band of monsoons. S. P. Khromov explained the appearance of this azonal region as a result of the intensification and merging of three monsoonal zones.

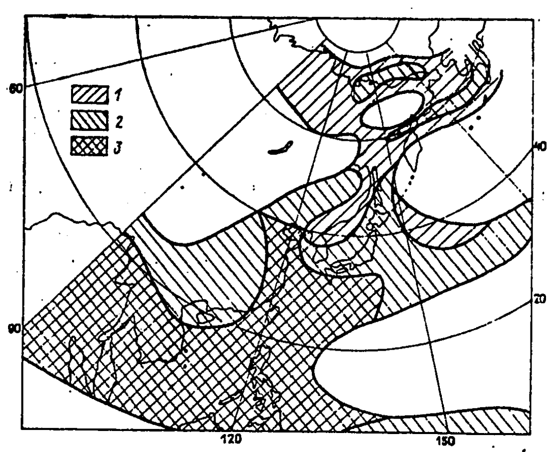

Fig. 1. Geographical propagation of monsoons according to S. P. Khromov. Regions with a monsoonal angle from 120 to 180° are shaded. The mean frequency of recurrence of prevailing wind directions in January and July: 1) less than 40%; 2) 40-60%; 3) more than 60%.

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However, it should be noted that in constructing the mentioned map the prevailing wind directions were determined only at the points of intersection and at the centers of 10° squares. In order for the map to attain a greater accuracy S. P Khromov proposed the use of original observational data in the network of stations.

In the years which followed a number of scientists made attempts at more precise determination of the boundaries of monsoonal circulation over individual regions of the earth. We will mention the most important of them.

In 1960 the boundaries of monsoonal circulation over China were defined by Chzhan Tszyachen using the Schick index [10]. He demonstrated that the center of monsoonal activity is not situated over northeastern China, but near its southeastern shores.

On the basis of use of data on the prevailing wind direction for each 5° grid square, found by computing wind roses, a refined map of the propagation of monsoons over the Pacific Ocean was compiled and published in [7]. This map gives a more detailed pattern of distribution of monsoonal phenomena over the ocean, being somewhat different than that obtained by S. P. Khromov.

In the early 1970's new boundaries of monsoons were proposed by K. Ramedzh in his monograph METEOROLOGIYA MUSSONOV (Meteorology of Monsoons) [5]. He regards as monsoonal only those regions of those defined by S. P. Khromov in which the mean velocity of the resultant wind in January or July exceeds 3 m/sec and in each 5° square in any 2-year period in any month there is less than one replacement of a cyclone by an anticyclone or vice versa. As a result, only the region bounded by 35°N-25°S and 30°W-170°E was included in the monsoonal region, that is, in the author's opinion [5] a monsoon is a purely tropical phenomenon.

After evaluating the results of regionalization of monsoons in East Asia it is easy to conclude that no unanimity has been achieved on these matters.

We feel that at the present time, when adequate archival material has been accumulated, it has become possible to return again to this monsoon problem, employing the criterion given by S. P. Khromov as the basis for identifying a monsoon.

In the investigation we used wind data published in the SPRAVOCHNIK PO KLIMATU SSSR [6] and the KLIMATICHESKIY SPRAVOCHNIK ZARUBEZHNOY AZII [2] (Handbook of USSR Climate; Climatic Handbook of Foreign Asia). The territory of East Asia from the shores of the Arctic Ocean to the Indochinese Peninsula and from 100°E to 180°E was considered. In this territory data on the mean monthly velocity and frequency of recurrence of the wind were obtained for 957 stations. We selected those stations at which the mean wind velocity in January or July exceeded 3 m/sec, that is, at least in one month of these two. Adhering to the proposal by Ramedzh [5], this condition was selected because in regions with weak winds monsoonal transport was poorly expressed. There were 393 stations satisfying this condition.

Using the observational data for the selected stations we computed the prevailing wind direction and its frequency of recurrence for January and July by the method proposed by Ye. S. Rubinshteyn [1]. Days with calms were taken into account when computing the frequency of recurrence of the prevailing wind direction. This is necessary because when there are a large number of such days the frequency of recurrence of the prevailing direction, computed without taking calms into account, becomes nonindicative. Then we computed the angle between the bisectors of the predominant squares and its values were plotted on the map, after which isogonic lines were drawn each 30°. According to the definition given by S. P. Khromov, regions are considered monsoonal when the angle between the predominating wind direction changed by 120° or more from January to July.

Next, for determining stability of the monsoonal regime we computed the S. P. Khromov index, representing the half-sum of the frequencies of recurrence of the prevailing wind directions for January and July. These data served as a basis for compiling a refined map of monsoonal regions over East Asia (Fig. 2), on which we showed the boundaries of propagation of monsoons and the degree of their stability. Taking into account the circumstance that the wind observations used in refining the S. P. Khromov map over the Pacific Ocean [7] were taken for approximately the same period as for the construction of our map, in Fig. 2 we deemed it possible to combine the results of the refinements obtained both in our studies and in [7].

A comparison of the map constructed in this way with the S. P. Khromov map shows that in general they coincide. However, Figure 2 reveals a number of new and significant details appearing due to the use of material for a considerably greater number of points. The greatest difference is that the azonally drawn-out band of monsoons in East Asia is broken down into individual zonal regions, much as is observed over other regions of the earth. This is not surprising because different air masses participate in the formation of monsoonal flows over this region, as already indicated by S. P. Khromov.

There are regions between the individual regions of active monsoonal activity where the S. P. Khromov index acquires minimum values or where a monsoonal angle is absent. As proposed by V. V. Shuleykin [11], these regions will be called "monsoon divides." To be sure, the appearance of monsoon divides is not related to the absence of monsoons in these regions. Their appearance is attributable to the fact that they are situated at the line of contact of monsoons caused by different circulatory processes. The alternate penetration of monsoonal flows into the monsoon divide region has the result that no clearly expressed prevailing wind direction is observed nere. The regions of the monsoon divides have a relatively small width and could be discovered only in a detailed investigation with the use of a great number of observations.

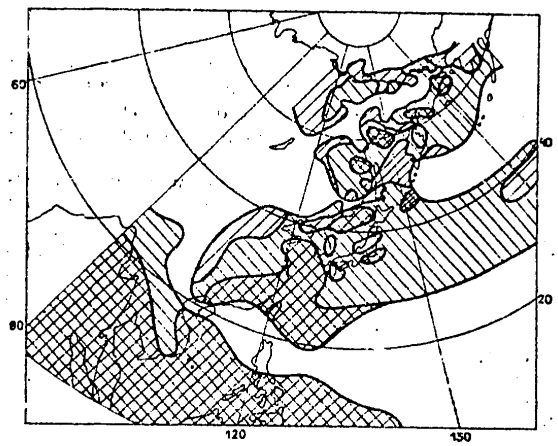

Fig. 2. Refined distribution of monsoonal regions over East Asia. For symbolization see Fig. 1.

The following principal monsoonal regions can be distinguished on the map (Fig. 2). Over the southern part of the Asian continent there is a region of tropical monsoons. This region is separated in the north from the subtropical monsoons by a monsoon divide whose axis passes approximately along 20°N. The position of this monsoon divide coincides with the July position of the ICZ [3, 4]. This circumstance once again confirms the prevailing opinion that equatorial air can penetrate to the southeastern coast of China. In the tropical monsoon region there is a seasonal change of the winter easterly Trade flows to summer westerly winds.

As might be expected, the most stable monsoon is observed in this region. Its mean frequency of recurrence at individual coastal stations exceeds 80%. In the central regions of the Indochinese Peninsula, in which calms frequently prevail, the stability of monsoons is reduced to 50-60%.

Then, to the north between 25-43°N, there is a region of subtropical monsoons taking in China, Japan, Korea, the south of Primor'ye and propagating into the depth of the continent to 105°E. In this region there is a seasonal change of the northerly winds associated with the centers of the Siberian anticyclone penetrating into China in the winter to the summer southeasterly flows arising as a result of interaction between the Asiatic Low and the spur of the subtropical North Pacific anticyclone extending to the shores of Asia. Thus, the polar continental air of the winter monsoon is replaced here by marine tropical air only in summer. This monsoonal region fits into the zone formed between the winter and summer positions of the polar front.

The stability of subtropical monsoons is relatively great and at coastal stations can attain 70%. With advance into the depth of the continent their stability decreases to 40-60%, and to the west of 110°E the mean frequency of recurrence becomes less than 40%. It is characteristic that the mean frequency of recurrence of prevailing wind directions over northern Korea and the southern part of Primor'ye exceeds 60%. The results obtained for this region differ considerably from the conclusions drawn by S. P. Khromov, who contended that only a monsoonal tendency should be observed there.

Temperate-latitude monsoons are very clearly expressed on the refined map; they take in the region from 45 to 65°N. During winter a monsoonal flow caused by interaction between the Siberian anticyclone and the Aleutian Low prevails over the mentioned region. In summer, however, monsoonal flows arise as a result of interaction between regions of reduced pressure forming over the continent and anticyclones over the marginal seas and the northwestern part of the Pacific Ocean. For example, the monsoonal flows in the region of the Sea of Japan and the Sea of Okhotsk arise during the lifetime of the summer Far Eastern Low and the predominance of regions of increased pressure over these seas. The monsoonal region in the northern part of Kamchatka and the southern part of Chukotka is formed with the formation of the summer anticyclones of the Bering Sea and the cyclones of the Arctic front over Chukotka.

The anticyclone situated over the Sea of Okhotsk is the most powerful and stable of all those arising in summer in the marginal seas of East Asia. The most active region of temperate-latitude monsoons is also situated here. Their stability at the center of this region exceeds 60%. With advance into the depth of the continent it decreases to 40%. Among the monsoons of the temperate latitudes the monsoon from the Sea of Okhotsk penetrates the greatest distance onto the continent and attains 120°E. Thus, the monsoons observed in the Sea of Okhotsk region are equal in stability to subtropical monsoons, but are propagated over a lesser area. The stability of Bering Sea monsoons is less than over the remaining regions of the temperate latitudes and is 40-60%. It exceeds 60% only in individual small regions. The Bering Sea monsoon penetrates 400-600 km onto the continent, that is, much less than the Sea of Okhotsk monsoon.

The monsoon divide between the temperate-latitude monsoons and the polar monsoon passes along 65°N. The polar monsoon is observed in a narrow zone along 70°N, penetrating 200-300 km onto the continent. However, along the valley of the Lena River it is propagated to its upper course. In this same region there is maximum stability of the polar monsoon -- 40-60%. In the remaining regions for the most part it is only a monsoonal tendency which is observed.

In summarizing what has been said above, the following conclusions can be drawn:

1. The stability of monsoonal activity in the temperate latitudes of East Asia is approximately the same as in the subtropical latitudes.

2. The monsoonal region of East Asia is divided by three monsoon divides into zonal parts agreeing with existing concepts concerning the zonal propagation of monsoons over the earth.

3. The position of monsoon divides agrees well with the position of the climatic fronts.

BIBLIOGRAPHY

1. Alisov, B. P., Drozdov, O. A., Rubinshteyn, Ye. S., KURS KLIMATOLOGII (Course in Climatology), Parts I, II, Leningrad, Gidrometeoizdat, 1952.

2. KLIMATICHESKIY SPRAVOCHNIK ZARUBEZHNOY AZII (Climatic Handbook of Foreign Asia), edited by A. N. Lebedev and N. D. Konanev, Leningrad, Gidrometeoizdat, 1974.

3. Kruzhkova, T. S., "Intertropical Convergence Zone and the Principal Trajectories of Cyclones in the Tropical Zone," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 87, 1971.

4. Minina, L. S., PRAKTIKA NEFANALIZA (Nephanalysis Experience), Leningrad, Gidrometeoizdat, 1970.

5. Ramedzh, K., METEOROLOGIYA MUSSONOV (Meteorology of Monsoons), Leningrad, Gidrometeoizdat, 1976.

6. SPRAVOCHNIK PO KLIMATU SSSR (Handbook of USSR Climate), Part III, VETER (Wind), Nos 22-27, 33, 34, Leningrad, Gidrometeoizdat, 1967-1968.

7. TIKHIY OKEAN. METEOROLOGICHESKIYE USLOVIYA NAD TIKHOM OKEANOM (Pacific Ocean. Meteorological Conditions Over the Pacific Ocean), edited by V. S. Samoylenko, Moscow, Nauka, 1966.

8. Khromov, S. P., "A Monsoon as a Geographical Reality," IZV. VGO (News of the All-Union Geographical Society), Vol 82, 1950.

9. Khromov, S. P., MUSSONY V OBSHCHEY TSIRKULYATSII ATMOSFERY (Monsoons in General Circulation of the Atmosphere), Leningrad, Gidrometeoizdat, 1956.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000300020010-5

10. Chzhan Tszyachen, "Some Points of View Concerning the Nature of Chinese Monsoons," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 90, 1960.

11. Shuleykin, V. V., FIZIKA MORYA (Physics of the Sea), Moscow, Nauka, 1968.

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VARIABILITY OF THE TEMPERATURE FIELD IN THE EQUATORIAL ATLANTIC

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[Article by Doctor of Physical and Mathematical Sciences V. V. Yefimov, Marine Hydrophysical Institute, submitted for publication 10 September 1979]

Abstract: The article gives the results of statistical processing of temperature data for different depths in the Equatorial Atlantic during the period 1961-1977. The characteristics of the annual variation of temperature, heat content in the upper active layer of the ocean and radiation heat flux are evaluated. A conclusion is drawn that advective heat transfer plays the predominant role in generating the annual harmonic. The distribution functions are computed for the difference temperature in dependence on depth. A comparison of the experimental distribution functions and the normal law is given.

[Text] Recently interest has increased in investigations of interaction between the atmosphere and ocean in the tropical and equatorial regions of the oceans. Such major experiments as TROPEKS-74 and the First Global Experiment of 1979 were carried out. It is assumed that the equatorial regions of the world ocean play a decisive role in the forming of weather anomalies on the continents in a subsequent period [1].

At an earlier time extensive investigations of dynamic and thermal processes were carried out in the central part of the Atlantic Ocean, combined in the general EKVALANT program. Accordingly, many important characteristics of the averaged temperature field of the Tropical Atlantic are quite well known [2]. However, quantitative evaluations of the temporal variability of the temperature field of this region of the ocean are still in need of refinement and further study. This applies, in particular, to long-term variations of parameters in the upper active layer on seasonal and year-to-year scales.

Below we will examine the results of statistical processing of all the materials from expeditionary investigations by scientific research vessels of the Marine Hydrophysical Institute Ukrainian Academy of Sciences, the "Mikhail Lomonosov" and the "Akademik Vernadskiy," carried out in the equatorial region of the Atlantic Ocean, supplemented by some data of expeditionary vessels of the Hydrometeorological Service. The primary materials are the results of standard hydrological soundings of temperature at individual points in the ocean. The processing was done using about 800 individual soundings at hydrological stations in the equatorial region of the ocean lying in the rectangle 5°N-5°S, 18-40°W., relating to the period 1961-1977. To be sure, the measurement data were not distributed uniformly through this period. A great many measurements were made during 1961-1964, 1973-1975 and 1977; there are considerably fewer data between these years.

In the analysis we used temperature data for standard horizons in the upper layer to a depth of 500 m. As a result we computed the mean temperatures and their dispersions, the distribution functions (histograms), and also the amplitudes A_n and phases φ_n of the harmonic components. A_n and φ_n were computed by the ordinary mean square fitting method. We found such amplitudes and phases of the harmonic component $\hat{T}_i = A_n \sin(\omega_n t_i + \varphi_n)$ that the standard deviation from the measured T_i values was minimum. Thus, we minimized the function

$$\varepsilon(A_n, \varphi_n) = \sum_{i=1}^{N} (T_i - \hat{T}_i)^2,$$

where N is the volume of temperature data used, ω_n is frequency, t_i is time.

The table gives the computation results. It gives the mean temperature values $\bar{T}$ at different depths, the dispersions of temperature fluctuations σ^2, the amplitude A and the phase φ of the harmonic component of the annual period, and also the residual temperature dispersion σ_T^2 (temperature dispersion less the annual periodic component: $\sigma_T^2 = \varepsilon_{min}/N$). In addition, we computed the heat reserve Q in the surface layer 0-150 and 0-500 m

$$\left(Q = c_p \rho \int_0^z T(z)\, dz\right)$$

and computed these same statistical characteristics for these reserves. The left half of the table describes the entire mass of data used (±5° in latitude and 18-40°W); the right half of the table gives sample data relating to a narrower latitude region near the equator: 3°N-3°S.

First we draw attention to the following peculiarity of the results: in the upper quasihomogeneous layer of the ocean the amplitude and phase of the annual temperature component vary relatively little. For example, for the entire mass of data the amplitude attenuates from 0.89 to 0.73°C and the phase varies from 0.12 to 0.45 rad in the layer from the surface to 30 m. For example, we note that $\varphi = -\pi/6$ denotes a phase shift between the annual variation of temperature and the beginning of the year of one month (that is, the temperature maximum falls at the end of April); in the case $\varphi = 0$ the maximum falls at the end of March, etc. Therefore, $\varphi = 0.12$ corresponds to a maximum of the annual temperature variation falling in the second half of March.

z м	$\overline{T}$	σ^2	σ_r^2	A	φ	$\overline{T}$	σ^2	σ_r^2	A	φ
	5° с. ш. — 5° ю. ш.; 18—40° з. д. (1, 2, 3)					3° с. ш. — 3° ю. ш.; 18—40° з. д. (1, 2, 3)				
0	27.12	1,15	0,71	0,89	0,12	27,14	1,0	0,64	0,92	0,21
10	27,08	1,13	0,73	0,84	0,12	27,11	1,04	0,69	0,9	0,19
20	27,0	1,13	0,79	0,78	0,18	27,0	1,05	0,74	0,86	0,24
30	26,8	1,29	1,01	0,73	0,45	26,8	1,07	0,85	0,76	0,52
50	25,7	3,44	3,0	1,0	1,55	25,8	3,3	2,5	1,18	1,71
75	22,1	12,0	9,4	2,19	2,26	22,7	9,7	5,6	2,5	2,37
100	18,4	12,8	10,6	1,24	2,47	18,0	12,0	8,3	2,5	2,87
150	14,2	2,5	2,4	0,4	2.47	14,1	2,03	1,94	0,45	3,14
200	12,8	0,65	0,64	0,13	2,75	12,8	0,38	0,36	0,23	0,28
300	10,7	0,66	0,64	0,2	2.76	10,8	0,59	0,53	0,3	2,97
500	7,0	0,23	0.23	0,09	1,67	6,9	0,2	0,2	0,06	2,37
Q(0—150)	325	710	610	14.2	2,07					
Q(0—500)	687	1126	950	17,1	2,27					
R	461	1852	1785	31	2,26					

4 Размерности: Q — в (кал/см²)·10⁻³; R — в кал/(см²·сут); $\overline{T}$, A — в °C; φ — в рад.

KEY:

1. N
2. S
3. W
4. Dimensionalities: Q -- in $(\mathrm{cal/cm^2})\cdot 10^{-3}$; R -- in $\mathrm{cal/(cm^2 \cdot day)}$; $\overline{T}$, A -- in °C; φ -- in rad.

The seasonal temperature changes are traced to a depth of 100-150 m. Deeper the A and φ evaluations become unstable. This can be seen from the fact that the residual dispersion σ_r^2 already differs little from the initial σ^2. What has been said is illustrated in Fig. 1, which shows changes in amplitude, dispersion and phase of temperature fluctuations with depth. It can be seen that there are small changes in all the characteristics in the upper quasihomogeneous layer and then a local increase in amplitude of the annual temperature variation in the upper thermocline. The phase regularly increases with depth so that, for example, at the 100-m depth the temperature maximum already occurs in time at the beginning of November.

What is the mechanism of the seasonal temperature change in the equatorial region of the ocean? As is well known, there are two possible reasons for such variations. These are seasonal changes in the heat balance components and advective heat transfer. Although at the equator the annual harmonic of variations of external solar radiation is virtually absent, the seasonal variations of the heat balance components are not equal to zero.

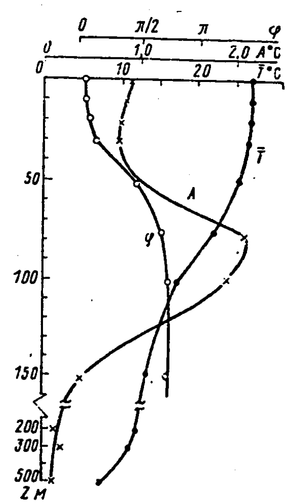

Fig. 1. Distribution of mean temperature $\overline{T}$, amplitude A and phase φ of annual harmonic of temperature variations.

At the present time little is known about their amplitude near the equator in the Atlantic Ocean [3]. As an approximate evaluation we used the results of measurements of total solar radiation R made on the scientific-research ships "Mikhail Lomonosov" and "Akademik Vernadskiy." The available data were processed by the same method and the results for the latitude zone ±5° are given in the table. The amplitude of the annual harmonic of total radiation was 31 cal/(cm^2·day), phase -- 2.26 rad. It is natural that the amplitude of the annual harmonic of the total heat balance at the ocean surface does not exceed this value. It is probably about 1/3 of it, that is, approximately the same fraction as the mean value of the total heat balance relative to the radiation balance [4].

It is easy to show that the mentioned variations of the total heat balance at the ocean surface cannot ensure the variations of heat content in the upper active layer of the ocean cited in the table. In actuality, In actuality, without taking advective heat transfer into account, the steady seasonal variations of the temperature field are related to variations of the heat flow at its surface (the heat flow at the lower boundary of the active layer is neglected) by the simple expression

$$\frac{\partial Q}{\partial t} = B_0 \sin \frac{2\pi}{365} t,$$

where B_0 is the amplitude of the annual harmonic of the total heat flow at the surface, Q is the heat content of the active layer.

Then

$$B_0 = \frac{2\pi}{365} Q^0,$$

where Q_0 is the amplitude of the annual harmonic of heat content variation.

Assuming the amplitude of heat content variations in the upper 150-m layer, as given in the table, to be $14.2 \cdot 10^3$ cal/cm^2, we obtain B_0 = 244 cal/(cm^2·day). This is considerably greater than that which was estimated earlier for seasonal variations of the heat flow at the surface. Thus, the annual temperature variations in the upper layer of the ocean greatly exceed the values which can be expected solely as a result of changes in the heat flow through the ocean surface.

Advective heat transfer is evidently the main reason for the seasonal temperature changes in the equatorial region of the Atlantic Ocean. This region is a dynamically active part of the ocean with quite intensive currents. Among these it is possible to mention the Lomonosov subsurface current, having a great extent, and the surface transfer in a predominately northwesterly direction, the South Trades Current. The latter also probably makes the main contribution to the seasonal variation of temperature near the equator. This is indicated by the phases of the annual temperature wave, close to the phase of the seasonal variation of surface temperature in the southern hemisphere.

The advective nature of the seasonal temperature variations near the equator distinguishes this region from other regions of the ocean. It is known that in the overwhelming part of the ocean the seasonal temperature changes in the upper active layer are caused by local variations of the heat balance components at the surface.

Now we will examine the variability of residual temperature of the upper layer of the ocean $T' = T - \hat{T}$, that is, the temperature less its seasonal variation $\hat{T}$. In the variations of residual temperature T' it is possible to discriminate the year-to-year variability and intermediate-scale variations (a period of months). Among these the year-to-year variability is the most important for the purposes of predicting weather anomalies. However, available data were inadequate and the evaluations of long-term variability are not reliable. Accordingly, the spectral composition of temperature variations in this region of the ocean could not be studied.

Nevertheless, useful information can be obtained from an analysis of the distribution functions. P(T') histograms were computed for all the temperature data. These characterize temperature variability. Figure 2 shows P(T') functions for the residual temperature at different horizons. We note that the histograms of initial temperature data P(T) have a two-peak appearance, as a result of presence of the harmonic component of seasonal variation, and therefore they are not cited. The P(T') distribution makes possible a direct evaluation of the probability of deviation of temperature values at different horizons from the mean square values given in the table (taking into account the regular seasonal variation).

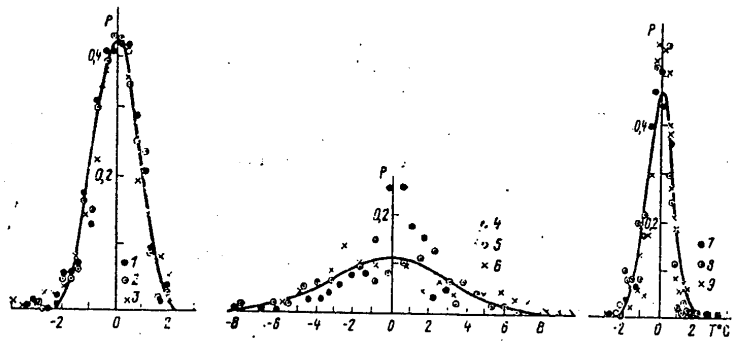

Fig. 2. Distribution function for residual temperature p(T') for different depths. 1) 0 m; 2) 10 m; 3) 30 m; 4) 50 m; 5) 75 m; 6) 100 m; 7) 200 m; 8) 300 m; 9) 500 m.

The P(T') experimental functions were broken down into three groups relating to the region of the upper quasihomogeneous layer, the upper part of the thermocline (region of the maximum temperature gradient) and the depths 200-500 m. For these groups the P(T') values behave in the same way. The broadest P(T') distribution is characteristic for the depths of the maximum temperature gradient. Here the standard deviations of residual temperatures T' attain 2-3°C. The P(T') scatter decreases above and below.

Figure 2, as a comparison, gives the theoretical distribution functions corresponding to a normal law with a dispersion equal to the mean dispersion of fluctuations T' in this layer, taken from the table. It can be seen that the experimental distribution functions differ insignificantly from the normal values. The difference from the normal law is manifested primarily for small depths. An asymmetry of the P(T') distribution is characteristic here: negative T' values are encountered with a greater probability than positive values.

Such a peculiarity of the P(T') behavior is naturally related to an essentially nonlinear mechanism of formation of heat flows through the ocean surface. With an increase in surface temperature there is a considerable increase in ocean heat transfer by means of evaporation and therefore a "saturation effect" arises. The temperature of the ocean surface in the equatorial region rarely increases above 28°C. We note that an essentially asymmetric form of the distribution function is characteristic for all flows through the ocean surface: flows of heat, moisture and momentum [5].

BIBLIOGRAPHY

1. Marchuk, G. I., Skiba, Yu. N., "Numerical Computation of Conjugate Problem for a Model of Thermal Interaction Between the Atmosphere and Ocean and the Continents," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences, Physics of the Atmosphere and Ocean), Vol 12, No 5, 1976.

2. Boguslavskiy, S. G., TEMPERATURNOYE POLE TROPICHESKOY ATLANTIKI (Temperature Field of the Tropical Atlantic), Kiev, Naukova Dumka, 1977.

3. Timofeyev, N. A., ATLAS TEPLOVOGO BALANSA OKEANOV (Atlas of the Heat Balance of the Oceans), Sevastopol', MGI AN UkrSSR, 1970.

4. Stepanov, V. N., MIROVOY OKEAN (World Ocean), Moscow, Znaniye, 1974.

5. Elsberry, R. L., Norman, T. C., "Oceanic Thermal Response to Strong Atmospheric Forcing. Characteristics of Forcing Events," J. PHYS. OCEANOGR., Vol 8, No 2, 1978.

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METHOD FOR DETERMINING THE DENSITY OF PACKING OF DRIFTING ICE USING SATELLITE DATA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 65-68

[Article by P. A. Nikitin and N. D. Lyubovnyy, State Scientific Research Center for the Study of Natural Resources, submitted for publication 28 August 1979]

Abstract: The authors have formulated and applied an algorithm for determining the density of packing of drifting ice using measurement data from a scanning microwave radiometer. The algorithm makes possible the processing of a mass of satellite data in an interactive regime and the representation of a map of the spatial distribution of sea ice in visualized form. At the same time, using the statistical characteristics of a signal from test sectors it is possible to evaluate the reliability of the output data.

[Text] Due to the greater volumes of sea transport and lengthening of the navigation season there is need for more detailed regular information on drifting sea ice. One of the new and promising methods for obtaining such information is microwave sensing from artificial earth satellites. This method has a significant advantage -- the possibility of making measurements through the cloud cover and at nighttime, which is especially important for the polar regions.

For the first time satellite microwave data on the density of packing of drifting ice were obtained when processing measurements from the artificial earth satellite "Cosmos-243" in 1968 [1]. Then similar studies were made in the United States using data from a scanning radiometer carried aboard the artificial earth satellite "Nimbus-5" [5].

A determination of the density of packing is possible due to the great difference between the measured radiobrightness temperatures of ice and water. The radiometer signal strength is proportional to the ratio of the areas occupied by ice and water in the field of view of the radiometer antenna [1]:

$$T_{я} = T_{я}^{л} S + T_{я}^{в}(1 - S). \quad (1)$$

[Я = br; Л = ice; В = water]

Here T_{br} is the measured radiobrightness temperature; S is the density of packing (relative area) of the ice cover, T_{br}^{ice} and T_{br}^{water} are the radiobrightness temperatures of ice and water respectively.

It follows from the cited simple relationship that the accuracy in determining the quantity of drifting ice will be dependent on the error in a priori stipulation of T_{br}^{ice} and T_{br}^{water} and the accuracy of measurements, including scaling of the radiometer signal into absolute values of the radiobrightness temperature. The method for the latter has not yet been adequately perfected and involves calibration against test sectors of the earth's surface or "against space," which can lead to considerable errors. The radiobrightness temperature of the water can be computed with a high accuracy. In this case it can be assumed that

$$T_{br} = qT_0, \quad (2)$$

where T_0 is the thermodynamic temperature of the emitting medium, q is the emitting power (emissivity), dependent on the electrophysical characteristics of the medium, the frequency of the radiation and the sighting angle.

The emission characteristics of sea water have been studied quite well [4] and its thermodynamic temperature in the zone near the ice edge is 273±1.5 K [2]. In this direction sea ice has been studied far more poorly. It is a complex heterogeneous medium whose electric properties are dependent on the age, thermal regime, time and place of formation. The model computations made by the authors indicated that the changes in T_{br}^{ice} can exceed 50 K. There are no reliable experimental data on the radiobrightness characteristics of sea ice. Accordingly, at the present time there is no possibility for making direct calculations of the density of packing or making a sufficiently precise determination of its possible accuracy. It is true that source [5] gives the figure 6% (that is, less than 1 "continuity" scale unit), but it was obtained for a fixed emissivity, which obviously does not correspond to reality.

In addition, the processing of experimental radiometer-polarimeter data from the instrumentation carried on the artificial earth satellite "Meteor-18" and theoretical computations of the radiobrightness characteristics of the arctic atmosphere indicate that at wavelengths less than 2 cm it is impossible to neglect the influence of the atmosphere, which attains maximum values specifically during the summer navigation period [3].

In connection with what has been said above, and also taking into account the great amount of information arriving from artificial earth satellites and requiring the automation of the interpretation process, at the present time the routine processing and sufficiently correct evaluation of the reliability of the computed parameters is possible only by dispensing with a priori stipulation of characteristics of the atmosphere and underlying surface. Such a possibility is afforded by the use of methods developed in the theory of image recognition. In this case it is possible to limit ourselves to a priori information only on the position (boundaries) of test sectors of the earth's surface. In a given case when it is known that the relationship between radiobrightness or the amplitude of a signal (absolute radiobrightness temperatures are no longer required) and the density of packing of the drifting ice is linear, in order to recognize sectors of any density of packing it is necessary to have only two test sectors -- the continuous ice cover and the open water surface. In the polar latitudes such sectors are virtually constant, for example, the continuous ice in the region near the pole and the open water surface in regions adjacent to the edge of the drifting ice.

Taking into account the virtually simultaneous making of measurements in the test sectors and their sufficient spatial extent, it can be assumed that the signal dispersion, computed from the totality of measurements within each of the test sectors, for the most part is determined by the spatial nonuniformity of properties of the atmosphere and underlying surface.

In applying the algorithm for breakdown of signal amplitude into classes corresponding to the required number of ice density gradations we used the known criterion of a "minimum of Euclidean distance." The boundaries of the classes (gradations) were found in the following way:

$$B_i = \frac{M_{i-1} D_i + M_i D_{i-1}}{D_i D_{i-1}}, \tag{3}$$

where $i = 1,\ldots,n$, B_i is signal strength at the boundary of the i-th and i - 1st classes, n is the number of classes to be determined, M_i is the mean value of signal amplitude, D_i is signal dispersion,

$$\left.\begin{aligned} M_i &= M_1 + \frac{M_n - M_1}{n} i \\ D_i &= D_1 + \frac{D_n - D_1}{n} i \end{aligned}\right\}, \tag{4}$$

M_1, D_1 and M_n, D_n are the statistical characteristics of a signal in the test sectors.

If the distribution function for the inhomogeneities responsible for the dispersion is normal, on the basis of the stipulated reliability it is possible to determine the possible number of ice density gradations. For example, with a 95% reliability

$$n = \frac{|M_1 - M_n|}{4\sqrt{D}}. \tag{5}$$

Or, by stipulating the required number of gradations, it is possible to compute the reliability of their determination:

$$c = \pm \frac{|M_1 - M_n|}{2n\sqrt{D}}, \quad (6)$$

where c is the half-width of the confidence interval in mean square error units.

The existing possibilities for automation of the processing process and the form of the primary information determined three work stages:
-- preparation of the initial mass of data;
-- determination of the density of ice packing and formation of the output mass of data;
-- representation of data in visualized form.

In the first stage, from the entire mass of data arriving from the satellite complex of microwave instrumentation and after primary processing of data registered on magnetic tape we select only the results of measurements made by the scanning radiometer in a stipulated geographic region. Parallely, the automatic digital printout unit delivers a mass of corresponding geographical coordinates of sectors sighted on the earth's surface. The measurement data are converted and quantized in such a way that they can be put out on a display. Since the quantization is accomplished at 255 levels and the amplitude of fluctuations of the measured radiobrightness temperature is approximately 200 K, the accuracy (detail) after conversion is not lost. The mass of data obtained as a result is registered on magnetic tape.

In the second stage the processing is in an interactive regime. The collected mass is visualized on a half-tone display and the operator, being guided by the table of geographic coordinates printed out in the first stage, which also gives the numbers of lines and elements, determines the limits of the test sectors in the coordinates of the "photograph." The criterion for choice of any sector is a priori data on the propagation of drifting ice and the minimum of the noise visible on the screen. In addition, visual monitoring makes possible preliminary determination of the position of the ice edge and the shoreline. After introduction of the corresponding coordinates into the electronic computer there is computation of the statistical characteristics of the signal in test sectors. Data are fed out by teletype which the operator uses in making a decision about a definite number of ice density gradations (probability level) and communicates his decision to the electronic computer. Then an element-by-element recognition is made in an automatic regime with registry of the results of processing on a magnetic tape.

The results are visualized in the third stage. The ice density map can be put on a photocarrier in a half-tone variant by means of a unit commutated with an electronic computer. It is also possible to make a photographic survey from a color display screen. In these cases the processing cycle must include programs for transformation into the map projection and "fitting" of the coordinate grid. At the present time it is most convenient and rapid to feed out the ice density map in symbols using the automatic digital feedout unit.

The entire cycle for one-time processing of data relating to the territory north of 50°N in a zone with a width of 800 km (data from one satellite revolution) with the use of a YeS-1022 electronic computer and the special complex for the processing of videoinformation available at the State Scientific Research Center for the Study of Natural Resources occupies about 30 minutes. But it must be noted that in the presence of the necessary a priori data the processing can be easily completely automated.

The method described above was used in processing data for 15 revolutions of the "Meteor-28." It was found that in summer, stipulating the 95% probability level, it is possible to obtain data on three gradations of the density of arctic drifting ice (with measurements at a wavelength 0.8 cm). This information was compared with aerial ice reconnaissance maps. The agreement can be considered completely satisfactory.

Thus, the installation of scanning microwave apparatus on operational artificial earth satellites and automation of the process of processing of measurements even now give a considerable economic effect.

BIBLIOGRAPHY

1. Basharinov, A. Ye., et al., "Results of Observations of Thermal Radioemission of the Earth's Surface Using Experimental Data from the 'Cosmos-243' Artificial Earth Satellite," KOSMICHESKIYE ISSLEDOVANIYA (Space Research), Vol 9, No 2, 1971.

2. Kuznetsov, I. M., "Change in Water Temperature in the Near-Ice Edge of Arctic Seas," TRUDY AANII (Transactions of the Arctic and Antarctic Scientific Research Institute), No 354, 1978.

3. Nikitin, P. A., Lyushvin, P. V., "The Possibility of Using Satellite Microwave Radiometric Information for Determining the Characteristics of the Ice Cover," KOSMICHESKAYA GEOFIZIKA: MATERIALY VSESOYUZNOGO SEMINARA (Space Geophysics: Materials of the All-Union Seminar), Leningrad, Gidrometeoizdat, 1978.

4. Rabinovich, Yu. I., Melent'yev, V. V., "Influence of Temperature and Salinity on Radiation of a Smooth Water Surface in the Centimeter Range," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 235, 1970.

5. Gloersen, P., et al., "Microwave Maps of the Polar Sea Ice of the Earth," BULL. AMER. METEOROL. SOC., Vol 55, No 12, 1974.

UDC 556.535.2

CHANGE IN WATER LEVELS WITH RETENTION OF FLOW VOLUME

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[Article by Candidate of Technical Sciences F. M. Chernyshov, Novosibirsk Institute of Water Transportation Engineers, submitted for publication 12 October 1979]

Abstract: The article describes a method for computing the mean long-term guaranteed probability of water levels for rivers in which intensive dredging is carried out for navigational purposes or in which sand, gravel or minerals are extracted, and also for those rivers in which there is active erosion of channels, such as in the reaches in the lower pools at hydroelectric power stations. The author examines different procedures for evaluating the annual change in the mean long-term guaranteed probability of the former planned or any other characteristic water level on free and regulated rivers.

[Text] At the present time the phenomenon of an annual decrease in water levels is observed on many rivers although their flow volume remains unchanged. This is attributable to a number of factors: intensive dredging for navigational purposes, exploitation of sand and gravel deposits on the bottom, active erosion of channels in the lower pools at hydroelectric power stations, etc. Accordingly, there is a noncorrespondence between water-gaging data for earlier years and modern data, and this will be true in the future with other changes in river channels. For this reason as we detect a noncorrespondence between water-gaging data for earlier years and the present-day state of river channels it is necessary to correct these data. In the case of a "continuous" change in the state of the river channel within the limits of a reach such a correction must be made annually prior to the onset of the navigation season, particularly with respect to the most important and decisive characteristics of the planned water level -- its relative or absolute reading and its mean long-term guaranteed probability (in days or in percent).

The years from which dredging work or deep erosion begin to exert an influence on the change (decrease) in the "planned" water level reading are usually called "years of intensive dredging" in waterway practice. For example, applicable to Ust'-Kutskiy water-gaging station on the Lena the onset of intensive dredging dates from 1961, whereas applicable to Podymakhinskiy water-gaging station the corresponding date is 1966.

Usually low and to some degree medium water levels are subject to change. During high-water periods, when the volumes of the dredged channels constitute but an insignificant fraction of the volume of the flow moving in the river the level readings remain virtually unchanged. Thus, the matched Q = f(H) curves in their upper parts merge into a single curve and somewhere in the middle parts they begin to separate, gradually increasing this separation in the range of low levels, attaining maximum discrepancies in the case of minimum navigation levels. Such Q = f(H) curves for the Ust'-Kutskiy water-gaging station on the Lena are shown in Fig. 1. It follows from this figure that the merging points of the Q = f(H) curves are "moving" points (see position of points a, b, c, etc.), moving upward with an increase in the duration of the period of intensive dredging.

Without question, the annual change in the guaranteed probability of the former readings in the direction of a decrease will be related to the phenomenon of a decrease in levels. The decrease in the guaranteed probability of the former reading of the planned level with its decrease can be so significant that it will not correspond, for example, with respect to navigation conditions, to a particular class of internal waterways. The approximate values of the guaranteed probabilities of the planned level in percent for different classes of internal waterways are given in Table 1.

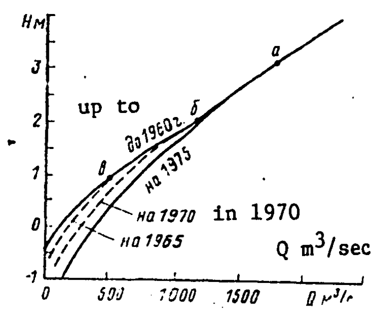

Fig. 1. Conjugation of Q = f(H) curves for years of intensive dredging with curve for 1960.

Table 1

Guaranteed Probabilities of Planned Level for Different Classes of Internal Waterways

Класс внутреннего водного пути (1)	Гарантированная судоходная глубина, см (2)	Ширина судового хода, м (3)	Обеспеченность проектного уровня, % (4)
I	>200	100—75	95—99
II	200—160	85—65	93—97
III	200—110	75—55	90—95
IV	150—80	70—45	85—93
V	110—60	50—30	80—91
VI	80—45	40—20	78—90
VII	<60	20—14	75—88

KEY TO TABLE: 1) Class of internal waterway; 2) Guaranteed navigable depth, cm; c) Width of channel, m; 4) Guaranteed probability of planned level, %

We note that the need for annual correction of the water level readings is caused primarily by the phenomenon of their "sinking," but the transformation of the lower segment of the guaranteed probability curve can exert a small influence on the change in these readings. The mentioned transformation is caused by "drawing out" of the series of medium and low water levels, imparting a definite asymmetry to this series. Accordingly, by retaining the guaranteed probability of the planned level constant, we can meet with some inconsistency in the resulting readings of the planned level when using the guaranteed probability curves and the Q = f(H) correlation curves, representing the planned water discharge for the earlier established planned level reading.

Proceeding to a description of the method for computing the guaranteed probability of water levels for the navigable reaches of free rivers with intensive dredging or with constant deep erosion, occurring due to the operation of hydroelectric power stations, we note that it has substantial differences from the earlier developed method for constructing the curve for the guaranteed probability of levels for the reaches of rivers whose channels to all intents and purposes persist in a natural regime [1]. The difference in the proposed computation method is that the actual series of observations of water levels in a long-term record in this new method is replaced using the matched Q = f(H) curves (see Fig. 1) by a fictitious series of levels reduced to the last (n-th) year in the series. The last year is the only year in the series whose actual level data are not corrected. Figure 2 shows the graphic procedure for scaling the factual data on water levels for n - 1 years in the series to the last, n-th year in the series, in the case of use of the matched Q = f(H) curves for the Podymakhinskiy water-gaging station on the Lena. In this figure, in order not to complicate the picture, the Q = f(H) curves for the period of intensive dredging (1966-1974) were plotted only for 1967, 1970, 1972 and 1974. An example of computation of the mean long-term guaranteed probability of the planned level applicable to the described conditions is given in the author's work [3].

Calculations of the frequency of recurrence of the considered series of levels are carried out in two stages: first we prepare a table of the frequency of recurrence of water levels for the entire series of years in the form of their actual excesses over the zero of the water-gaging station, corresponding in each navigation season to the true state of the river channel; then, using the graph of matched Q = f(H) curves (see Fig. 2) we prepare a computed table of the frequency of recurrence of a fictitious series of levels covering n - 1 years and related to the last n-th year. Then a summary table of the duration (in days and months) of the new series of water levels by years is prepared.

A curve of the guaranteed probability of water levels is constructed on the basis of the data in the summary table. The sought-for planned level reading is determined on the basis of this guaranteed probability curve for a stipulated guaranteed probability percentage (for example, equal to that adopted earlier -- 95.65%); at the end of the 1974 navigation season for the Podymakhinskiy water-gaging station this reading corresponds to a value 0 cm (Fig. 3).

In constructing the guaranteed probability curve in percent it is possible to use the following empirical formula [2]:

$$p = \frac{m - 0,3}{n + 0,4}\, 100\%,$$

where m is the sequence number of the term in the series and n is the total number of terms in the series.

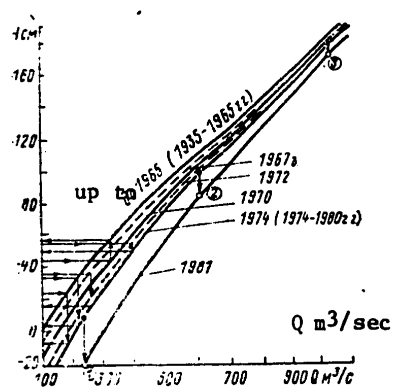

Fig. 2. Q = f(H) graph used for forming reduced series of levels to last n-th year.

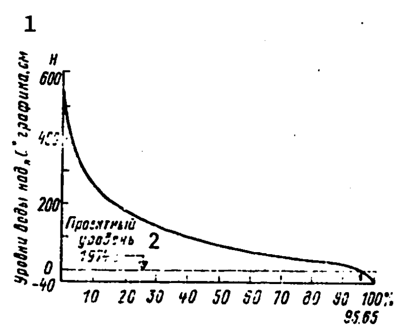

Fig. 3. Guaranteed probability curve for navigational water levels for Podymakhinskiy water-gaging station on Lena with allowance for their change at end of 1974 navigation season.

KEY:

1. Water level over "0" curve, cm
2. Planned level

In preparing the table of the frequency of recurrence of fictitious water levels it is also possible to use data from the annual correlation graphs for the corresponding water levels between the considered water-gaging station H_1 and the station H_2, on whose readings dredging work exerts no influence. The use of these graphs is similar to the use of the Q = f(H) curves described above, and they must also be represented in the form of matched annual curves $H_1 = f(H_2)$.

It is also not without interest to note that in case of necessity for extending the series of water level observations applicable to the state of a river channel, in which the influence of dredging work (or deep erosion) is not reflected, the observational data for the years of the occurring decreases in level can be reduced to the preceding period (see Fig. 2). In particular, the mentioned lengthening of the water level observation series makes it possible to obtain more reliable data on the soundness of the guaranteed probability of the planned or other characteristic water level adopted earlier on the basis of a short series of observations.

In order to estimate the change in the guaranteed probability of the former reading of the planned level in years of intensive dredging it is necessary to use a curve of the mean long-term guaranteed probability of navigational water levels (see Fig. 3) constructed applicable to these conditions of the river reach. For the case which we considered, with the Podymakhinskiy water-gaging control station on the Lena, a distinguishing characteristic is that the planned water level reading of +35 cm adopted in this region prior to 1966 (before the process of decrease of levels) was kept by the Kirenskiy waterway technical section in unmodified form up to 1972. In the years which followed this reading was changed to +25 cm (1973-1974), then to a reading +20 cm (1975-1976), next to a reading of +15 cm (1977) and +10 cm (1978), and finally, to a "0" reading (1979). However, this change does not reflect the actual state of affairs. Moreover, for the organization of hydroengineering, waterway and field research work it is very important to know how the guaranteed probability of the adopted planned water level readings change from year to year and to what extent these new guaranteed probabilities correspond to the standard data for the considered class of waterway (see Table 1).

In particular, the planned levels with readings +35 and +25 cm had mean long-term guaranteed probabilities at the end of the 1974 navigation season of 76.5 and 83.0% respectively, which is considerably lower than the earlier adopted guaranteed probability for the planned level, equal to 95.65%. At the end of the 1975 navigation season a reading with the same guaranteed probability of the planned water level at the Podymakhinskiy water-gaging station was -10 cm. As might be expected, the guaranteed probabilities of the former planned level readings +35, +25 and +20 cm were somewhat reduced in comparison with 1974 and at the end of the 1975 navigation season assumed values 73.3, 78.3 and 81.0% respectively. However, applicable to the level data for the end of the 1976 navigation season the guaranteed probabilities of the former planned level readings + 35, +25 and +20 cm were reduced to 67.0, 73.3 and 75.5% respectively and the guaranteed probability of the planned level +15 cm adopted for 1977 was already at the beginning of the navigation season only 78.1% (the water level reading with a guaranteed probability 95.65% at the end of the 1977 navigation season was close to -35 cm, and at the end of the 1978 navigation season was already -45 cm).

It should be added that the computations which we made for the curve of mean long-term guaranteed probability of water levels for the Ust'-Kutskiy water-gaging station on the Lena, situated 47.5 km above the Podymakhinskiy water-gaging station, in the case of scaling of the series of years for the period 1911-1975 relative to the last year, 1975, indicated that the "normal" guaranteed probability of the planned level 95.65% corresponds to a reading -100 cm. With respect to the former value of the planned water level reading for this water-gaging station +10 cm (up to 1961), its guaranteed probability at the end of the 1975 navigation season was only 40%.

Similarly it is possible to determine the change in guaranteed probability for any other characteristic level on the considered river reach. We will also add that the developed method makes it possible to predict the change in guaranteed probability of the existing planned level (or other characteristic levels) also in the case of continuation of the process of a decrease in levels with retention of flow volume. For this purpose using graphs of the type shown in Fig. 2 it is sufficient either to assume (stipulate) the position of the $Q = f(H)$ curve for the future, for example, for 1981 (see Fig. 2), or to construct the curve on the basis of three (or possibly more) points 1-2-3, obtained as a result of hydraulic computations anticipated additional changes of low, medium and high levels corresponding to the volumes of dredging work planned for this river reach. On the basis of this same predictive computation it is possible at the same time to determine the new planned water level reading corresponding to the standard guaranteed probability adopted for it earlier.

However, it must be noted that in predictive computations of the level guaranteed probability curves one must deal with a lack of factual data on water level observations for the future, for one or for a whole series of years. In such cases it is recommended that one have recourse to the following four computation procedures.

1. Limit oneself to the available series of years of observations of water levels, especially when it is a sufficiently long series. Such a series of levels is also scaled applicable to the future year in which one is interested (in Fig. 2 such a series includes a 40-year period -- from 1935 through 1965 and from 1966 through 1974, the future year being 1981).

2. For the entire chronological series of water level observations construct a successive series of annual $H = f(t)$ curves so as to ascertain (in years) the duration and pattern of alternation of periods of different water volume (high-, medium- and low-volume periods). On the basis of these data for the future period of years it is necessary to assume the variation of levels most probable in their repetition in the future on the basis of one, two, three, etc. actual years in the past.

3. In the initial tables the columns for the future years are filled with actual data on levels for particularly characteristic years: low-, medium- and high-volume years, alternating them each time in the indicated sequence.

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4. The actual data for the most recent years are repeated, especially when reference is to prediction of the water level guaranteed probability curves for the next one or two years.

With a temporary or constant cessation of the process of decrease of water levels (in cases when over a period of years the dimensions of the waterways remain unchanged, no sand and gravel are exploited from the channel, when natural evening-out occurs in the river channel, etc.) on graphs of the type in Figure 2 and in the computation tables for the guaranteed probability curves there will be an alternation of intraseries (one or more) scalings of individual years with definite groups of years characterized by a "stationary" character of the levels (in Fig. 2 see the initial period 1935-1965, the period 1974-1980, which is "internal" in the series, both in parentheses, and the final year in the series, 1981).

As an illustration of the results of computation of the water level guaranteed probability curves, under conditions of a decrease in these levels, we have the curve in Fig. 3 and the data in Table 2, based on the use of both factual annual series of level observations (1974, 1975, 1976 and 1977-1978; for 1978 we meet the phenomenon of a disruption of the process of a decrease in levels), and with allowance for the employed fictitious data for future years applicable to predictive computations at the end of the 1979, 1980 and 1981 navigation seasons, carried out under the direction of the author by the engineers T. F. Kling and L. Ye. Pleskevich, employing the above-mentioned first (see columns 7 and 9 in Table 2) and the fourth (see columns 8 and 10 in this same table) procedures for computing the pertinent values. It follows from the data in Table 2 that the use in predictive computations of different procedures for the replacement of future years by actual years in the considered chronological series is entirely admissible (see the guaranteed probability values in columns 7 and 8 and also in 9 and 10).

We also note, if we ignore the obvious change in the nature of the ground water supply to river reaches in which a considerable decrease in the planned level takes place, and other low levels, that is, if we ignore some change in the water discharges in the lower part of the long-term (and it goes without saying, also the navigational) series, and if we also ignore the partial difference of the guaranteed probability curve itself for the longer series of the considered river flow elements in comparison with the short series, then it is possible to assume the condition of retention of a constancy of the curves of long-term guaranteed probabilities of water discharges during the entire time period with which we are concerned, including a period of intensive dredging or a period of active channel erosion. Such an assumption, adequately sound from the practical point of view, makes it possible to avoid carrying out time-consuming annual computations associated with the described method for the scaling of actual water levels to the fictitious levels and with preparation of the corresponding very extensive computation tables, repeating themselves from year to year. For example, applicable to the data in Fig. 2 it is sufficient to construct the curve of long-term guaranteed probability of water discharges a single time (either by means of direct writing of a long-term series of discharges, or by reconstructing, using the available quasistationary Q = f(H) graph of long-term guaranteed probability of water levels curve into a curve of the guaranteed probability of discharges) for the period 1935-1965 when there were still no level changes. Then, matching this curve of the long-term guaranteed probability of water discharges with the Q = f(H) curves for the years of intensive dredging of interest to us, it is easy to solve graphically problems relating to changes by years both of the percentage of the guaranteed probability of the former planned water level reading (see the points 1, 2, 3 and 4 on the right-hand side of Fig. 4 for the level reading +20 cm) and the very reading of this level with its standard guaranteed probability, corresponding to a constant value of the water discharge (in this same Fig. 4 see the points 1, 5, 6 and 7).

Table 2

Data on Computed Readings and Guaranteed Probabilities of Planned Level for the Podymakhinskiy Water-Gaging Station on the Lena River

Относительные отметки проектного уровня воды, см (1)	Обеспеченности различных отметок проектного уровня по годам, % (2)								
	1974	1975	1976	1977—78	1979 (прогноз)	1980 (прогноз) (3)		1981 (прогноз) (3)	
						по 1-му приему вычислений (4)	по 4-му приему вычислений (5)	по 1-му приему вычислений (4)	по 4-му приему вычисл. (5)
1	2	3	4	5	6	7	8	9	10
+35	76,5	73,3	67,0	66,0	62,0	61,5	61,3	46,0	45,0
+25	83,0	78,3	73,3	71,0	67,5	67,4	67,0	51,5	49,0
+20	90,0	81,0	75,5	72,5	70,0	69,5	69,5	53,5	51,3
+15	94,0	83,3	78,1	74,6	74,0	73,6	72,5	57,6	56,8
+10	95,2	86,8	82,0	76,6	75,0	73,0	73,0	60,6	60,0
0	95,65	91,7	87,5	80.0	78,5	77,2	77,1	67,5	66,5
—10	98,0	95,65	93,8	83,0	82,0	81,6	81,5	71,0	67,5
—20	99,0	97,3	95,65	87,7	87,5	87,2	87,0	75,0	72.0
—35	99,8	99,2	99,0	93,8	92,0	91,8	91,8	79,2	77,5
—45	99,9	99,3	99,2	95,65	94,6	94,0	94,0	84,5	84,4
—50	≈100,0	99,9	99,4	96,5	95,65	95,0	95,0	86,5	86,5
—65		≈100,0	≈100,0	98,2	98,0	96,9	96,8	92,0	92,5
—80				99,6	99,5	99,4	99,4	95,6	94,8

KEY:

1. Relative readings of planned water level, cm
2. Guaranteed probabilities of different readings of planned level by years, %
3. Prediction
4. Using first computation procedure
5. Using fourth computation procedure

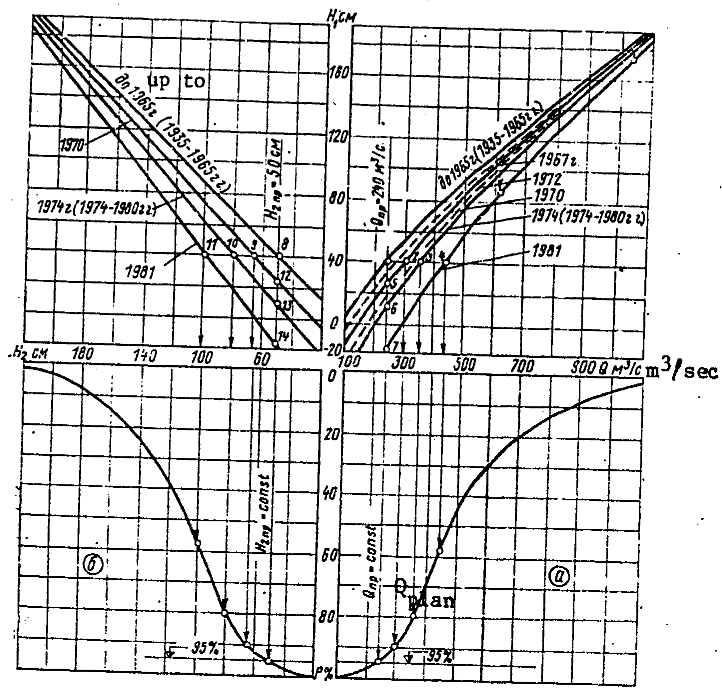

Fig. 4. Graphic determination (for water-gaging station H_1) of the change in the reading and the guaranteed probability of the planned water level in the case of its decrease. a) using the guaranteed probability curve for discharges at this same gaging station; b) using the guaranteed probability curve for levels at the adjacent gaging station H_2 at which the influence of dredging work or channel erosion is insignificant.

In the absence of reliable data on the annual Q = f(H) curves for the period of a water level decrease the same constructions are possible applicable to the graphs of annual correlations of the corresponding levels at two water-gaging stations $H_1 = f(H_2)$, one of which (H_2) still does not experience the process described in the article and for which the long-term water level guaranteed probability curve is constructed once. The matching of these categories of curves is illustrated on the left side of Fig. 4 and their use in solving the considered problems is similar to the preceding case (in Fig. 4 see the groups of points 8-11 and 8, 12-14).

Accordingly, it is necessary to have recourse to the use of the method for computing water level guaranteed probability curves by using the so-called fictitious series of levels for n - 1 years in cases when at all water-gaging stations on a hydrologically uniform reach on a river there is the phenomenon of a decrease in levels, when the above-mentioned assumptions lead to considerable errors in the results of computations, when in predictive computations it is necessary to take into account different alternations of the volumes carried in the river reach in different years and in different periods, and finally, when the available series of years of observations of water levels prior to the onset of the process of their decrease is inadequately long.

The use in engineering work of the described method for computing the mean long-term guaranteed probability of water levels for river reaches with intensive dredging or with a constant deep erosion of their channels will make it possible to increase the quality and effectiveness of waterway and engineering field work and also to obtain data on change in the guaranteed probability of the planned and other characteristic water levels of preceding years, which must be known in order to evaluate the operational qualities of navigable rivers and the hydroengineering and water intake structures built along them. It is also important that using the described method it is possible to make a reliable prediction of change in the guaranteed probability of some characteristic water levels for virtually any time in a case of prolongation of the process of their decrease. In all cases the developed computation method makes it possible to take into account the temporary or permanent cessation of changes in water level readings in a considered river reach.

BIBLIOGRAPHY

1. Denisovich, P. A., Makkaveyev, N. I., Rzhanitsyn, N. A., et al., PRAKTICHESKOYE POSOBIYE NACHAL'NIKU PLESA (Practical Aid for the River Reach Supervisor), Moscow, Izd-vo MRF SSSR, 1951.

2. Lebedev, V. V., GIDROLOGIYA I GIDROMETRIYA V ZADACHAKH (Hydrology and Hydrometry in Problems), Leningrad, Gidrometeoizdat, 1955.

3. Chernyshov, F. M., "Validation of the Position of the Planned Water Level for the Navigable Reaches of Free Rivers With Intensive Dredging," TRUDY NIIVTa (Transactions of the Scientific Research Institute of Water Transportation Engineers), No 102, Novosibirsk, 1976.

UDC 556.535.5(571.2+573)

SUPPORTING CAPACITY OF THE ICE COVER ON RIVERS IN THE ZONE OF THE BAYKAL-AMUR RAILROAD DURING SPRING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 77-84

[Article by Ye. F. Zabelina, USSR Hydrometeorological Scientific Research Center, submitted for publication 21 November 1979]

Abstract: The author obtained the stochastic times of onset of a definite supporting capacity of the ice cover for a number of river reaches and developed a method for their computation which can be used in the planning of ice roads and crossings and in establishing the optimum regime for their operation, including for river reaches for which there are no long-term observation series. A method is proposed for computation and short-range forecasting of onset of a definite supporting capacity of the ice cover on rivers in the zone of the Baykal-Amur Railroad.

[Text] The severe climatic conditions of the zone of construction and exploitation of the Baykal-Amur Railroad cause prolonged periods of ice cover on rivers. Accordingly, construction of different structures requires solution of a number of ice engineering problems. In particular, it is of great practical interest to use the supporting capacity of the ice cover on rivers for carrying out different kinds of work with ice, construction of ice roads and crossings.

The theory of computation of the supporting capacity of the ice cover has now been well developed and great experience in its use has been accumulated in practice. A sufficiently complete bibliography on this question is given in [2, 7].

Important aspects of improvement of computations are evaluation and prediction of supporting capacity of the ice cover during thaw periods.

The ice cover during the prespring and spring periods is weakened by through cracks, washed-out hollows and marginal breaks. It is therefore necessary to determine the supporting capacity of a semi-infinite plate on an elastic base with central flexure under a load at the edge of a crack or polynia. For solving this problem D. F. Panfilov [8] proposed a computation equation in the form

$[\sigma_u = \sigma_{flex}]$

$$P = \frac{0.375\,\sigma_u h^2 (1 + 4.1\,\alpha)}{2.75}, \qquad (1)$$

where P is the limiting load on the ice, tons; σ_{flex} is the breaking point of ice under flexure, tons/m^2; h is ice thickness, m; $\alpha = r_0/l$; (in this expression r_0 is the radius of an equivalent circle over whose area the load P is distributed; this radius is found using the formula $r_0 = \sqrt{\omega/\pi}$, where ω is the area of the load support); l is a characteristic of the ice cover, being a function of plate rigidity D and the elastic base coefficient γ;

$$l = \sqrt[4]{\frac{D}{\gamma}}; \quad D = \frac{Eh^3}{12(1-n^2)},$$

accordingly

$$l = \sqrt[4]{\frac{Eh^3}{12(1-n^2)\gamma}}.$$

where n is the Poisson coefficient, E is the elastic modulus of ice.

D. F. Panfilov demonstrated that when α falls in the limits 0.1-0.7 equation (1) ensures an accuracy in computations exceeding practical requirements.

The principal difficulty in computing the supporting capacity of the ice cover during spring is the choice of an acceptable value of the breaking point of ice under flexure in connection with the rapid change in the mechanical properties of ice during the thawing period.

The present status of investigations makes it possible to carry out an indirect evaluation of the strength characteristics of the ice cover during the thawing period on the basis of the factors determining them. The method developed at the USSR Hydrometeorological Center by S. N. Bulatov [3] makes it possible to compute the thickness and strength of the melting ice each day, beginning with the date of the disappearance of snow from it to the moment of total loss of strength.

The relative strength of the melting ice cover is expressed by the relative breaking point φ, which is the ratio of the breaking point of melting ice under flexure σ_{flex} to the breaking point of ice prior to the onset of thawing σ_0. In the computations σ_0 was assumed to be constant, equal to 5 kg/cm^2 [2]. The relative breaking point of melting ice under flexure

φ is determined in dependence on the quantity of solar radiation absorbed by the ice. The computation formula has the form

$$\varphi = \left(1 - \sqrt{\frac{S}{S_0}}\right)^2, \quad (2)$$

where S is the quantity of solar radiation absorbed by the ice, determining the content of the liquid phase in the ice, S_0 is the quantity of solar radiation with the absorption of which the ice completely loses its strength. The S_0 value is dependent on the ice structure. In the above computations S_0 was assumed to be constant, equal to 44 cal/cm^3 [2]. As a characteristic of ice cover strength we use the product (complex) φh, where h is the thickness of the thawing ice, cm.

Assuming $\alpha = 0.7$ and taking into account that $\varphi = \sigma_{flex}/\sigma_0$, the computation equation (1) can be written in the following form

$$P = \frac{1{,}306 \cdot \sigma_0 \varphi h^2}{2{,}75 \cdot 10^3}, \quad (3)$$

An estimate of the supporting capacity of the ice cover of rivers in the zone of laying of the Baykal-Amur Railroad during the melting period was made using data for six points for the period from 1950 through 1975. The computations were made for each day using equation (3) with the corresponding φ and h values.

The limiting loads determined using formula (3) correspond to conditions of ice cover destruction. The safety factor 1.6 was introduced for safe operation of the crossing, as recommended in [5].

These computations make it possible to give a general description of the change in the supporting capacity of the ice cover in the thawing process. The most convenient index of the course of decrease in the supporting capacity of the ice cover is the time of onset of definite, stipulated values; the ending of crossing of specific loads is determined by the corresponding values.

In order to obtain the stochastic characteristics of the dates of onset of a stipulated supporting capacity (that is, the dates corresponding to a supporting capacity of the ice cover of not less than 30 tons, 20 tons, 10 tons, 5 tons, with the safety factor taken into account) we constructed probability curves whose coordinates are given in the table. The computed supporting capacity sets in no later than on the date indicated in the table for a given probability. The table shows that the nature of the changes in supporting capacity of the ice cover is dependent to a considerable degree on the maximum ice thickness. The greater it is, all other conditions being equal, the greater is the supporting capacity of the ice cover.

It must be noted that for river reaches with an ice thickness by the onset of thawing of 1.7 m or more the supporting capacity of the ice cover can attain 40-50 tons. For example, for the Olekma River at Ust'-Nyukzha post the ice thickness by the onset of thawing in most cases is 1.7-2.7 m; the probability that the ice cover will retain a supporting capacity of not less than 40 tons by 15 April is 50% and by 30 March -- 5%, that is, the crossing of such loads should end so early only once in 20 years.

The influence of ice thickness on the nature of change in supporting capacity of the ice cover made it possible to generalize the computation data and obtain a single nomogram for estimating the supporting capacity of the ice cover for all rivers in the zone except for river reaches with anomalous melting conditions, determined by the influence of local factors (outlets of warm springs, etc.).

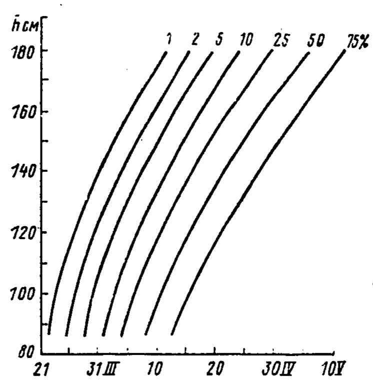

Fig. 1. Nomogram for determining the dates prior to which a supporting capacity of the ice cover of not less than 5 tons is retained with a stipulated probability.

Figure 1 shows a nomogram making it possible, in dependence on the norm of the maximum ice thickness ($\bar{h}$ cm), to determine the stochastic characteristics of the times by the moment of whose onset the supporting capacity of the ice cover will be not less than 5 tons. The probable error in determining these times does not exceed ±1-2 days. A similar nomogram was constructed for determining the times of onset of a supporting capacity of the ice cover of 10 tons.

The cited nomogram can be used under the following conditions: first, the norm of the maximum ice thickness varies in the range from 0.8 to 1.8 m, and second, the mean long-term dates of opening-up of the rivers should fall in the range from 28 April through 10 May. These conditions are characteristic for most of the rivers in the zone of construction of the Baykal-Amur Railroad. For using the nomogram applicable to rivers for which there are no data on the ice thickness or whose data are inadequate the mean

Table 1

Stochastic Characteristics of Dates of Onset of a Stipulated Supporting Capacity of the Ice Cover on Rivers

Река 1	Пункт 2	3 Норма максимальной толщины льда, м	4 Даты наступления заданной грузоподъемности, обеспеченные на						
			1 %	2 %	5 %	10 %	25 %	50 %	75 %
		5 Грузоподъемность 30 т							
6 Олекма 12	Усть-Нюкжа	1,82	27 III	29 III	2 IV	5 IV	11 IV	17 IV	—
		5 Грузоподъемность 20 т							
6 Олекма 12	Усть-Нюкжа	1,82	1 IV	4 IV	8 IV	11 IV	17 IV	25 IV	—
7 Селемджа 13	Стойба	1,31	21 III	24 III	27 III	30 III	—	—	—
8 Амгунь 14	Ирумка	1,28	17 III	22 III	25 III	28 III	1 IV	9 IV	—
		5 Грузоподъемность 10 т							
6 Олекма 12	Усть-Нюкжа	1,82	8 IV	10 IV	15 IV	18 IV	22 IV	30 IV	—
7 Селемджа 13	Стойба	1,31	24 III	27 III	2 IV	5 IV	9 IV	13 IV	—
8 Амгунь 14	Ирумка	1,28	22 III	26 III	31 III	4 IV	9 IV	15 IV	—
		5 Грузоподъемность 5 т							
9 Киренга 15	Казачинское	0,81	22 III	25 III	27 III	31 III	2 IV	—	—
6 Олекма 12	Усть-Нюкжа	1,82	14 IV	17 IV	22 IV	25 IV	1 V	7 V	13 V
10 Нора 16	Устье Эльги	1,05	24 III	27 III	1 IV	5 IV	11 IV	16 IV	20 IV
7 Селемджа 13	Стойба	1,31	27 III	31 III	5 IV	9 IV	14 IV	19 IV	22 IV
11 Бысса 11	Бысса	0,87	23 III	26 III	30 III	1 IV	4 IV	8 IV	11 IV
8 Амгунь 14	Ирумка	1,28	28 III	3 IV	7 IV	11 IV	16 IV	22 IV	26 IV

KEY:

1. River
2. Station
3. Norm of maximum ice thickness, m
4. Dates of onset of stipulated supporting capacity, ensured by...
5. Supporting capacity...tons
6. Olekma
7. Selemdzha
8. Amgun'
9. Kirenga
10. Nora
11. Byssa
12. Ust'-Nyukzha
13. Stoyba
14. Irumka
15. Kazachinskoye
16. Ust'ye El'gi

long-term maximum ice thickness can be determined from the map cited in [4].

It must be noted that on such rivers as the Vitim, Chara, Goudzhokit, tributaries of the Aldan and a number of refreezing rivers the opening-up usually occurs later -- in mid-May. In these cases one must expect a greater supporting capacity of the ice cover on these same dates.

For the proper operation of crossings and carrying out work on ice it is very important to predict the times of onset of a definite supporting capacity of the ice cover in each year. For this same purpose it is also possible to use computations by the S. N. Bulatov method [3] with the use pf the program which we proposed. It is difficult to carry out such computations by the S. N. Bulatov method under the real conditions of prediction in the field due to the excessive work involved in making these computations without an electronic computer. This makes it necessary to seek more accessible methods for precomputing the strength of the ice cover and the dates of onset of a definite supporting capacity.

We recall the availability of the V. M. Timchenko formula [11] for determining the complex φh in dependence on the number of days of melting n and on the thickness of the ice cover on the first day of melting h_0, that is, on the first day after disappearance of the snow from the ice cover.

$$\varphi h = h_0\left(1 - \sqrt{\frac{n}{0.32h_0}}\right)^2 \qquad (4)$$

This dependence was derived in the example of the Ussuri River using data for eight points for an ice thickness not exceeding 100 cm and for periods of thawing of the ice cover not exceeding 30 days. The φh values computed using formula (4) reflect the mean characteristics of decrease in strength for a particular ice thickness and the possible minimum values of the φh complex are not taken into account.

On the considered rivers the thickness of the ice cover by the beginning of thawing during the period from 1950 through 1975 changed on the Selemdzha at Stoyba post from 80 to 220 cm and the thawing time varied from 26 to 38 days; on the Olekma at Ust'-Nyukzha post — from 116 to 270 cm with a thawing time from 30 to 50 days. Accordingly, computations of the φh complex using equation (4) for a number of years gave results differing greatly from the true figures.

Below we outline a method for precomputing the strength of the ice cover and the dates of onset of a definite supporting capacity, developed in the example of the Selemdzha and Olekma Rivers.

Without question, the intensity of thawing and the decrease in the strength of the ice cover are determined primarily by the arrival of heat at its surface. The heat receipts at the ice cover can be calculated by computing the heat exchange q on the basis of meteorological data. The q value consists of the specific values of receipts of the heat of solar radiation q_s, heat exchange due to evaporation (condensation) LE, convective heat exchange P, and effective radiation I_{eff}.

$$q = q_s + LE + P + I_{eff}. \quad (5)$$

The heat exchange components can be computed using formulas recommended in [3].

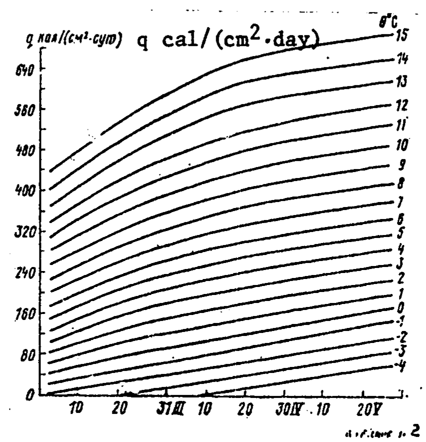

Fig. 2. Nomogram for determining the specific daily heat exchange at the surface of the ice cover of rivers in the zone of the Baykal-Amur Railroad on the basis of mean daily air temperature and date.

The computation nomogram shown in Fig. 2 was constructed on the basis of equation (5) using data for Stoyba meteorological station in accordance with the recommendations in the manual [9]. Using such a nomogram it is possible to determine the heat exchange through a unit (cm^2) of the upper surface of the ice cover in a day on the basis of the date and the mean daily air temperature. The heat exchange values obtained using the nomogram are used as the specific values of the daily heat exchange q cal/(cm^2·day).

In constructing the nomogram the computations of the resulting heat exchange values q were made on the 15th of each month, in this case March, April and May, for each whole degree of mean daily air temperature from -4 to +15°C. The albedo was assumed to be constant for the thawing period, equal to 0.35. The cloud cover and mean daily wind velocity were assumed to be constant in accordance with data from many years of observations at Stoyba meteorological station [10]. The mean daily vapor elasticity in the air was determined from a graph showing the correlation with mean daily air temperature.

Since the route of the Baykal-Amur Railroad extends latitudinally in the limits 51-57°N it can be assumed that the difference in the mean long-term receipts of solar radiation is small and the influence of this factor is the same over the territory. The nomogram (Fig. 2) can therefore be recommended for computing the heat receipts by the ice cover on all rivers of the Baykal-Amur Railroad zone.

It must be noted that the heat sums determined using the nomogram must be regarded as relative characteristics of thawing of the ice cover since they do not reflect the singularity of the heat balance of thawing ice [2]. The process of thawing and destruction of the ice cover is determined not only by the total quantity of heat expended in melting, but also by the nature of the effect exerted on the ice by individual heat exchange components. In particular, in the zone of the Baykal-Amur Railroad the snow frequently disappears long before the appearance of a positive heat balance at the surface of the ice cover, after which, as a result of the intensive influx of solar radiation during spring, there is thawing in the ice layer. Within the ice there is formation of fluid inclusions and fluid layers between crystals. The presence of the liquid phase in the thawing ice is the basic reason for the decrease in its strength.

For those cases when the heat balance at the surface of the ice cover during a number of successive days has a minus sign, proceeding on the basis of the concepts concerning the processes transpiring during melting of the ice, it was agreed that the following procedure be adopted for determining q. The period during which a negative heat balance is observed is broken down into three-day intervals. In each interval we determine the mean daytime reduced cloud cover N, then the sum of the mean daily negative air temperatures θ, from which a value equal to -20°C is then subtracted and the duration (in days) of the period D from 20 March to the mean date of the considered interval is determined. The computation formulas have the following form

$$\text{when} \quad 0<N<2 \qquad q=9{,}77\,D+7{,}50\,\theta+72, \tag{6}$$

$$\text{when} \quad 3<N<7 \qquad q=7{,}52\,D+7{,}50\,\theta+32, \tag{7}$$

if N > 7, then q is assumed equal to zero.

Thus, with the use of the nomogram (Fig. 2) and formulas (6), (7) it is possible to determine q during all the days after the disappearance of the snow and the total heat receipts

$$Q=\sum_{i=1}^{n} q_i$$

for the entire thawing period.

It was established that at Stoyba post on the Selemdzha River and at Ust'-Nyukzha post on the Olekma River the dependence of the value of the φh complex, characterizing ice strength, on the quantity of heat incident on the ice cover during a period of thawing can be expressed using the empirical formula

$$\varphi h = ae^{-bQ} + c, \quad (8)$$

where Q is the total heat receipts on the computation date, a, b, c are parameters which are established empirically for the computation points.

Taking into account a definite degree of risk in the planning of ice roads and crossings, the parameters a, b, c in formula (8) were selected in such a way that the values of the φh complex were the minimum of those possible. For this purpose, during the period from 1950 through 1975 we constructed graphs showing the correlation between the parameters a and c and the thickness of the ice cover on the first day of thawing. The lower envelope of the field of points was drawn on the graphs.

The derived dependences are approximated by the following equations:

for the Selemdzha River at Stoyba post

$$a = 11{,}0 + 0{,}56\, h_0, \quad (9)$$

$$c = 1514{,}0\, e^{-0{,}054\, h_0} + 0{,}33\, h_0 - 39{,}26; \quad (10)$$

for the Olekma River at Ust'-Nyukzha post

$$a = 4{,}76 + 0{,}68\, h_0, \quad (11)$$

$$c = 227{,}3\, e^{-0{,}023\, h_0} + 0{,}45\, h_0 - 66{,}0, \quad (12)$$

where h_0 is the thickness of the ice cover on the first day of thawing, cm. The parameter c when the ice thickness is less than 100 cm must be assumed equal to 0. The b value for both points is equal to 0.001.

A guaranteed prediction of the onset of the times of reaching of a definite supporting capacity is prepared using the following scheme. First the date of onset of ice melting is determined. The first day of ice melting is the day following the date of snow disappearance. The latter is computed. Then successively, day after day, the nomogram (Fig. 2) is used in determining the heat receipts with the possible advance time and equations (8) and (3) are used in precomputing the φh complex and the supporting capacity of the ice cover. The date adopted for the onset of a definite supporting capacity is that on which for the first time, with the strength safety factor 1.6 taken into account, there is satisfaction of the condition $P \simeq P_0$, where P_0 is the stipulated supporting capacity for which computations are made in the prediction.

[redacted]

The adopted prediction model excludes cases of the onset of a stipulated supporting capacity earlier than the predicted date. In 50% of the cases the actual dates are up to two days later and in 30% of the cases -- up to 4-5 days later than expected.

It should be noted that if an error in prediction in the early direction, at least in the range of two days, is considered admissible, then in 84% of the cases the error will not exceed the limits ±2 days.

As is customary in short-range ice forecasts, in preparing this type of prediction use is made of an air temperature forecast for 3-5 days in advance. Accordingly, the advance time of the prediction will be determined by the advance time of the temperature forecast. Long-term experience in the preparation of short-range predictions of the freezing and opening-up of rivers indicates that the use of a temperature forecast does not substantially reduce the probable success of these predictions in comparison with the guaranteed probability of the method [1].

The materials presented above make it possible to conclude that the supporting capacity of the ice cover on rivers of the Baykal-Amur Railroad zone during spring persists for a considerable time after its weakening by thawing processes.

BIBLIOGRAPHY

1. Antipova, Ye. G., Balashova, I. V., "Analysis and Generalization of Experience in Preparing Short-Range Forecasts of the Times of Ice Phenomena," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 186, 1977.

2. Bulatov, S. N., "Computation of a Thawing Ice Cover and Onset of the Wind Drift of Ice," TRUDY GIDROMETTSENTRA SSSR, No 74, 1970.

3. Bulatov, S. N., METODIKA RASCHETA TOLSHCHINY I PROCHNOSTI TAYUSHCHEGO LEDYANOGO POKROVA DLYA TSELEY RASCHETA I PROGNOZA SROKOV VSKRYTIYA REK I VODOKHRANILISHCH (Method for Computing the Thickness and Strength of a Thawing Ice Cover for the Purposes of Computing and Predicting the Times of Opening-Up of Rivers and Reservoirs), Moscow, Gidromettsentr SSSR, 1974.

4. Ginzburg, B. M., et al., OSNOVNYYE KHARAKTERISTIKI LEDOVOGO REZHIMA REK RAYONA BAYKALO-AMURSKOY MAGISTRALI (Principal Characteristics of the Ice Regime of Rivers in the Region of the Baykal-Amur Railroad), Moscow, Gidromettsentr SSSR, 1976.

5. Gusev, O. V., PEREPRAVY PO L'DU (Ice Crossings), Leningrad, Gidrometeoizdat, 1961.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000300020010-5

6. Zabelina, Ye. F., "Some Characteristics of Strength of the Ice Cover During the Period of Opening-Up of Rivers in the Baykal-Amur Zone," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 10, 1979.

7. Marchuk, A. N., PEREKRYTIYE REK POD LEDYANYM POKROVOM (Crossing of Rivers With an Ice Cover), Moscow, Energiya, 1973.

8. Panfilov, D. F., "Approximate Method for Computing the Supporting Capacity of an Ice Cover," IZVESTIYA VNIIG (News of the All-Union Scientific Research Institute of Hydroengineering), Vol 64, 1960.

9. RUKOVODSTVO PO GIDROLOGICHESKIM PROGNOZAM. VYP. 4. PROGNOZY LEDOVYKH YAVLENIY NA REKAKH I VODOKHRANILISHCHAKH (Manual on Hydrological Forecasts. No 4. Forecasts of Ice Phenomena on Rivers and Reservoirs), Leningrad, Gidrometeoizdat, 1963.

10. SPRAVOCHNIK PO KLIMATU SSSR (Handbook of USSR Climate), Leningrad, Gidrometeoizdat, No 25, Part II, Part III, Part IV, Part V, 1966.

11. Timchenko, V. M., "Computation and Precomputation of the Strength Characteristics of the Ice Cover on Rivers for the Purpose of Predicting Their Opening-Up," TRUDY DVNIGMI (Transactions of the Far Eastern Scientific Research Hydrometeorological Institute), No 47, 1975.

UDC 632.11:633.11(574.11)

CORRELATION BETWEEN THE YIELD OF WINTER WHEAT AND PHOTOSYNTHETICALLY ACTIVE RADIATION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 85-92

[Article by Candidate of Agricultural Sciences L. G. Pigareva, West Kazakhstan Agricultural Institute, submitted for publication 28 November 1979]

Abstract: The author has demonstrated the influence of agrometeorological conditions prevailing in the autumn, winter and spring-summer periods on the yield of winter wheat grain. In the example of the production of sown crops the article demonstrates the effectiveness of use of photosynthetically active radiation by wheat plants in the case of a north-south orientation of the plant rows.

[Text] In the grain zone of northwestern Kazakhstan the highest percentage of sown areas is occupied by spring wheat. However, a comparative analysis of the change in the yield of spring wheat of the Saratovskaya-42 variety and winter wheat of the Mironovskaya-808 variety during the last five years (1974-1978) shows that winter wheat should occupy a leading place among the other grain crops (see Table 1).

Winter wheat has a greater yield than spring wheat; it reacts considerably better to favorable agrometeorological conditions, ensuring a very high yield (41.3 centners/hectare in 1978) and sharply reducing it in years unfavorable for the wintering of crops (9.4 centners/hectare in 1977).

In evaluating the agroclimatic resources for the yield of winter wheat, A. R. Konstantinov [1] notes that isolines pass through Ural'sk and Aktyubinsk (northwestern Kazakhstan), to the east of which its yield is reduced by 50-75% as a result of a deterioration of wintering conditions.

The great value of the Mironovskaya-808 variety encouraged us in an attempt to find in the first approximation, at least, the dependence of the yield of a particular "regionalized" variety on the agrometeorological indices and obtain some idea concerning the rationality of cultivating a particular crop under the conditions of the very continental climate of our zone.

Table 1

Yield of Winter and Spring Wheat (Centners/Hectare) at the Zelenovskaya Strain-Testing Station in Uralskaya Oblast

Сорт 1	1974	1975	1976 *	1977	1978	Среднее 2 / наим.—наибольш. 3
4 Мироновская-808	36,8	12,5	13,3	9,4	41,3	25,0 / 9,4—41,3
5 Саратовская-42	21,6	5,3	17,4	6,0	33,7	16,6 / 5,3—33,7

6 * Урожайность по Зеленовскому району в целом

KEY:

1. Variety
2. Mean
3. Minimum-maximum
4. Mironovskaya-808
5. Saratovskaya-42
6. Yield for Zelenovskiy Rayon as a whole

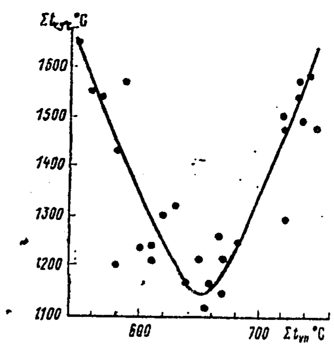

Fig. 1. Dependence of sum of negative temperatures during the winter period on the sum of mean daily July temperatures.

An analysis of available data from the Hydrometeorological Service, state strain-testing stations in Ural'skaya Oblast during 1964-1978 and also our field crops on farms and the results of experiments in the experimental field of the West Kazakhstan Agricultural Institute during 1974-1978 reveals a high dependence of the yield of the Mironovskaya-808 variety on agrometeorological indices. For example, in such five-year periods as 1965-1969, 1970-1974 and the last four years (1975-1978) there was an increase in the amplitude of variation in the yield of 17.9, 30.4 and 31.9 centners/hectare respectively. At the same time, the indices of the mean yield for the indicated periods (12.1, 18.0 and 19.1 centners/hectare) once again confirm the assumption that under the conditions prevailing in northwestern Kazakhstan the moisture supply limits the effectiveness of the use of the heat supply and solar radiation by plants.

The complexity of use of the "weather-yield" problem with respect to winter wheat is also governed by the fact that the two periods defined in its active growing season are separated; on their agrometeorological conditions is dependent to a large extent whether or not there will be a spring-summer growing season for the particular crop.

The sowing of winter wheat of the Mironovskaya-808 variety under the conditions prevailing in northwestern Kazakhstan is carried out for the most part in the third 10-day period of August when the mean daily temperatures during the sowing-sprouting period attain 18-19°C and the moistening coefficient ($K_{moist} = \sum h/0.45\sum d$, where $\sum h$ is the sum of falling precipitation in mm, $\sum d$ is the sum of the mean daily dew-point spreads) for August-September varies from 0.01 to 0.60.

Data on the mean yield of this variety at seed selection stations in Uralskaya Oblast during 1965-1978 show that with their increasing distance from north to south there was a decrease in the moistening coefficient from 0.15 at the more northerly Zelenovskaya station to 0.12 at the more southerly Dzhambeytinskaya station which caused a decrease in the mean crop yield -- from 16.2 to 9.7 centners respectively. And the high correlation coefficient between the grain yield and the moistening coefficient (0.688) is evidence of the important role of moisture supply conditions of the autumn period in the fate of the future yield.

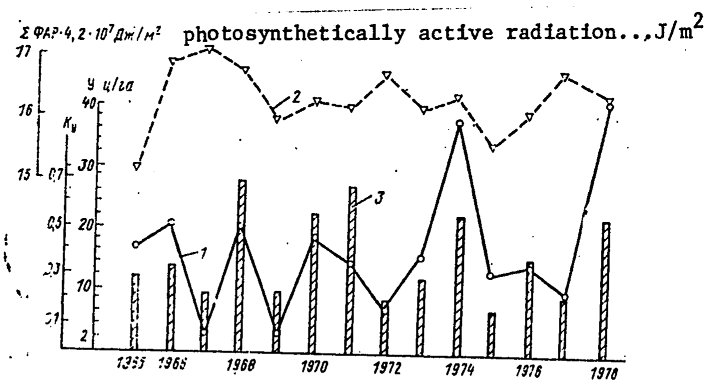

Fig. 2. Dependence of grain yield of winter wheat Mironovskaya-808 (1) on sum of photosynthetically active radiation (2) during spring-summer growing season and moistening coefficient (3) during agricultural year.
1) photosynthetically active radiation...J/m^2; 2) yield, centners/hectare; 3) K_{moist}

A thorough analysis of the influence of meteorological conditions of the winter period (depth of the snow cover, depth of soil freezing, sum of negative temperatures by months, absolute and mean minimum temperature of the air, soil, etc.) on the yield of grain of the Mironovskaya-808 variety indicated that the highest correlation coefficient (-0.625) is noted between the yield and the sum of the mean daily negative temperatures ($\Sigma t < 0°C$) of the autumn-winter - early spring period. In such years as 1967, 1969, 1972, 1976 and 1977, when the sum of negative temperatures attained 1,500°C or more, at the state strain testing stations there were areas either of death of crops or a minimum yield (in the range 2.0-3.1 centners/hectare). Our further investigations indicated that the indicated sum of negative temperatures usually corresponds to a low moistening coefficient for the autumn period (August-September) and a definite sum of the mean daily temperatures in July.

We found a high correlation coefficient (0.630) between the sum of mean daily temperatures in July and the sum of mean daily temperatures during the subsequent cold period. It was established that a sum of mean daily temperatures in July from 600 to 700°C corresponds to a sum of negative temperatures from 900 to 1,300°C (Fig. 1), that is, a sum of temperatures relatively favorable for the wintering of crops of the Mironovskaya-808 variety. Beyond the limits of these temperatures, both less than 600°C and greater than 700°C, the sums of negative temperatures attain 1,500°C or more. Thus, the sums of mean daily temperatures in July, on the one hand, and the moistening coefficient in August, on the other hand, indicate the degree of rationality of sowing of winter wheat in a specific year. The mean yield of winter wheat during 1965-1978 (Zelenovskiy rayon and Zelenovskiy strain testing station) was 16.2 centners/hectare. However, during years when the percentage of wintering plants attained more than 80 it rose to 20.9 centners/hectare.

The extent to which wintering conditions exert an influence on the grain yield is also indicated by the following facts: wheat not sprouting in autumn (Dzhambeytinskiy state strain testing station, 1967 and 1972), with a sum of negative temperatures in the winter period 1,200°C and 1,250°C, gave a yield of 16.5 and 11.4 centners/hectare respectively.

For wintering plants we found a high correlation coefficient (0.814) between the yield and the reserves of productive moisture in the soil layer 0-100 cm at the beginning of the spring growing season. This indicates that the spring moisture supplies in the soil are a highly important agrometeorological "inertial factor," exerting a considerable influence on the grain yield.

We also found a high dependence ($r = 0.757$) between the yield of winter wheat of the Mironovskaya-808 variety and the moistening coefficient during the agricultural year, which is clearly traced on the graph (Fig. 2).

An analysis of this graph indicates that the low moisture reserves in the soil in such years as 1967, 1969, 1972 and 1977 correspond to low moistening coefficients 0.22, 0.23, 0.20 and 0.23 and as a result -- low grain yields: 2.5, 2.1, 6.4 and 9.4 centners/hectare. In years when the reserves of productive moisture are greater than 50% of the field moisture capacity a high yield also corresponds to a high moistening coefficient.

An analysis of the data in Fig. 2 also shows that in years with identical moisture reserves in the soil layer 0-100 cm at the beginning of the spring growing season and a relatively identical moistening coefficient the high sum of photosynthetically active radiation during the period of the spring-summer growing season in these years also causes a higher grain yield. This dependence is traced in such years as 1966 and 1976, 1969 and 1972, 1968 and 1971, 1970 and 1974, 1970 and 1978, 1974 and 1978.

In a comparison of the indices of receipt of photosynthetically active radiation during the period of the spring-summer growing season and the moistening coefficients at the northern Zelenovskaya and the more southerly Dzhambeytinskaya state strain testing stations it was noted that with an increase in the receipts of energy of photosynthetically active radiation during the indicated period with movement from north to south through Ural'skaya Oblast the grain yield increases even with relatively lesser moistening coefficients. On the basis of these data it can be concluded that photosynthetically active radiation under the conditions of our zone is an important agrometeorological factor governing the formation of the yield of winter wheat grain.

An analysis of available data for Ural'skaya Oblast for 1964-1978 indicated that the correlation coefficient between the grain yield and the sum of photosynthetically active radiation with a moistening coefficient from 0.16 to 0.20 is -0.326. This indicates that with a moistening coefficient less than 0.20 the solar radiation is excessive for winter wheat plants. However, with a moistening coefficient greater than 0.23 the dependence between the grain yield of winter wheat and the sum of photosynthetically active radiation during its spring-summer growing season increases considerably ($r = 0.821$). In the autumn winter wheat growing season we did not find a high dependence between the solar radiation elements and the grain yield. This is attributable to the low moistening coefficient for this period.

Solar radiation is a highly important climatic factor exerting a great influence on all aspects of the life of plants. For the plant organism the duration of the solar day, the quantity and quality of solar radiation are vitally important factors regulating the development and maturing of plants, the grain yield and its technological indices.

The life of plants is dependent to a considerable degree on the heat and water regimes, on soil conditions, agricultural techniques, etc. The significance of these factors in the formation of the future yield of agricultural crops has been studied relatively completely, whereas until recently inadequate attention has been devoted to the study of the role of solar radiation for a number of reasons.

Solar radiation is absorbed in the photosynthesis process. The greatest effectiveness of photosynthesis requires not only the creation of a favorable medium, but also the directing of the plant growth processes in such a way that they give the maximum, most valuable production for man.

As early as 1882 I. A. Stebut noted that the illumination of plants and their use of solar energy considerably change in dependence on the direction of sowing of agricultural crops.

It has now been established that the upper erect wheat leaves transmit solar light better at midday and more effectively absorb it in the morning and evening hours (F. Mota, M. Acosta, 1970; Ch. Baldy, 1973). G. P. Maksimchuk (1970) points out that with a slope of the leaf blade of 87.3° the wheat grain yield is 23.9 centners/hectare, whereas with a slope of 33.2° it is 34.7 centners/hectare. It has been calculated that the photosynthetic potential of the upper leaf and the upper internode determines 60-80% of the yield (J. Spiertz, B. Hag, 1971).

In order to study this problem, during 1974-1978 in an experimental field of the West Kazakhstan Agricultural Institute and at sovkhoz enterprises in the oblast we carried out experiments with the sowing of winter wheat of the Mironovskaya-808 variety in rows with a north-south and west-east orientation.

The actinometric and meteorological measurements made during the period from sprouting to gold ripeness indicated that the plants in rows with a north-south and west-east orientation were exposed to different microclimatic conditions. The results of measurement of the total solar radiation and air temperature both in rows with different orientation of sowing and in open sectors of fields indicate that the daytime variation of solar radiation in rows with a north-south orientation has two clearly expressed maxima: the first from 0700 to 1000 hours and the second from 1500 to 1700 hours.

Converting the indices of the curve of variation of total solar radiation to energy units, by means of computations it was established that winter wheat plants in rows with a north-south orientation in the morning hours (from 0700 to 1000 hours) receive an energy of 0.99 cal/cm^2 per minute, and in the evening hours (from 1500 to 1700 hours) -- 0.71 cal/cm^2, whereas in rows with a west-east orientation -- 0.40 and 0.57 cal/cm^2 respectively.

Accordingly, plants in rows with a north-south orientation receive an energy in the morning hours which is 2.5 times greater and in the evening hours which is 1.3 times greater than in rows with a west-east orientation.

With an increase in solar altitude the plants in rows with a north-south orientation exhibit a considerably slower increase in leaf temperature and at midday it is usually 0.5-1.5°C lower than in rows with a west-east orientation. The wind velocity in rows with a north-south orientation from 1000 to 1700 hours attained 0.1-0.3 m/sec, whereas in rows with a west-east orientation a calm was noted.

It is entirely evident that a change in solar radiation leads to a change in air and soil temperature. As indicated by our measurements, the air temperature curve for midday in rows with a west-east orientation rises considerably higher than for rows with a north-south orientation, attaining differences among the plants of 5°C, and at the soil surface greater than 7°C. The mean daily (from 0400 to 1900 hours) temperature in rows of plants with a west-east orientation (27.1°C) is higher than in rows with a north-south orientation (26.6°C) by 0.5°C. This difference arises due to the fact that from 1000 to 1700 hours plants in rows with a west-east orientation in comparison with those having a north-south orientation are at a lesser angle of incidence to the solar rays.

All these factors (maximum content of physiologically active radiation in the morning and evening hours and its direct access to plants, great receipts of total solar radiation, lower air and soil temperature at midday, presence of air mass circulation, enriching plants with carbon dioxide and increasing photosynthesis), characteristic for rows with a north-south orientation, exert a greater influence on structural elements of the wheat yield in comparison with wheat in rows having a west-east orientation.

The reaction of winter wheat plants to the rays of the rising sun, that is, to orange-red rays, is manifested as follows: the highest percentage of ear emergence for rows of both north-south and west-east orientation begins with the part of the stem turned toward sunrise. The north-south orientation of the crop ensures direct access of the energy of photosynthetically active radiation, whereas in rows with a west-east orientation the plants considerably shade one another.

As noted by P. V. Denisov (1970), a study of the yield structure in turn makes possible a more thorough understanding of the nature of the yield, a more complete clarification of the potentialities of individual varieties and favors the development of procedures exerting a positive influence on individual yield structural elements.

Table 2 gives the characteristics of individual structural elements of the yield of winter wheat in dependence on orientation of the crop rows. The data in this table, prepared using the data from our experiments carried out in the institute's experimental field in 1974-1978, indicate that individual structural elements of the yield of winter wheat in the case of a north-south orientation of the crop rows are characterized by higher indices. For example, as an average during the investigated period the number of plants remaining intact at the time of harvest, productive bushiness, mass of 1,000 grains and the number of grains in a wheat ear of the Mironovskaya-808 variety were, in the case of a north-south orientation of the rows 64%, 2.0, 35.3 g, 27 grains respectively, whereas in the case of a west-east orientation — 58%, 1.9, 33.9 g, 24 grains respectively.

Table 2

Dependence of Structural Elements of Yield of Winter Wheat, Mironovskaya-808 Variety on Orientation of Crop Rows. Experimental Field, Agricultural Institute, Ural'skaya Oblast

Ориентация рядков посева 1	1975					1977				
	1	2	3	4	5	1	2	3	4	5
2 Север—юг	51	22	27,3	1,1	8,9	63	25	31,0	1,3	13,4
3 Восток—запад	45	20	25,7	1,0	7,1	60	23	29,7	1,2	10,0
4 Разность	6	2	1,6	0,1	1,8	3	2	1,3	0,1	3,4

Ориентация рядков посева 1	1978					Среднес за 3 года				
	1	2	3	4	5	1	2	3	4	5
2 Север—юг	79	33	47,6	3,5	48,2	64	27	35,3	2,0	23,5
3 Восток—запад	69	30	46,2	3,4	44,1	58	24	33,9	1,9	20,4
4 Разность	10	3	1,4	0,1	4,1	6	3	1,4	0,1	3,1

Note: 1 -- percentage of plants remaining intact at harvest time, 2 -- number of grains in ear, 3 -- mass of 1,000 grains, 4 -- productive bushiness, 5 -- yield, centners/hectare

KEY:

1. Orientation of crop rows
2. North-south
3. East-west
4. Difference
5. Average for three years

An analysis of the collected data indicated that the winter wheat plants in rows with a north-south orientation had a better-developed leaf surface and root system; in the long run this gave a higher grain yield. The average grain yield increment for the three years (1975, 1977, 1978 -- see Table 2) is 3.1 centners/hectare. The more favorable the agrometeorological conditions developed, the more effective was the reaction of the plants to the course of solar radiation in rows with a north-south orientation in comparison with a west-east orientation.

For example, in 1975, an arid year with a moistening coefficient 0.16, the increment of the yield of winter wheat in the case of sowing in rows with a north-south orientation, in comparison with a west-east orientation, was 1.8 centner/hectare. In 1977, when the moistening coefficient was 0.23, the increment increased to 3.4 centners/hectare, whereas in 1978, a crop year favorable with respect to agrometeorological indices, the increment in the yield of the varieties Mironovskaya-808 and Yershovskaya-3 attained 4.1 centners/hectare.

Table 3

Dependence of Yield of Winter Wheat Grain, Mironovskaya-808 Variety, on the Orientation of Crop Rows. Sovkhoz imeni Frunze, Zelenovskiy Rayon, Ural'skaya Oblast

Год 1	Ориентация рядков посева 2	Площадь посева, га 3	4 Урожай		Экономический эффект от прибавки 7	
			вал., ц 5	ц/га 6	в центнерах 8	в рублях 9
1975	север—юг 10 восток—запад 11 прибавка 12	274 400	3014 3120	11,0 7,8 3,2	876,8	7 540
1976	север—юг восток—запад прибавка	2	56,0 50,0	28,0 25,0 3,0	6,0	52
1977	север—юг восток—запад прибавка	663 779	6019 6071	9,1 7,8 1,3	861,9	7 412
1978	север—юг восток—запад прибавка	1306 375	51075 13139	39,1 35,0 4,1	5354,6	50 654
Среднее за 1975—1978 гг.	север—юг 10 восток—запад 11 прибавка 12			21,8 18,9 2,9	7099,3	65 658

KEY:

1. Year
2. Orientation of crop rows
3. Sown area, hectares
4. Yield
5. Gross, centners
6. Centners/hectare
7. Economic effect from increment
8. In centners
9. In rubles
10. North-south
11. East-west
12. Increment
13. Average for 1975-1978

The introduction of the results of our experiments with the sowing of winter wheat in rows with a north-south orientation into production work at the sovkhoz imeni Frunze in Zelenovskiy Rayon in 1975-1978 (Table 3) ensured a mean yield increment in comparison with rows of a west-east orientation of 2.9 centners/hectare and management without the slightest additional expenditures during these years obtained an additional 7,099.3 centners of high-quality grain or 65,658 poods. The effectiveness of the rational use of agrometeorological resources was especially manifested in 1978 when the increment of the grain yield from each hectare was 4.1 centners.

Thus, field plantings of winter wheat confirmed the importance of timely allowance for and rational use of solar radiation in increasing grain production in our zone.

Summary

1. The wintering of winter wheat under the conditions prevailing in northwest Kazakhstan with a small snow cover has a maximum dependence on the sum of negative mean daily air temperatures during the particular period.

2. With an increase in the sum of photosynthetically active radiation during the spring-summer growing season for winter wheat, in the case of a satisfactory moisture supply (moisture reserves in the soil greater than 50% of the potential moisture or $K_{moist} > 0.23$), there is also an increase in the grain yield.

3. A north-south direction of rows for the winter wheat crop is an important agroengineering procedure for the more effective use of photosynthetically active radiation for increasing the winter wheat grain yield.

BIBLIOGRAPHY

1. Konstantinov, L. R., POGODA, POCHVA I UROZHAY OZIMOY PSHENITSY (Weather, Soil and Yield of Winter Wheat), Leningrad, Gidrometeoizdat, 1978.

2. Tooming, Kh. G., SOLNECHNAYA RADIATSIYA I FORMIROVANIYE UROZHAYA (Solar Radiation and Yield Formation), Leningrad, Gidrometeoizdat, 1977.

3. Ulanova, Ye. S., AGROMETEOROLOGICHESKIYE USLOVIYA I UROZHAYNOST' OZIMOY PSHENITSY (Hydrometeorological Conditions and Winter Wheat Yield), Leningrad, Gidrometeoizdat, 1975.

4. Shul'gin, I. A., SOLNECHNAYA RADIATSIYA I RASTENIYE (Solar Radiation and Plants), Leningrad, Gidrometeoizdat, 1967.

UDC 551.553.6

FREQUENCY OF OBSERVATIONS FOR COMPUTING THE PERIOD OF RECURRENCE OF WIND VELOCITY EXCEEDING A STIPULATED LEVEL

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 93-94

[Article by Candidate of Technical Sciences I. A. Savikovskiy, Belorussian Territorial Hydrometeorological Center, submitted for publication 27 August 1979]

Abstract: The author demonstrates the incorrectness of computation of the period of recurrence T when using a great frequency of observations. Such computations lead to T values which are too low and which have no real meaning. The need is pointed out for a correct definition of the concept "case with a wind velocity exceeding a stipulated level" and the advantages of use of diurnal maxima are pointed out.

[Text] In computing the probability F(u) that the wind velocity v will exceed a stipulated level u by the Anapol'skaya-Gandin method [1] use is made of the totality of regularly scheduled observations. Usually F(u) is used to compute the period of recurrence T -- the mean number of years corresponding to one case with $v > u$:

$$T = \frac{1}{NF(u)} = \frac{1}{365\, nF(u)}. \tag{1}$$

Here N and n are the numbers of observations in a year and a day respectively. The authors of the method [1] stipulate that four regularly scheduled observations are used.

The processing of wind observations with different numbers of observation times was carried out, in particular, by S. D. Koshinskiy and L. S. Rudova [4]. They confirmed the natural assumption of a nondependence of F(u) on the number of observation times (in the case of a sufficiently long series). It therefore follows that it is possible to determine F(u), for example, on the basis of four regularly scheduled observations and calculate T using formula (1) for observations made hourly, once each three hours, etc., regardless of their actual frequency. In this case T will be inversely proportional to the frequency of observations n adopted for computations. The problem arises of the choice of n.

The authors of [3, 5] advance the idea that preference should be given to large n. It is correctly noted that in the case of small n some of the wind strengthenings occur between the observation times and are not taken into account. However, it escapes their attention that in the case of a high frequency in each interval with $v > u$ there will be several observations, each of which in the computation of T will be incorrectly taken into account as an individual case. (The fact that the adopted frequency of observations in actuality is not adhered to, but is only "fitted into the computations," does not change matters.)

A. D. Drobyshev [3] proposes that the point of departure should be continuous observations, the number of which per day is 24, divided by the averaging period (in hours), in particular, 720 in the case of a two-minute period and 28,800 in the case of a three-second period (gusts). We will assume that once in 100 years the velocity, measured with 3-second averaging, in the course of 5 minutes exceeds 30 m/sec. There are 100 "cases" of exceeding of the mentioned velocity and therefore the period T of recurrence of v 30 m/sec is equal to 1 year. Such a T is a purely formal characteristic and does not have practical meaning.

The authors of [5] propose that n = 24 or 144 (continuous observations with 10-minute averaging). In the latter case it is "recommended that there be an increase in the calculated velocity, computed from four regularly scheduled observations...by 15-20%." This is equivalent to proposing retention of the computed velocities obtained for n = 4, but with a decrease of all the corresponding T periods by a factor of 36. In our opinion the results of such scaling are without practical sense.

The reason for the unjustified use of formula (1) is the absence of correct definition of the concept "case with $v > u$," which is necessary if we use the characteristic "mean number of years per one case." We will examine some possible definitions.

1. A "case" means an individual observation. With n = 4 the definition is applicable because the computed u usually do not include several observation times in a row.

2. A "case" is the time interval during which $v > u$ persists without interruption (this "continuity" must be rationally determined). It is desirable that the interval between observations correspond to the mean duration t of such an interval, that is, n = 24/t. With a lesser frequency some of the intervals will be missed, whereas with a greater frequency one case will be noted as several. Unfortunately, in this case n will be different for different u (and to one degree or another will be local).

3. A "case" is a 24-hour period during which at least at some moment $v > u$. Such a definition evidently corresponds to a higher degree to practical requirements than the preceding definitions. It requires computation of F(u) on the basis of diurnal maxima, not on the basis of regularly scheduled observations. Since at the present time the diurnal maximum is obtained on the basis of data from continuous tracking of wind velocity, the problem of the frequency of observations is completely eliminated.

If u is so great that $v > u$, as a rule occurring not more than one day a month, close results should be obtained by computations using the VNIIE method [2], using monthly maxima.

BIBLIOGRAPHY

1. Anapol'skaya, L. Ye., Gandin, L. S., "Method for Determining the Computed Wind Velocities for Planning Wind Loads on Construction Jobs," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 10, 1958.

2. VETROVYYE NAGRUZKI VOZDUSHNYKH LINIY ELEKTROPEREDACHI V SSSR (Wind Loads on Overhead Electric Power Lines in the USSR), TRUDY VNIIE (Transactions of the All-Union Scientific Research Institute of Power Engineering), No 14, 1962.

3. Drobyshev, A. D., "Determination of the Stochastic Characteristics of Wind Velocities With Different Time Averaging Using Standard Nomograms," TRUDY ZSRNIGMI (Transactions of the West Siberian Scientific Research Hydrometeorological Institute), No 39, 1978.

4. Koshinskiy, S. D., Rudova, L. S., "Dependence of Computed Wind Velocity With a Small Guaranteed Probability on the Number of Wind Observations Daily," TRUDY ZSRNIGMI, No 20, 1976.

5. Koshinskiy, S. D., et al., "Computation of Averaged and Instantaneous Wind Velocities With a Small Guaranteed Probability Using Data from Different Numbers of Daily Observations," INFORMATSIONNOYE PIS'MO GUGMS (Information Letter of the Main Administration of the Hydrometeorological Service), No 21, 1977.

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INFLUENCE OF SOME HYDROMETEOROLOGICAL FACTORS ON THE "BLOOMING" OF WATER IN RESERVOIRS

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[Article by Candidate of Geographical Sciences B. I. Novikov, Hydrobiology Institute Ukrainian Academy of Sciences]

Abstract: A study was made of the movement of blue-green algae in disperse and aggregated states (spots and "blooming" fields) under the influence of runoff and wind-induced currents. It was established that with a wind with a velocity of 7 m/sec or more the wave oscillations destroy the aggregates of algae and scatter them in the water layer.

[Text] The problem of regulating the quality of water in reservoirs involves a study of a complex of hydrological, hydrochemical and hydrobiological phenomena. One of these is the mass development of blue-green algae -- the "blooming" of water, which has long attracted the attention of researchers. The harmful effects of "blooming" include not only an undesirable change in the ecosystem of the water body, but also a deterioration of water quality as a result of its saturation with the products of decomposition of algae. These investigations, in which the leading role is played by the Hydrobiology Institute Ukrainian Academy of Sciences, have yielded extensive information on the taxonomy, ecology and physiology of algae, causing "blooming." At the same time, it is impossible to overlook the inadequate study of the influence of a number of abiotic factors, including hydrometeorological factors: wind, waves, currents. Much of the information on the influence of these factors on the "blooming" of water has a descriptive character [1, 5, 9].

During the course of the entire growing period the blue-green algae are in the water in a suspended state. Their physiological peculiarities predetermine movement with the water masses, that is, under the influence of currents and waves. It is known that a concentration of algae with a biomass of about 10-40 km/m^3 results in the dying of fish and the poisoning of water and this is also determined by the influence of these factors [1].

The objective of our study included a determination of the empirical dependences reflecting the influence of the wind (through waves and currents) on the concentration and distribution of blue-green algae in reservoirs. In solving the problem we used information from a series of published studies [1, 2, 5, 7, 8] and observational data from the hydrology and algae physiology sections of the Hydrobiology Institute Ukrainian Academy of Sciences in Dnepr reservoirs in different years. These materials represent measurements of the biomass of algae in the water surface layer and at depth at permanent verticals and sectors, as well as wind velocities at a height of 2 m above the water surface. In addition, measurements were made of the velocity of movement of the upper half-meter water layer with algae suspended in it under the influence of a stable wind with a velocity 0-10 m/sec.

Before proceeding to solution of the fundamental problem of this study, we will turn our attention to still another factor acting on algae suspended in the water -- runoff currents. They are constant during the course of the entire year and move the water masses of the reservoirs toward the discharge structures. During the growing period the algae also move together with them. Approximate computations for the Dnepr reservoirs reveal that with a duration of this period of 2-3 months, with an intensity of water exchange from 2 to 4 times a year, the entire volume of water with vegetating algae can be discharged into the lower pool. In actuality, this does not occur due to a superposing of the system of wind currents and the retention of algae in bays, in gulfs and on the bottom. Nevertheless, runoff currents must be taken into account both in evaluating the total biomass of algae in a single reservoir and in the analysis of their development in the cascade.

We will illustrate the first in the example of the Kremenchugskoye Reservoir. Its reach from Cherkassy city to the dam has a length of 85 km. According to data published by N. V. Pikush [4], its mean flow during the growing season is 0.9-1.7 cm/sec or from 0.8 to 1.5 km/day. In accordance with these figures, by the end of the vegetation period the algae forming at the upper boundary of the reach arrive at the dam, but the interval in the observations in adjacent reaches, equal to several days, leads to a distorted idea concerning the distribution of algae in the water body. The second consequence of the runoff currents is the movement of the algae into the lower pool, that is, into the cascade lying below the reservoir. Some of the cells perish when passing through the discharge structures, but not all. As a result, there can be activation of the development of algae and a broadening of the "blooming" area into the lower-lying reservoir as a result of increased multiplication of these organisms in the water body situated above; this often occurs in the first years of formation. For example, a burst of "blooming" in 1967 in the Kiyevskoye Reservoir (filled in 1966) was accompanied by an intensive development of algae in the lower-lying Kremenchugskoye and Dneprodzerzhinskoye Reservoirs in 1968 and 1969 [2]. Such a phenomenon can be attributed to the movement of algae by runoff currents, not excluding, naturally, the influence of other factors.

The redistribution of blue-green algae within the reservoir occurs under the active influence of wind waves and currents. These factors can be regarded as decisive for the aggregated phase. It is known from the published data [1, 8] that "blooming" spots and fields are formed and persist only when there is a weak wind and in a calm. Most of the algae (80-95%) in these formations are concentrated in the upper half-meter water layer. But specifically this layer is also under the direct influence of wind-induced flows. An investigation of the character of its movement indicated that within the limits of the open water body the direction of movement deviates from the wind direction by not more than 5-10° and only with entry into the shallow-water zone along the shore forms a circulation, as we investigated before [3]. For an open water body and a range of wind velocity 0-10 m/sec, using observational data, we derived an empirical dependence described by the equation

$$v_{0.5} = 2{,}3\ W - 0{,}5,$$

where $v_{0.5}$ is the velocity of movement of the upper half-meter water layer, cm/sec; W is wind velocity at a height of 2 m above the surface, m/sec.

The correlation coefficient is equal to 0.72; the error with a guaranteed probability 99% does not exceed 1.2 cm/sec.

With a wind velocity of 5 m the movement of the algae is 8.5-10.5 km/day, which coincides with the already known data [4], and a velocity of 0.22 m/sec is probably expended on overcoming layer viscosity. Checking of the equation by special intersections of navigational markers in the Kanevskoye Reservoir indicated that the equation corresponds well to the velocity of drift of "blooming" spots and fields.

The concentration of algae in the upper half-meter water layer is retained in calm weather and when there is a weak wind. With an intensification of the wind the wave oscillations destroy the algae aggregates and scatter their colonies and cells within the limits of the layer affected by these oscillations. Observational data registered in Dnepr reservoirs were used in writing empirical expressions characterizing the process of scattering of algae at different wind velocities for both ordinary and aggregate states. The first dependence was derived for an open water body with depths greater than 6 m, has a power-law character and and is represented below.

Relative Concentration (B) of Blue-Green Algae in Upper Water Layer for Different Wind Velocities (W)

W m/sec	Calm	1	2	3	4	5	6	7	8	10
B%	82	51	35	26	18	13	10	8	6	6

In accordance with these data, when there is a calm in the upper water layer there is concentration of an average of 82% of the entire quantity of algae at the vertical, whereas with a wind greater than 6 m/sec less than

10% of them remain. In the case of an aggregated state of the algae ("blooming" spots and fields) the algae are concentrated in the upper half-meter water layer and a wind intensification lessens the concentration in accordance with the equation

$$B_W = B_0 (0,89 - 0,12 W),$$

where B_W and B_0 is the quantity of algae g/m^3 with a wind W m/sec and with a calm (initial concentration). The correlation coefficient of the equation is 0.82 with a reliability 0.99. It must be emphasized that both dependences were derived using data obtained with a wind not greater than 10 m/sec, that is, they have limited applicability.

The results of this investigation can be formulated as follows:

1. Runoff currents are an important factor in the dynamics of blue-green algae both within the limits of one reservoir and in the cascade.

2. The concentration of algae, including their aggregation in the surface layer in the form of "blooming" spots and fields, is reduced with an increase in wind velocity. With a value of the latter 7 m/sec or more the algae are uniformly scattered in the water layer.

3. The nonuniformity of distribution of algae over the surface of the reservoir is related to wind currents which with a wind velocity of 5 m/sec can move the algae 8.5-10.5 km/day.

We note in conclusion that the results presented above are only a first attempt at a quantitative evaluation of the effect of some hydrometeorological factors on the "blooming" of water in reservoirs. It is obvious that the formulation of broader complex investigations will make it possible to refine and broaden the described peculiarities of the wind effect mechanism and also to obtain new information on other factors. This will make it possible to clarify an important aspect of monitoring of the quality of the environment -- the water "blooming" problem.

BIBLIOGRAPHY

1. Braginskiy, L. P., et al., "'Blooming Spots,' Wind-Driven Water Masses, Outbreaks of Blue-Green Algae and the Biological Processes Transpiring in Them," "TSVETENIYE" VODY (Water "Blooming"), Kiev, Naukova Dumka, 1968.

2. Guseva, K. A., et al., "Intensity of 'Blooming' and Times of Mass Vegetation of Blue-Green Algae in Reservoirs of Hydroelectric Power Stations in the USSR," FORMIROVANIYE I KONTROL' KACHESTVA POVERKHNOSTNYKH VOD (Formation and Monitoring of the Quality of Surface Waters), Kiev, Naukova Dumka, No 2, 1976.

3. Novikov, B. N., "Wind Currents in an Unclosed Shallow-Water Sector of a Water Body," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 11, 1976.

4. Pikush, N. V., "Hydrological Investigations of Reservoirs on the Dnepr," VESTNIK AN UkrSSR (Herald of the Ukrainian Academy of Sciences), No 2, 1965.

5. Priymachenko, A. D., Litvinova, M. A., "Distribution and Dynamics of Blue-Green Algae in Dnepr Reservoirs," "TSVETENIYE" VODY, Kiev, Naukova Dumka, 1968.

6. Priymachenko, A. D., "Factors Determining the Productivity of Blue-Green Algae in Dnepr Reservoirs," FORMIROVANIYE I KONTROL' KACHESTVA POVERKHNOSTNYKH VOD, Kiev, Naukova Dumka, No 2, 1976.

7. Priymachenko, A. D., "Phytoplankton of Gor'kovskoye Reservoir During the First Years of its Existence (1956-1957)," TRUDY IBVV [Expansion Unknown], 4(7), 1961.

8. Sirenko, L. A., Gavrilenko, M. Ya., "TSVETENIYE" VODY I EVTROFIROVANIYE ("Blooming" of Water and Eutrophic Studies), Kiev, Naukova Dumka, 1978.

9. Tseyeb, Ya. Ya., Litvinova, M. V., Gusinskaya, S. D., "Quantitative Dynamics of Plankton Blue-Green Algae in Relation to Their Influence on the Numbers and Distribution of Zooplankton in the Kakhovskoye Reservoir," EKOLOGIYA I FIZIOLOGIYA SINE-ZELENYKH VODOROSLEY (Ecology and Physiology of Blue-Green Algae), Moscow-Leningrad, 1965.

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MEASUREMENT OF INTEGRAL HUMIDITY BY AN OPTICAL METHOD

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[Article by V. N. Marichev, Institute of Atmospheric Optics Siberian Department USSR Academy of Sciences, submitted for publication 11 September 1979]

Abstract: The article describes measurement of integral humidity along a surface path by an optical method in the IR range. Problems involved in the choice of the optimum parameters of an optical hygrometer, its calibration and measurement accuracy are discussed. A comparison of data obtained using an optical hygrometer and psychrometers set up at the ends of the path is given.

[Text] The water present in the atmosphere determines its thermal regime and the dynamics of atmospheric processes and is one of the fundamental factors in planetary weather formation. It is therefore easy to understand the enormous interest which is manifested in study of the dynamic characteristics of atmospheric moisture content. For example, the authors of [1, 2, 10] carried out investigations of the moisture content of the entire thickness of the atmosphere under different meteorological conditions and at different latitudes and its relationship to surface humidity, and also give a review and analysis of a number of other studies made of this problem. However, an important aspect is a determination of the integral moisture content on surface paths. This is necessary in solving such problems as investigation of the characteristics of humidity in the surface air layer, remote monitoring of the humidity level over soils, evaluation of the influence of the water vapor concentration on the attenuation of optical radiation and the calibration of meteorological lidars.

A model of instrumentation making it possible to determine the integral content of atmospheric water vapor on a horizontal path was developed for these purposes. The principle for determining moisture content is based on the measurement of radiation transmission by the atmospheric layer in the region of the water vapor absorption band and the transparency window, as was done by Fowle [12] as early as 1912 and which was further developed in [5-8, 11].

The optical instrument for measuring humidity consists of two separable parts: radiation source and receiving system. The radiation source includes an incandescent lamp of the KIM-75 type, installed in the lens focus. The divergence of radiation forms an angle of about 1°. The ray from the source is transmitted through an atmospheric layer with a thickness L = 0.98 km and then transmitted into the receiving system. The latter consists of a lens (diameter 30 cm), matched with a high-transmission MDR-2 monochromator and a FEU-62 photodetector. The electric signal from the FEU could be registered with a voltmeter or an automatic recorder.

The vibrational-rotational band of the water molecule in the region $\lambda = 0.94$ μm was selected for operation of the optical hygrometer (the so-called σ-band). A distinguishing characteristic of this band is its greatest intensity among the adjacent IR bands and the absence of the spectra of extraneous gases in it [3].

For the particular absorption band the influence of change in temperature and the complexes of H_2O molecules on transparency, according to [2], does not exceed 1% for each effect. It is considerably less, for example, than for the band with $\lambda = 2.7\,\mu$m. It should be noted that in the selected spectral region it is possible to use photodetectors with a high response -- photomultipliers.

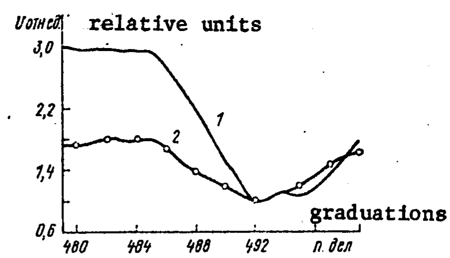

Fig. 1. Registry of signal in working part of spectrum. 1) w = 7.1 mm, 2) w = 4.7 mm.

The monochromator calibration was carried out using the radiation of a He + Ne laser with wavelengths $\lambda = 0.63$ and $1.15\,\mu$m, and also using the lines of a mercury lamp with $\lambda = 0.69$, 0.83, 0.94, 1.014 μm.

The calibration of hygrometer readings using the precipitable layer of water vapor was carried out in the following way. First the radiation source was placed directly in front of the receiving unit and the electric signal was registered in the spectral region of interest. It was found that in the working range from 0.92 to 0.94 μm the signal decreased by only 1% toward the center of the absorption band with spectral resolution intervals 2-8 nm. Then the source was placed at the other end of the path with registry of the spectral signal obtained in the presence of an absorbing layer of H_2O molecules between the receiver and transmitter. In this case the maximum signal fell in the region 0.93-0.94 μm, that is, the choice of the working absorption band with its center at λ= 0.94 μm was also optimum from the point of view of the effectiveness of instrument operation: the greatest signal-to-noise ratio was attained here. For example, the ratio of the signal to the photodetector dark current was 100, and to the background of the daytime sky -- 50. The wavelengths corresponding to the maximum signal in the atmospheric transparency window and the minimum signal in the absorption band are equal to 0.929 and 0.942 μm respectively. Subsequently the spectral resolution of the monochromator was set at 6 nm.

Simultaneously with the registry of signals in the working spectral range there was measurement of atmospheric humidity at both ends of the path by means of psychrometers. The integral moisture content (precipitable water) was determined as the average of the psychrometer readings:

$$w\,[\text{мм}] = l\,[\text{км}]\,\frac{a_1 + a_2}{2}\quad [\text{g/m}^3]. \tag{1}$$

where L = 0.98 km is the length of the path, $a_{1,2}$ is the humidity at the ends of the path.

An example of signal registry in the working spectral range for two w values obtained using formula (1) is given in Fig. 1.

The signals arriving from the photodetector can be written as follows:

$$U_{\lambda_1} = \gamma_1 c_1 I_{01} e^{-\alpha_1 L}\, e^{-k_1(w)\, w},$$
$$U_{\lambda_2} = \gamma_2 c_2 I_{02} e^{-\alpha_2 L}\, e^{-k_2(w)\, w}, \tag{2}$$

where the subscripts 1 and 2 relate to the window of atmospheric transparency and the water vapor absorption band; I_{0i} is the intensity of the initial radiation; γ_i is the spectral response of the receiving part of the system; α_i is the coefficient of aerosol and molecular scattering; $k_i(w)$ is the coefficient of absorption by water vapor; c_i is a coefficient taking into account the interception of the ray by the receiving telescope.

Since in the measurements the geometry of the ray does not change, then $c_1 = c_2$.

From the equality of the electric signals in the spectral ranges near the wavelengths 929 and 942 nm, obtained as a result of hygrometer calibration (that is, in the absence of an absorbing layer of water molecules and an aerosol layer), it follows that $\gamma_1 I_{01} = \gamma_2 I_{02}$ with an error of about

0.5%. If it is taken into account here that the coefficient of refraction of the collimator lens (glass K = 8) at the wavelengths 929 and 942 nm differs only in the fourth decimal place, or by 0.01% (in accordance with GOST 13659-68), then we have the right to assume the formation of the two spectral rays to be adequate and the density of the spectral fluxes arriving at the spaced detector to be identical (without allowance for attenuation). On the basis of what has been set forth above, we have the equality $\gamma_1 c_1 I_{01} \simeq \gamma_2 c_2 I_{02}$.

Next we will examine the attenuation of radiation as a result of scattering. In our experiments the measurements were made with a meteorological range of visibility $S_m \geqslant 10$ km. It follows from an analysis of theoretical studies and experimental work on investigation of the spectral transparency of atmospheric haze in a broad range of change in S_m and aerosol composition, which were described in a monograph by V. Ye. Zuyev [4], that for our case with $S_m \geqslant 10$ km and L = 0.98 km due to the small difference in wavelengths it can be assumed that $e^{-\alpha_1 L} = e^{-\alpha_2 L}$ with an error less than 1%. The transparency for λ = 942 nm within the limits of this error is greater than the atmospheric transparency at λ = 929 nm. Taking into account that the electric signal in the absence of an attenuating layer at λ = 929 nm was approximately 0.5% higher than at λ = 942 nm, this difference in the signals is compensated as a result of the nonuniformity in the scattering of radiation. Thus, it can be assumed that the difference in the signals must be caused only by absorption by water vapor.

The correlation of optical thickness $\tau(w)$, in this case completely caused by the absorption of radiation, and the precipitable layer of moisture, was determined through the differential absorption coefficient $k(w) = k_2(w) - k_1(w)$,

$$\tau(w) = \ln \frac{U_{\lambda_1}}{U_{\lambda_2}} = k(w)\, w. \qquad (3)$$

It was found that with an increase in w there is a decrease in the absorption coefficient k(w), as is a corollary of work on the unresolved spectral structure [5]. On the basis of [5] we represented the correlation between τ and w in the form

$$\tau = C w^{0.63}. \qquad (4)$$

The experimental results are shown in Fig. 2. The coefficient C, obtained by an analysis of the straight line in Fig. 2 by the least squares method, is equal to 0.242 ± 0.013 mm$^{-0.63}$. In order to discuss the experimental data it is first necessary to determine the measurement errors τ and w, obtained using the optical hygrometer and the psychrometers respectively.

The accuracy in measuring the τ value, or atmospheric transparency, in two spectral ranges will be dependent on such factors as radiation of the background, the photodetector dark current, instability of the radiation source, fluctuations of atmospheric transparency and its turbulence and the accuracy of the recorder.

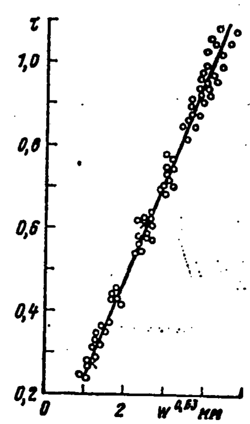

Fig. 2. Calibration curve.

The first two types of errors are excluded by the registry of signals with the radiation source operative and inoperative, and in the further processing of data use was made of the signal difference:

$$U = U_{with} - U_{without}, \quad (5)$$

where U_{with}, $U_{without}$ are signals received with and without a light flux from the source.

Then tests of the radiation source for stability indicated that in the absence of an atmospheric layer (the incandescent lamp was placed at a distance of 1-2 m from the receiving telescope) the electric signal of the photodetector remained constant. This gives basis for neglecting the errors related to the instability of radiation.

The errors introduced by the atmosphere were evaluated in the following way. Using the recorder it was possible to register automatically the maximum and minimum amplitudes of the signals encountered in the course of the time which is usually expended on the working measurements (1-2 minutes). Thereafter we computed the value

$$2\delta = \frac{U_{max} - U_{min}}{U}. \quad (6)$$

Processing of the accumulated data indicated that in the overwhelming majority of cases $2\delta \leqslant 0.04$; this value was used as the general error in measurements (the error of the recorder -- a voltmeter of the type 4027 -- does not exceed 0.2%). Thus, in accordance with (3), the error is

$$\Delta\tau = 2\delta = 0{,}04. \qquad (7)$$

The error Δw is determined by the error of aspiration psychrometers. Since in accordance with (2)

$$\Delta w = \Delta a, \qquad (8)$$

then it is necessary to find the Δa value. The absolute humidity value a can be computed through water vapor elasticity as

$$a[g/m^3] = 217\ e/T\ [mb/K], \qquad (9)$$

which is determined using the formula [8]

$$e = E_{t'} - Ap\,(t - t')(1 + 0.0015\,t'), \qquad (10)$$

where t, t' are the temperatures of the dry- and wet-bulb thermometers of the psychrometer, p is air pressure, mb, A is the psychrometric coefficient, equal to $7.947 \cdot 10^{-4} (°C)^{-1}$, E_t is the saturating elasticity over water at the temperature t'.

On the basis of the cited formulas we can write:

$$\frac{\Delta a}{a} \approx \frac{\Delta e}{e} = \frac{1}{rE_{t'}}\,(\Delta E_{t'} + 2\,Ap\,\Delta t), \qquad (11)$$

where $r = e/E_t$ is relative humidity.

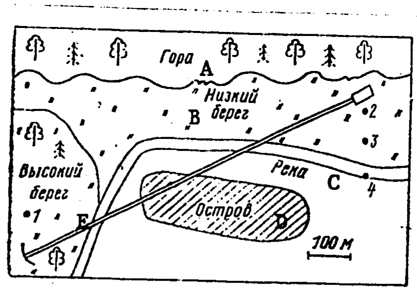

Fig. 3. Diagram of measurement path. A) Mountain; B) Low shore; C) River; D) Island; E) High shore.

The error in determining absolute humidity in percent under the condition of taking the temperature readings from thermometers with an accuracy to 0.1°C for different t and r values is given in Table 1 (error ΔE_t, determined from the psychrometric tables [8], p = 1000 mb). The table shows that with an increase in air temperature and relative humidity the accuracy in measuring absolute humidity increases.

Table 1

T°C	r %					
	10	20	40	60	80	100
−5	41,3	20,6	10,3	6,8	5,2	4,1
0	30,2	15,1	7,6	5,0	3,8	3,0
+6	22,3	11,1	5,6	3,7	2,8	2,2
+10	16,5	8,2	4,1	2,7	2,1	1,7
+15	12,9	6,5	3,2	2,2	1,6	1,3
+20	16,3	5,2	2,6	1,7	1,3	1,0
+25	8,4	4,2	2,1	1,4	1,1	0,8
+30	7,1	3,6	1,8	1,2	0,9	0,7
+35	6,1	3,1	1,5	1,0	0,8	0,6

Table 2

Дата 1	Время 2	1	2	3	4
31 мая 3 1977 г.	14^{50}—15^{00}	5,1	6,5	7,2	8,3
	15^{25-35}	5,6	6,5	7,1	8,9
	16^{35-45}	5,3	7,0	7,7	8,7
	16^{50}—17^{00}	5,5	6,4	7,7	8,7
7 июня 4 1977 г.	15^{20-40}	8,3	10,0	10,8	11,2
	15^{50}—16^{00}	9,5	10,0	10,8	11,8
	16^{40-50}	8,8	10,3	11,5	12,1
	17^{30-40}	6,1	7,2	8,7	9,9
	17^{55}—18^{05}	5,0	6,1	7,2	7,9

KEY:
1. Date
2. Time
3. May
4. June

The scatter of experimental points relative to the line of their mean value in Fig. 2 exceeds the limits of errors in measuring τ and w. This fact indicates the incorrectness of restoration of integral humidity using measurements of two psychrometers set up at the ends of a path, especially in the case of a complex path, as in this study. In the experiment the source ray passed successively over a glade, low river bank, river, island and high river bank (Fig. 3). The height of the ray above the surface along the path changed and the height difference between the ends of the path was 40 m. Accordingly, it was natural to assume that the humidity distribution along the path is nonuniform. Also in support of this assumption is the fact that the absolute humidities a_1 and a_2, measured simultaneously, in most cases differed; the difference frequently exceeded the limits of measurement errors and in some cases attained 35%. As an example in Table 2 we give some results of humidity measurements. There the indices 1-4 relate to the measurement points; 1-2 are the ends of the path, 3 is a point situated at a distance of 50 m from 2 in the direction of the river perpendicular to the path (see Fig. 3) and 4 is the river (distance from point 2 is 100 m).

It can be seen from Fig. 2 that with an increase in the precipitable layer there is an increase in the scatter of the experimental points relative to the mean values. In winter (w = 1-2 mm) this scatter is small and falls in the limits of measurement errors; during this period the surface is covered by snow and the distribution of humidity along the path becomes more uniform and constant, which is immediately reflected in the small difference in the values a_1, a_2, determined at the ends of the path. For example, the crosses in Fig. 2 indicate control measurements made when there was a coincidence of humidity values. When working over an open river (w > 2 mm) the scatter immediately increases and continues to increase with an increase in temperature (of the precipitable layer).

The mean square error in determining the precipitable layer of water vapor by an optical hygrometer, using the calibration straight line, is written as follows:

$$\frac{\delta w}{w} = \sqrt{\left(\frac{\delta C}{C}\right)^2 + \left(\frac{\delta \tau}{\tau}\right)^2}, \qquad (12)$$

where $w' = w^{0.63}$.

The mean value $\delta C/C$ was determined and is about 6%. For winter conditions $\delta C/C$ = 2%. As was demonstrated earlier, $\delta\tau$ = 0.04, and the $\partial\tau/\tau$ error will be dependent on the quantity of water vapor on the path. The evaluations show that the error in an individual measurement of integral humidity during winter (a = 1-2 g/m^3) is 20-28%, and in the summer time (for a = 10 g/m^3) the error is equal to 10%. For intermediate humidity values a = 2-10 g/m^3 the error is in the range 10-20%. The accuracy in measuring the precipitable layer with the optical hygrometer can be increased if its calibration is accomplished on a path with a constant humidity. In this case the measurement error can be decreased at the limit by 6%. The use of the effective quantity of moisture [5] in place of the precipitable layer of water vapor in constructing the calibration curve also will make it possible to increase the accuracy of the graph.

In conclusion it should be noted that the optical hygrometer is advantageous and feasible to use in the measurement of integral humidity on paths passing over a nonuniform surface because in these cases the accuracy of the proposed measurements is higher than the accuracy of humidity measurements with psychrometers placed at the ends of the path. It is very possible to use the instrument for determining precipitable moisture at negative temperatures at which the accuracy of standard meteorological instruments becomes unsatisfactory.

BIBLIOGRAPHY

1. Badinov, I. Ya., Andreyev, S. D., Lipatov, V. B., "Some Results of Surface Spectrometric Investigations of the Moisture Content of the Atmospheric Layer," PROBLEMY FIZIKI ATMOSFERY (Problems of Atmospheric Physics), Leningrad, Izd-vo LGU, No 4, 1966.

2. Badinov, I. Ya., Gal'tsev, A. P., Nikol'skiy, G. A., "On the Spectroscopic Method for Determining the Integral Moisture Content in a Column of the Atmosphere," PROBLEMY FIZIKI ATMOSFERY, Leningrad, Izd-vo LGU, No 2, 1963.

3. Gudi, R. M., ATMOSFERNAYA RADIATSIYA (Atmospheric Radiation), CH. 1. OSNOVY TEORII (Part 1. Theoretical Principles), Moscow, Izd-vo "Mir," 1966.

4. Zuyev, V. Ye., RASPROSTRANENIYE VIDIMYKH I INFRAKRASNYKH VOLN V ATMOSFERE (Propagation of Visible and Infrared Waves in the Atmosphere), Moscow, Sov. Radio, 1970.

5. Kiseleva, M. S., "Determination of the Moisture Content of Gas Mixtures from the IR Absorption Spectra," OPTIKA I SPEKTROSKOPIYA (Optics and Spectroscopy), Vol 24, No 3, 1968.

6. Neporent, B. S., Kiseleva, M. S., "Measurement of Direct Change in the Distribution of Atmospheric Water Vapor by the Spectral Method," IZV. AN SSSR, GEOFIZIKA (News of the USSR Academy of Sciences, Geophysics), No 4, 1957.

7. Neporent, B. S., Kiseleva, M. S., "Measurement of the Moisture Content of Gas Mixtures from IR Absorption Spectra," OPTIKA I SPEKTROSKOPIYA, Vol 16, 1964.

8. Neporent, B. S., Kiseleva, M. S., Fedorova, Ye. O., "Absorption of IR Radiation for an Unresolved Spectral Structure for Slant Paths in the Atmosphere (H_2O and CO_2 Effect)," IZV. AN SSSR, FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences, Physics of the Atmosphere and Ocean), Vol 3, No 6, 1967.

9. PSIKHROMETRICHESKIYE TABLITSY (Psychrometric Tables), Gidrometeoizdat, 1972.

10. Snopkov, V. G., "Correlation Between Atmospheric Water Vapor Content and Air Humidity Characteristics at the Earth's Surface," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 12, 1977.

11. Toropova, T. P., "Calibration Curves for Determining the Water Vapor Content in the Entire Thickness of the Atmosphere by the Spectral Method," ISSLEDOVANIYE ASTROKLIMATA I OPTICHESKIKH SVOYSTV ATMOSFERY KAZAKHSTANA. TRUDY ASTROFIZICHESKOGO INSTITUTA AN KAZ. SSR (Investigation of Astroclimate and Atmospheric Optical Properties in Kazakhstan, Transactions of the Astrophysical Institute Kazakh Academy of Sciences, Vol 4, 1963.

12. Fowle, F. E., "The Spectroscopic Determination of Aqueous Vapor," ASTROPHYSICAL JOURNAL, Vol 35, 1912.

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IDENTIFICATION OF METEOROLOGICAL SUMMARIES

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Abstract: The author proposes a new approach to solution of the problem of identification of meteorological summaries in the process of automatic processing of information passing through communication channels to an electronic computer. Since meteorological summaries are a component part of the language of transmission of meteorological data, which in turn is related to a class of context-free languages, an automatic unit is devised having a modular memory for applying an algorithm for the grammatical analysis of the constructions of meteorological communications.

[Text] The problem of identifying meteorological summaries passing through communication channels into electronic computers arose in connection with the acute need for machine preparation of information for the introduction of methods for numerical hydrodynamic forecasting of meteorological elements into operational practice. The first studies in the field of identification of summaries made it possible to discriminate from the total flow of information such data contained in surface synoptic and aerological telegrams necessary in forecasting [1, 2, 6, 7, 11, 12]. The most modern Soviet program for the identification and interpretation of meteorological information, described in [7], makes it possible to identify, interpret and accumulate synoptic data up to the moment of the forecast with one scrutiny of the flow of information. At the present time data are supplied for numerical forecasting precisely through this program.

There are also other applications of the problem of identifying meteorological summaries. For example, this includes the production of actual weather maps in an automatic regime. Although the results of the procedure of identification and interpretation of data in principle are one and the same for different applications, the different requirements imposed by operational technology in different cases (for example, feedout of the results at a real time scale) have led to the need to seek other approaches to the formulation of an identification program differing from those described in the already mentioned studies.

This study gives a new approach to the problem of identification of meteorological summaries, the simplest variant of which is now realized in the programming-instrument complex used at the USSR Hydrometeorological Center. It is based on use of the advances in mathematical linguistics, the theory of context-free languages, and makes it possible to make broad generalizations of the problem.

The need for preparing an ever-increasing volume of different types of information for numerical forecasting, the forming of considerable masses of data for scientific investigations on the basis of observational data sent through communication channels to an electronic computer (for example, GARP data), the problem of automatic plotting of synoptic charts and other operational (and nonoperational) materials -- all this requires improvement in the methods for the identification of meteorological summaries, writing of new algorithms and programs and devising of new technology for a system for the automatic processing of information. It appears that the approach to solution of the problem of identification of meteorological summaries described below in this paper will be useful for this purpose.

In accordance with the established procedure [8], a meteorological communication transmitted through the global telecommunication system should consist of the following elements: initial line, heading, text, end "signal." Example:

```
ZCZC 333  37435
UERS15 RUMS 010000
TTDD 0100/ 34172  11347  71343  22094  74147=
NNNN
```

Here the first line is the initial line; the second is the title; the last is the end signal.

The structure of the communication is described by the following scheme:

Initial line		Communication
Heading	Bulletin	
Text		
End signal		

However, for convenience in exposition we will modify these definitions and at the same time require that the text consist of individual phrases which henceforth will be called telegrams. Accordingly, the following revision of communication construction is proposed:

Initial line				COMMUNICATION]
Heading			BULLETIN]	
Telegrams		TEXT]		
End signal	END]			

We will somewhat refine the informal understanding of what a telegram is, specifically: we will assume that sometimes the sequence of telegrams within a communication can have a special construction of one line of teletype text which is common for all the telegrams situated below. For example, a line in the form MMXX 0212 for SYNOP telegrams [9]:

```
ZCZC 720  12304
SMIN10 DEMS 021200
MMXX 0212
43369  20000  96011  10426  22500  25914  40790=
43371  20000  96011  10725  15501  29910  40390=
NNNN
```

We will specially discriminate such a construction and call it the "common block." Source [10] gave a formal description of the common block and all the constructions mentioned above. Accordingly, here we will assume that the principal elements of the communication are the terminal symbols; we will use lower-case letters for writing them. Capital letters will be used for the defined concepts:

<COMMUNICATION>	: : =	initial line	<BULLETIN>	(1)
<BULLETIN>	: : =	heading	<TEXT>	(2)
<TEXT>	: : =	telegram	<TEXT>	
		| common block	<TEXT> | <END>	(3)
<END>	: : =	end signal		(4)

These definitions do not contradict those given earlier in [10]. However, the rule [3] allows a more complex construction of the communication -- with several common blocks. It is not difficult to give another rule for a text avoiding repetition of the common block. This is done by introducing the additional construction:

<TEXT>	: : =	common block	<TELEGRAMS>	(5)
<TELEGRAMS>	: : =	<END>	telegram<TELEGRAMS>	

Nevertheless, we will retain a more general construction of rule (3) because there are communications with several common blocks:

```
ztszts 032 9149512
tssra 12 runv 010800
klimat 11979
29789 9753 0324 1194 01412 0029/ 036// =
30037 9898 0232 1139 02011 00445 047// =
klimat 11979 2130
29789 8642 0186 1176 02107 0007/ =
30521 9603 0234 1142 01304 0013/ =
nnnn
```

Thus, we have determined a "grammar" which is automatic [3] or regular [5] because all its rules have the form $Z \to bY$ or $Z \to b$, where b is the terminal and Z and Y are nonterminal symbols. The COMMUNICATION is the noted initial symbol.

By means of the rules of derivation of (1)-(4) it is possible to obtain any final chains corresponding to properly formed communications.

On the other hand, there is a well-developed method for recognizing the correct parts of the language formally generated by the regular grammar [4].

We will recall, in accordance with [3], the definition of a "final automatic element" or "acceptor" with a finite number of states. The set of five symbols $[X, S, \nu, s_0, F]$ is an acceptor with a finite number of states.

Here X is a finite set of input symbols; S is a finite set of internal states; ν is a function of X x S into S; s_0 is the initial state; $F \subset S$ is the set of developing final states.

Such an automatic unit reads from the input tape the lines of the terminal symbols of some language and after reckoning the symbol $x \in X$ into the state s passes into the new state $\nu(x, s)$. After reading the last symbol, the automatic element stops. If it stops in one of the developing final states of F, the input line is received, but if the final state belongs to S - F, the line is rejected. Accordingly, it is usually said that these lines are "received" or "rejected" by an automatic element with a finite number of states.

As is well known [3], for any "automatic grammar" G there is a final acceptor accurately receiving those lines which G generates.

Small grammars and their corresponding acceptors are conveniently described by diagrams of state.

For this it is necessary that the following be satisfied:

Set the peak of the oriented graph in accordance with each nonterminal symbol from G. (6)
Set the arc from Z to Y, marked b, in accordance with each rule in the form $Z \to bY$. (7)
Set the arc from Z to the new peak RECEIVED, marked as in (7), in accordance with each rule $Z \to b$. (8)

Adhering to this algorithm and the rules (1)-(4), we will construct a diagram of the final acceptor, recognizing the correct communications (Fig. 1).

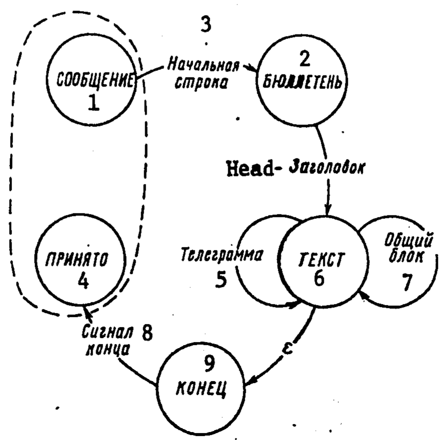

Fig. 1. Diagram of acceptor recognizing correct communications.

KEY:

1. Communication
2. Bulletin
3. Initial line
4. Received
5. Telegram
6. Text
7. Common block
8. Signal of end
9. End

As is known from [3], the sequence of marks of the arcs along any finite path, beginning from the peak s_0 (COMMUNICATION) on the diagram of the grammar G, is the line generated by G. The reverse assertion is also correct.

In such an interpretation of the operations of the automatic element it is assumed that someone sets the automatic element in the initial state and sends to its input the first symbol of the communication, for example, for the automatic element of a communications computer operating in circuits with a programmed control system in the MTK-5 code this can be the symbol SOH [8]. However, it is easy to visualize a more complex situation when no one has given attention to synchronization of the beginning of operation of the automatic element and the beginning of the communication. This occurs, for example, in circuits without reverse confirmation or in low-speed communication lines operating in the MTK-2 code. In addition, the real scheme for operation of the automatic element differs from that proposed in that it describes the recognition of an infinite chain of communications following one another through the communication channel. This means that after the final state RECEIVED the automatic element is again activated, being in the initial state COMMUNICATION. It actually identifies nothing between these two states because it is usually assumed that the input chain exists only from the initial state to the final stage and the chain does not exist in the cycle of transition from the final to the initial stage.

However, it can be assumed that this infinite input chain of communications exists in all the states of the automatic element and the automatic element itself moves along this chain from left to right in accordance with the possible transitions in the diagram.

For greater clarity in the operation of such an automatic element it is possible to propose the following change in the diagram: we will combine the final state (RECEIVED) and the initial state (COMMUNICATION), as indicated by the dashed line in Fig. 1.

It is obvious that the sequence of inscriptions along the possible finite paths, beginning and ending at the COMMUNICATION peak, corresponds to the sequence of communication lines. A set of such sequences corresponds to a set of communications present in the input chain. Thus, we obtained a transformation of a set of communications into a set of finite paths in the diagram, since in one communication there is only one common block, whereas on a finite path of the diagram there can be several of them.

In order to formulate an algorithm recognizing the lines of an infinite chain of communications it is also necessary to take another important detail into account -- the chain of communications is infinite both to the left and to the right. In other words, it constantly exists in time and the recognizing automatic element begins to operate at some arbitrary moment (for example, after ending of its operation). Therefore, the first arriving line is not mandatorily the initial line.

In addition, it must be taken into account that in the practical transmission of data through communication channels there will be different deviations from WMO rules. First of all, there are different errors in the preparation of data, then different commentaries or open texts between communications and also within telegrams. The errors in preparing data can be divided into two types. The first type of error is the omission of a construction, when a whole teletype line is absent. For example, the operator forgot to prepare the headings of the communication. The second type of error is a case when due to some circumstances the construction becomes ununderstandable. For example, the next-to-the last line in the communication:

```
ZCZC 169  16309
SMZM1  NSTU  110600
91765  33004  63011  08327  22532
QTA  QTA  A
NNNN
```

Thus, summarizing everything stated above, we obtain two types of deviation from the rules: presence of unidentifiable lines in the text and absence of some constructions.

Naturally, it is impossible to introduce any syntax for the unidentifiable lines. With respect to the absence of some constructions in the communication, this is easily described by the following rules:

<COMMUNICATION> : : = ε <BULLETIN>
<BULLETIN> : : = ε <TEXT>
<TEXT> : : = ε <END>
<END> : : = ε , where ε is an empty symbol

Combining these rules with the preceding ones (1)-(4), we obtain rules describing a part of the communication, and also the empty communications. In accordance with the algorithm for constructing the diagram using a regular grammar and taking into account the considerations concerning an infinite line, we can construct a new diagram. The chains of inscriptions along the paths through this diagram will correspond to the sequences of lines of communications in which the absence of some constructions is allowed. In addition, this diagram eliminates the problem of synchronization of activation of the automatic element and delivery of the initial line. In other words, the automatic element can begin the processing of an infinite line from any place to the right, provided that unexpected constructions do not appear.

Now we wish to allow in the initial line such constructions which were not provided for by the rules of the constructed grammar. In other words, we will allow commentaries between the constructions in an infinite chain of communications. For this purpose we will considerably complicate the automatic element, adding two new components to it: a memory and a counter.

Now we will assume that it is possible in some way to store, finish registry and erase the final chains in the memory. Any process of finishing of registry involves the splicing of a new chain with the old from the right. The erasure process relates to the right part of the chain in the memory; in place of the erased part there is a special chain in the memory -- the initial symbol for the memory. We stipulate more precisely that the non-empty chain in the memory consists of the initial line, heading and text; in addition, there is one initial memory symbol for the initial line -- ZCZC 333 ///// and one -- for the heading:
XXXX// XXXX /////.

The operation of an automatic element with a memory is characterized by cycles. The automatic element performs a series of cycles for each symbol in the input chain. Each cycle corresponds to a transition from state to state and some operation in the memory with the chain present there. This operation may be finishing of registry, erasure or both together.

Now we will describe the cycles of automatic element operation. As soon as the automatic element receives the new input symbol the counter assumes the value 4. Then if the result of analysis of the input symbol is negative we subtract unity from the counter and check the result; if the result is equal to zero, the input symbol is entered in the memory and we proceed to the next symbol in the input chain; if the result is non-zero, we register an empty symbol in the memory and change the state of the automatic element in accordance with the diagram (block diagram). Proceeding to a new state, the automatic element performs similar operations with the sole difference that the counter value has already decreased. Now we will assume that the result of analysis of the input symbol is positive or that the automatic element has identified this symbol. In such a case we must examine five variants corresponding to the principal elements of the communication (see [10]).

If the initial line is identified, then the entire chain in the memory is erased and two initial symbols are registered. The initial line is registered over the first initial symbol. The automatic element shifts into a state "Identification of Heading."

If the heading is identified, the right part is erased in the memory, beginning with the heading. Then the new heading is registered. The automatic element passes into the state "Identification of Bulletin Text." If a common block is identified, the entire text is erased and the common block is registered in its place. The state is not changed.

If the beginning of the telegram is identified, a special symbol is also registered in the memory -- the end of the telegram, when there is an unended telegram in the memory. Then the found telegram is completely registered. If, in the identified telegram the symbol for the end of the telegram is also found, there is a shift to the state "Identification of End." Otherwise the state is not changed.

If the end is found, the signal for the end is fully registered; then all the memory is emptied [4]. Thereafter, the first and second initial symbols are registered in it again and the automatic element passes into the initial state "Identification of the Initial Line."

Thus, we have described an automatic element with a memory and a counter.

We note that in place of a counter it suffices to have final entry of some four memory symbols, for example π; in place of subtraction of unity -- -- the erasure of the symbol farthest to the right; and in place of a reaction to zero -- reaction to the absence of this symbol in the memory.

Figure 2 is a diagram of the transitions of the considered automatic element. The symbols "π" in the diagram denote the procedure of erasure of the memory symbol π in the case of unsuccessful identification.

Now it can be seen that this automatic element cannot be "cycled" when processing an unfamiliar input symbol. Receiving such a symbol in any state, the automatic element makes all possible attempts at its identification. Finally this symbol is registered in the memory and the automatic element is returned to the initial state. Thus, the automatic element is not sensitive to the different commentaries between the communication constructions.

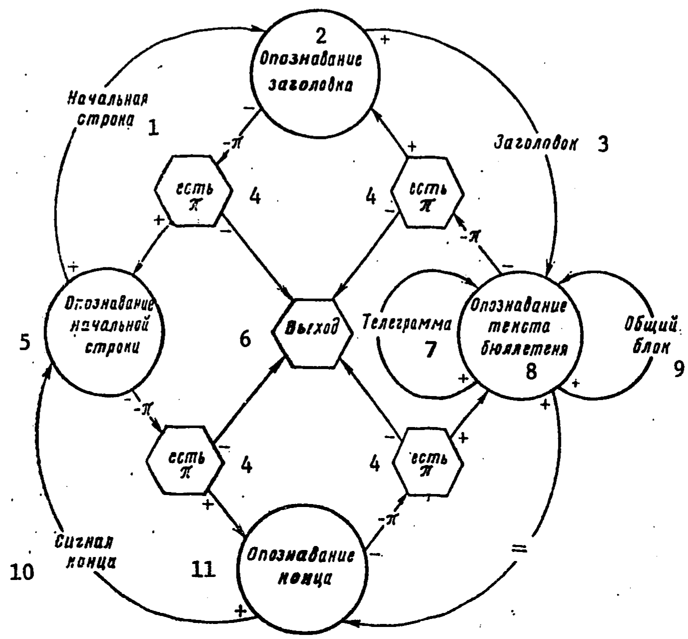

Fig. 2. Diagram of transitions for automatic element with memory.

KEY:

1. Initial line
2. Identification of heading
3. Heading
4. there is...
5. Identification of initial line
6. Output
7. Telegram
8. Identification of bulletin text
9. Common block
10. Signal for end
11. Identification of end

Thus, the automatic element correctly identifies any sequence of communication constructions, including arbitrary texts. As a result, on the basis of the input chain of communications, from parts of communications alternating with arbitrary texts, this automatic element constructs an output chain of properly formulated communications. To be sure, for many communications received in this way there is a coincidence of the initial lines or headings, but on the other hand, from the syntaxis point of view, they do not contain errors and they can be identified by the final automatic element which is constructed at the very beginning.

Therefore, we constructed a "determined" automatic element with a modular memory [4] which identifies any correctly formed communications and corrects communications with grammatical errors. It should be noted that for identification of correct communications it was sufficient to have a final automatic element.

Applicable to the processing of meteorological data reaching the electronic computer through communication channels, such an automatic element solves the problem of control of processing of communications (suitable for telecommunication methods) and control of processing of telegrams for systems for the primary processing of meteorological data. This automatic element is particularly useful in organizing the operation of a communications computer in a telecommunication complex accomplishing the automatic collection and transmission of data.

The basic principles for the design of an automatic element with a memory were successfully used in the primary processing system of a programming-instrument complex; the full construction of the automatic element was realized in FORTRAN IV for the primary processing system using a YeS electronic computer.

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BIBLIOGRAPHY

1. Belousov, S. L., "Automation of Processing of Operational Information of Aerological Stations in the Soviet Union," TRUDY MMTs (Transactions of the Moscow Meteorological Center), No 7, 1965.

2. Belousov, S. L., Gandin, L. S., Mashkovich, S. A., OBRABOTKA OPERATIVNOY METEOROLOGICHESKOY INFORMATSII S POMOSHCH'YU ELEKTRONNYKH VYCHISLITEL'NYKH MASHIN (Processing of Operational Meteorological Information Using Electronic Computers), Leningrad, Gidrometeoizdat, 1968.

3. Birkgof, G., Barti, T., SOVREMENNAYA PRIKLADNAYA ALGEBRA (Modern Applied Algebra), Moscow, Mir, 1976.

4. Ginzburg, S., MATEMATICHESKAYA TEORIYA KONTEKSTNO-SVOBODNYKH YAZYKOV (Mathematical Theory of Context-Free Languages), Moscow, Mir, 1970.

5. Gris, D., KONSTRUIROVANIYE KOMPILYATOROV DLYA TSIFROVYKH VYCHISLITEL'NYKH MASHIN (Designing of Compilators for Digital Computers), Moscow, Mir, 1975.

6. Kartasheva, M. V., Popova, T. V., "Principles for Constructing a Program for Sampling Synoptic Telegrams from a Common Flow of Meteorological Information," TRUDY GIDROMETTSENTRA SSSR (Transactions of the USSR Hydrometeorological Center), No 1, 1967.

7. Kastin, O. M., Semendyayev, K. A., SISTEMA PERVICHNOY OBRABOTKI METEOROLOGICHESKOY INFORMATSII (System for the Primary Processing of Meteorological Information), Moscow, Gidrometeoizdat, 1973.

8. NASTAVLENIYE PO GLOBAL'NOY SISTEME TELESVYAZI (Instructions on a Global Telecommunications System), No 386, Vol 1, Geneva, 1974.

9. NASTAVLENIYE PO KODAM (Instructions on Codes), No 306, Geneva, Vol 1, 1974.

10. Shmel'kin, Yu. L., "Formal Generating Grammar of a Language for Transmitting Meteorological Information," EKSPRESS-INFORMATSIYA (Express Information), Obninsk, VNIIGMI-MTsD, No 3 (51), 1977.

11. Bedient, H. A., Cressman, G. P., "An Experiment in Automatic Data Processing," MON. WEATHER REV., Vol 85, No 10, 1957.

12. Hinkelmann, K. H., "Automatic Data Processing of Synoptic and Upper Air Reports," WMO. Regional Training Seminar of Numerical Weather Prediction, Leningrad, Gidrometeoizdat, 1969.

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CLEARING OF WARM FOGS USING ARTIFICIAL HEAT SOURCES

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[Article by Candidate of Physical and Mathematical Sciences I. M. Zakharova, Institute of Experimental Meteorology, submitted for publication 15 November 1979]

Abstract: The author reviews the principal results of experimental and numerical study of the possibility of clearing of a warm fog using artificial heat sources. The article describes the thermal systems used in Japan, France (Orly and Charles de Gaulle airports) and in the United States at Vandenberg, Travis and Otis Air Force Bases. The review gives an analysis of the influence exerted by the produced heat on the clearing of a fog, the influence of the wind on the behavior of the warm current and its characteristics. The increase in the turbulence level as a result of the action of thermal systems is analyzed. The problems involved in evaluating energy expended on the scattering of a fog by the use of thermal systems are considered. The economic effectiveness of thermal systems for the scattering of a fog is demonstrated.

[Text] During recent years, when there has been a strong increase in the intensity of air traffic, the problem of finding successful methods for fog dispersal has become especially acute.

The thermal method is directed to the evaporation of fog droplets by an increase in temperature in the volume to be cleared by means of artificial heat sources. The systems scattering a fog must be compatible with automatic landing systems. With respect to conditions for visibility at the earth's surface the International Civil Aviation Organization (ICAO) has established three categories of complexity in executing an automatic landing: with respect to height there are three categories -- 60 m (category I), 30 m (category II) and 0 m (category III) and with respect to horizontal visibility -- 800 m (category I), 400 m (category II) and 200, 50 and 0 m (IIIA, IIIB and IIIC) [6]. Thermal systems are used in clearing a fog in cleared zones to the limiting (or greater) visibility ranges.

History of Development of Thermal Systems for Fog Dispersal

The first mention of the successful use of the thermal method for fog dispersal dates back to 1935 [14]. The practical use of this method began during the Second World War in Great Britain, where thermal systems called FIDO were installed at 15 airports. Fuel was fed through lines along the runways. This fuel was burned when it flowed through small openings in the pipes. By the end of the war 10,000 landings had been made using FIDO [33].

The FIDO system was developed further in the United States from 1946 through 1950. By the use of an improved FIDO system at the Arcata base it was possible to carry out aircraft landings with minimum visibility in dense fog in 94% of all the cases which were checked out [33]. However, due to the fact that no optimum variant had been developed for the placement of the burners and their intensity, in some cases it was not possible to disperse fog to the necessary visibility. As a result of the high cost of the thermal systems and their inadequate effectiveness, in 1953 the practical use of FIDO systems was abandoned. It was concluded by USAF representatives that the use of the exhaust heat of a jet engine can be more effective and economical than the use of the FIDO system [9]. We note, to be sure, that a system using jet engines in tests in Alaska gave no effect in the case of ice fogs [33].

In 1958 it was established that this technique can be used in the dispersal of warm fogs. Intensive tests carried out in the 1960's in France jointly by Bertain, Air France and Air Inter at Orly airport led to the creation of a system suitable for practical use of the system called the "Turboclair" [16, 17, 19, 20, 28, 32].

In 1968, in California, experiments were carried out by specialists at the Travis Air Force Base by the United States Weather Service using four military aircraft of the C-141 type [10, 12, 13], which once again demonstrated the possibilities of this method. However, it was noted that the clearings produced after the engines were cut off close in rapidly: visibility had already fallen to the initial level within two minutes.

In investigations of the thermal method carried out in the 1960's in Japan [5] particular attention was given to the construction of burners capable of complete combustion of a large quantity of propane gas at a high rate. Burners with a combustion of 2.5 kg of gas per minute were designed.

The most extensive series of tests of the thermal method for fog dispersal with the use of burners was carried out in 1972 in the United States in California at Vandenberg AFB under the direction of the Cambridge Research

Laboratory [22, 23, 27]. The purpose of the tests was the development of a thermal system based on the controllable merging of the heat from a stream of burners arranged in a definite order in order to obtain a uniformly heated mass of pure air over the airport runway. Model computations [21, 22] helped in detecting the optimum intensity and distribution of burners required for obtaining a clearing suitable for landings and takeoffs under different meteorological conditions. When carrying out field tests particular attention was devoted to an experimental determination of the optimum intensity and positioning of the burners, determination of the physical and dynamic properties of the formed clearings and clarification of the influence of meteorological conditions on the behavior of the warm current and its characteristics.

Early in 1973 the Cambridge Laboratory began investigations for the purpose of creating the prototype of an operational thermal system for the dispersal of fog at Travis AFB [29]. Serious climatic and meteorological investigations [33-35] were carried out which made it possible to ascertain the periods of the greatest frequency of fogs in this locality and the meteorological conditions characteristic for these periods, especially the most probable wind strengths and directions. A comparison of data on air traffic at Travis AFB with statistical data on fogs, as well as the cost of the dispersal system with the losses as a result of disruptions and the suspensions of flights made it possible to document the economic effectiveness of using a thermal system [29, 33].

The testing and adjustment of this system was to have been completed in five years. However, information appearing on the thermal system at Otis AFB [24] gives basis for assuming that the researchers of the USAF Geophysical Laboratory (earlier called the Cambridge Research Laboratory) have decided on a variant for the combined use of thermal and kinetic energy. Thermokinetic energy is created by the burners by the combustion of aviation fuel and the propulsion of a hot current by means of kinetic energy fans. In the course of testing of this system during 1978-1979 it was proposed that optimum parameters of the system be developed in dependence on meteorological conditions and studies be made of effectiveness of operation of the apparatus, the reliability of equipment operation and that the possibility of carrying out of repair work be checked. Upon successful completion of the tests the system for the dispersal of warm fogs will be installed at a United States Air Force base and will begin to operate in 1982.

Description of Thermal Systems Used and Results of Field Experiments

A thermal system for fog dispersal consists of four subsystems [29]: heat sources (burners or jet engines arranged in a definite way near the runway); fuel storage unit; system for distributing the fuel from the storage unit to the heat sources and a control-measuring system. The principal requirements imposed on the system as a whole and therefore on each of the subsystems are reliability and safety, absence of contaminants and efficiency.

We note that the thermal systems in Japan and in the United States at Vandenberg AFB had a purely research character. In France there is an operational system used in fog dispersal at Orly and Charles de Gaulle airports. The designs of the systems at Travis and Otis Air Force Bases are prototypes of operational systems.

Seven experiments were carried out in Japan in 1963 near Chitose airport. Five of these were in advective fogs of marine origin and two were in a radiation fog; there was a control experiment in the absence of fog [15]. The wind velocity in these experiments did not exceed 3 m/sec; the wind direction in advective fogs was always oblique to the runway. In a radiation fog there was a very weak wind with a velocity of about 1 m/sec; the direction, however, was parallel to the runway.

The fuel used was propane so that there would be complete combustion in the burners. The constructed burners were capable of complete combustion of 2.5 kg of gas fed under a pressure of 6 atm for 1 minute. A hundred burners were situated on either side of the runway for a distance of 500 m. The propane was stored in the liquid phase in 10 tanks, each with a capacity of 500 kg.

The experiments provided for the measurement of air temperature and humidity, wind direction and velocity, horizontal and slant visibility, concentration of droplets and their size distribution.

The experiments carried out in a fog indicated that with the operation of all burners for a period of 5 minutes the visibility improved in comparison with the initial level by a factor of two, from 100-400 to 250-800 m; the temperature increased by approximately 0.5°C; the relative humidity either decreased by several percent or remained constant; the concentration of droplets decreased by almost half; the maximum diameter of the droplets decreased from 45 to 35 μm.

Researchers attribute the observed decrease in the anticipated results of the modification first of all to a decrease in the rate of combustion due to a pressure drop in the storage tanks and second, to a wind direction oblique to the runway. These experiments enabled the authors to conclude that the thermal method for fog dispersal, with some improvements in the system, must be used.

The French "Turboclair" system [16, 17, 19, 20, 28, 32] consists of 12 jet engines placed at 80-m intervals in the landing zone, then 120 m along the runway. Each engine is situated in its own underground chamber, covered by a heavy cast iron grating in order to ensure safety during the landings of aircraft. The heat from the engine exhaust pipe is directed toward the surface through a vertical channel where the hot gases by means of reflectors are directed toward the runway. The fuel is fed to all the engines from a single tank buried in the ground at some distance from the runway. Each engine is supplied with an automatic firing device and remote control. The latter corrects the heat being produced and orientation of the reflectors.

The engines can be fired both individually and all simultaneously. When the jet engine is operating at full power the escape velocity of the hot gas is about 500 m/sec at a temperature of about 500°C [32] (about 600°C [20]). However, diffusing and mixing with the surrounding unheated air, the hot gases increase the temperature of the space occupied by the fog by 2-3°C, which is entirely adequate for the evaporation of droplets. The apparatus was capable of improving visibility from a point situated approximately 600 m from a landing point, and then for a distance of 600 m along the runway and guaranteed the successful completion of a landing in categories II and IIIA in an instrument approach.

In order to clear a fog over a runway five minutes must elapse from the time when the engines are started. With a decrease in engine power to operation at an idle the visibility deteriorates and after 1.5 minutes its background level is restored.

The greatest shortcoming associated with the use of jet engines as heat sources in a system scattering a fog is the great turbulence of the lower layer of the atmosphere with a thickness somewhat greater than 15 m. The turbulence exerts a strong influence on small aircraft and also on systems for automatic landing. For example, the Sud Ler automatic landing system used in Air Inter aircraft was very sensitive to turbulence.

The "Turboclair" system was discussed by three persons. According to [33], the installation of a "Turboclair" system cost 3 million dollars and its operation cost about $3,400 per hour.

The thermal system at Vandenberg base [21-23, 25] had a purely research character and therefore the carrying out of the tests was planned with minimum expenditures directly on the thermal system and with great capital investment on the instrumental outfitting of the experiments. The system consisted of four parallel lines of liquid propane burners oriented perpendicular to the prevailing wind direction. Liquid propane was fed to all 213 burners from four tanks with a capacity of 22,500 liters each. The burners were of different size.

The heating system must create a clearing of the fog when there is a considerable wind in the range 1.5-4.5 m/sec in a region with a width of 120 m and a height up to 60 m in the neighborhood of the instrument tower.

In order to investigate the influence of the produced heat and the positioning of the burners on clearing of the fog the design of the system provided for the possibility of shutting off the individual burners and combining burners into groups of four.

The control-measuring system consisted of a 60-m instrument tower, two control towers on the windward and leeward sides of the line of burners and a lidar. The instrumentation installed on the towers made it possible to measure temperature, dew point, wind velocity and direction, vertical component of wind velocity, visibility, liquid-water content of a fog and the droplet-size distribution. Using a lidar it was possible to determine visibility profiles in the entire extent of the warm current and also the distribution of visibility in the cross section of the current. During a six-week field program measurements were made in 14 fogs, in five of which 43 experiments were carried out with dispersal and 96 checks were carried out in the pure air. The duration of each experiment was 10-15 minutes.

The experiments carried out at Vandenberg Air Force Base with thermal modification of a fog when there was a wind intersecting the runway enabled the researchers to draw some important conclusions.

In a case when the wind component intersecting the runway is greater than 1.5 m/sec it is sufficient to have one line of burners on the windward side in order to create the necessary improvement of visibility over the runway. When the velocity of the wind intersecting the runway is less than 1.5 m/sec it is necessary to place the burners along the sides of the runway, as was done in the FIDO system, or to create a mechanically moving thermal system.

The clearings created by the experimental system, as a result of the incomplete evaporation of fog droplets due to the spatially nonuniform movement of warm currents, were characterized by high-frequency fluctuations of visibility. However, the fog patches situated in the cleared region should not seriously worsen the pilot's view when coming in for a landing.

The degree of clearing is highly dependent on the heat intensity. In field experiments it was possible to create conditions corresponding to automatic landings of categories of complexity II and IIIA. Landing conditions of category I can be achieved with an increase in the heat produced by the burners by a factor of 2.1 in comparison with the necessary heat for a category II landing and by a factor of 3.5 in comparison with a category III landing.

The wind velocity exerts a substantial influence on the vertical distribution of heat. With an intensification of wind velocity the current becomes thinner and is bent toward the earth. With wind velocities greater than 2 m/sec the maximum temperature increase occurs at the earth. With $V < 1.5$ m/sec the warm currents rather rapidly rise upward and the maximum is at higher levels. With wind velocities between 1.5 and 2 m/sec the maximum clearing was above the earth, but a considerable improvement in visibility was also observed at the ground level. With winds greater than 4 m/sec the upper boundary of the current did not attain 60 m with the available heat.

The efficiency of the experimental thermal system was considerably lower than 100% because, first of all, a greater quantity of heat is required in order to evaporate the droplets in the required time, and second, the produced heat is propagated nonuniformly in space. The turbulence generated by the thermal system is of the same order of magnitude as that measured at hot summer midday and therefore it should not create any difficulties during aircraft landings and takeoffs.

Energy and Economic Expenditures on Fog Dispersal Using the Thermal Method

The quantity of heat which must be introduced into some volume in order to evaporate fog droplets and prevent the reverse condensation of water vapor can be computed as a function of the liquid-water content of the fog and ambient temperature. However, the values obtained in this case will be minima [33], since, first of all, in actual practice it is necessary that although the fog droplets need not necessarily be evaporated completely, it must be done rapidly. Second, with the combustion of fuel an additional quantity of vapor enters the air and at a constant temperature this increases relative air humidity. Third, the computations are made on the assumption of a uniform spatial distribution of heat. All this increases the quantity of heat required for clearing a particular volume. The actual quantity of heat which the thermal system must generate must be still greater in order to compensate the heat losses due to wind velocity and edge effects. In theoretical evaluations of the required energy expenditures it is possible to take into account the influence of the water vapor formed during fuel combustion and the wind, but the influence of the non-uniformity in the distribution of heat and heat losses due to edge effects cannot be evaluated on a practical basis. Accordingly, a final evaluation of the energy expenditures can be obtained only experimentally.

As a comparison, the table gives the energy expenditures in an operational thermal system capable of improving visibility to operational levels according to the estimates of different authors (scaled to kerosene, whose heat-generating capacity is 10^4 cal/g). The energy expenditures pertaining to the systems installed at the Orly and Los Angeles airports represent the real expenditures. It must be noted that the system installed at Los Angeles is old (1949), a slightly improved "FIDO" system. Evaluations of the energy expenditures published in [33] and [15] were based on earlier experimental investigations.

In order to evaluate the economic effectiveness of the thermal system it is necessary to compare the total cost of the system (including the cost of its operation) and the losses which are experienced by the airport at which the particular system is installed due to the closing-in of a fog, for example, in the course of a year. The annual cost of system operation must include amortization costs, costs of repair and fuel. In order to estimate the cost of the fuel expended by the system in the course of a year it is necessary to know the number of hours of system operation annually. This requires a determination of the number of flights affected annually by a fog. Thus, an evaluation of the economic effectiveness must be preceded by investigations of meteorological conditions at the airport, analysis of the air traffic schedule and evaluation of the cost of the system (capital investments, expenditures on installation and adjustment of the system).

The authors of [11, 29, 33-35] established the cause-and-effect relationships between the appearance of a fog and the decrease in air traffic and determined the number of flights influenced by fog at Travis AFB [33],

Table 1

Energy Expenditures on Operational Thermal System According to Evaluations of Different Authors

Operational systems	Power of system, Cal/hour	Rate of fuel expenditure, tons/hour	Fuel expenditure per landing (5 minutes), tons	Cleared volume, m^3	Remarks
FIDO system in Los Angeles [31]	$3.15 \cdot 10^9$	315	26.3	--	
According to estimates in [15]	$1.1 \cdot 10^9$	108	9	$2.5 \cdot 10^7$	Category I landings
Planned according to estimates in [33]	$2.5 \cdot 10^9$	250	21	$9 \cdot 10^6$	Category I landings. Weak and parallel winds
Installation at Orly [32]	$2.1 \cdot 10^8$	21	1.8	$5 \cdot 10^6$	Category II landings

at 15 air force bases in Europe and America and at the civilian airport in Los Angeles (LAX) [34,35] and at 41 civilian airports in the United States [11]. It was found that a fog affects 0.8-2% of the flights in the United States and 5-7% of the flights in Europe in an average fog year. Since a fog is a seasonal phenomenon, in months with the greatest frequency of occurrence of a fog from 5 to 15% of the flights are subjected to its influence in an average fog year and more than 40% in an extremely foggy year.

Source [29], giving the results of investigations published in [11, 33, 35], presents an evaluation of the economic effectiveness of the thermal system for the large civilian airport LAX. The planned installation cost for the thermal system was 6.5 million dollars. The annual cost of operation of the system, including amortization costs (10%), repair (1%) and fuel was 1.465 million dollars in 1973 and will be 1.627 million dollars in 1981. The annual losses due to disruption of air traffic were 8.0 million dollars in 1973 and will increase to 24.0 million dollars in 1981. Source [29] gives a comparison of the average cost per aircraft for operation of the system and the average losses per aircraft. The ratio of these figures is 1 to 6 in 1973 and 1 to 20 in 1981.

According to the estimates [11, 29], the losses in annual income by transport aircraft (first and second levels) at 41 main airports in the United States as a result of fogs were 25.5 million dollars in 1971 and will be about 93.2 million dollars in 1981.

Comparing the fuel expenditure by the system for the assistance of one aircraft with the rate of fuel expenditure by an aircraft in flight, the authors of [29] demonstrate the fuel saving due to use of a thermal system. For example, aircraft of the Boeing-747 type, being detained in landing for more than 35 minutes, expend more fuel than the thermal system expends per one landing.

Thus, the use of thermal systems at airports with a high volume of air traffic will make it possible to improve the operation of airports, reduce economic expenditures, save fuel and increase flight safety.

Numerical Modeling of Thermal Modification

The field experiments which have been made indicated that the discrete positioning of heat sources around the region to be cleared, wind strength and direction exert an appreciable influence on the heat distribution in the clearing volume. Another important conclusion from the field experiments is that inverse relationships are involved: an influence of the produced heat on the background characteristics, such as an increase in turbulence in the lower layer of the atmosphere and an intensification of the wind by 30-35% near the ground (at the level 6 m) and by 10% at the level 60 m [22]. Under real conditions it is necessary not simply to scatter the fog, but disperse it in a relatively short time so that an aircraft in the course of

5 minutes can make a takeoff or a landing. These experiments indicate that during the course of this time interval the process is essentially nonstationary.

Thus, in order for the physicomathematical models describing the process of a thermal effect on fogs to approach real processes it is necessary to solve the nonstationary spatial problem, taking into account inverse relationships and the discreteness of positioning of sources.

At the present time we can mention only a few studies [1-4, 8, 21] in which by the use of simplified models the authors examine different aspects of the thermal modification method. Closest to field experiments are descriptions of the thermal modification method in [21, 30]. The physicomathematical models themselves are not given in these publications.

A model study of the thermal modification method [21], preceding field experiments in the United States at Vandenberg AFB, made it possible to select the geometry of the system (positioning of the lines of burners, spacing between burners) and the intensity of the heat sources. The numerical modeling was based on a stationary model of the rising of the heat current. The principal assumption made in the model was that there is a uniform distribution of temperature, humidity and liquid water content in the cross section of the current and retention of mass, momentum and buoyancy along the current trajectory. In the computations the trajectory of the current, its radius, and mean temperature, humidity and liquid-water content were determined in the cross section. The formulated model was used in studying the influence of intensity of the burners, the spacing between burners, and wind velocity on the position of the central line of the current (trajectory). A comparison of the results of computations with the experimental data indicated that the model reproduces the position of the current, that is, its trajectory, quite well. However, the assumptions made did not make possible a correct reproduction of the influence of the produced heat on the surrounding fog.

The numerical model of dispersal of fog by means of burners presented in [30] is based on a two-dimensional nonstationary model of a convective cloud developed by Murray [25, 26]. This model, as is noted in [30], was improved by the introduction of a vertically nonuniform grid, variable coefficients of turbulent viscosity and some other small refining details. This model was employed in investigating the influence of the produced heat and the positioning of the lines of burners on heat distribution in the volume to be cleared. Numerical experiments were carried out with one row of burners with a wind intersecting the runway and with two rows of burners under windless conditions. The influence of wind velocity, initial temperature, liquid-water content of a fog and its thickness on fog dispersal was checked.

In the case of a wind intersecting the runway the wind was stipulated constant with height. The computation results indicated that with an intensification of the wind the height to which heat is propagated decreases.

Neither changes in the mean temperature (from 7.5 to 15°C) nor its profile (isothermal to dry-adiabatic) exert a significant influence on heat propagation from a row of burners in a case of a wind intersecting the runway. With an increase in the liquid-water content of the fog the zone of fog dispersal decreased. For the evaporation of droplets with an increase in liquid-water content from 0.1 to 0.2 and 0.4 g/kg the increase in heat expenditure was 22, 34 and 51% respectively. With an increase in fog intensity in short distances (up to 100 m) no differences were observed on the leeward side of the line of burners.

A study was made of the advantages of using two rows of burners in comparison with one row (with one and the same total intensity). In a comparison of the results it was found that the heat from one row of burners was propagated more rapidly in a vertical direction. The only advantage from the use of two rows of burners was an intensification of fog dispersal at the ground.

In the numerical modeling of windless conditions there was found to be an air circulation with ascending movements above the lines of burners and descending movements between them. Such a circulation, on the one hand, favored the movement of the fog layer from the region over the runway to the warm current created by the burners, as a result of which the space over the runway was cleared; on the other hand, a constant inflow of fog from the surrounding space was created. The results of the computations revealed that under windless conditions the decisive role is played by the intensity of the heat sources, since with a decrease in the intensity of the lines of burners, although the form of circulation virtually did not change, ascending and descending currents with a weak intensity did not create a convergent flow necessary for eliminating the entire fog from the zone over the runway.

Fog dispersal is also dependent on the distances between the lines of burners. With increasing distance of the lines of burners from the runway there is a decrease in the interaction of the circulations created by the sources. Since in this case there is no warm flow over the runway, the fog is dispersed only as a result of outward transport, which is ineffective.

The influence of atmospheric stratification on heat distribution in the zone over the runway under windless conditions is greater than when a wind is present.

The results of computations using this model qualitatively correctly reflect the physics of the process, but the study gives no quantitative comparison with the experimental results.

Not one of the studies [1-4, 8] reflects the real physical conditions when using the thermal method for fog modification and nevertheless they unquestionably are of theoretical interest because they are directed to an investigation of individual aspects of a complex process, a clarification of some physical laws in the thermal method for fog modification.

In [8] the model is stationary; it does not take inverse relationships into account; a heated surface is used as the heat sources. After analyzing the restructuring of the temperature and humidity fields in special examples, the authors of [8] note that there is some combination of conditions which is the most favorable from the economic point of view.

The effect exerted on the process of cooling of the atmospheric boundary layer for the purpose of preventing a fog in [4] and on a fog in [3] is considered within the framework of one-dimensional closed models. Allowance for the inverse relationships in these models made it possible to demonstrate that some of the energy generated by the heat sources is expended on atmospheric turbulence: the coefficient of turbulent exchange increases by an order of magnitude. In analyzing the influence of height of positioning of the source and its intensity, it is noted in [4] that in each specific case there is an optimum combination of these parameters from the point of view of more economical use of heat.

Studies [1, 2] were devoted to development of a method for computing the spatial change of meteorological fields when a fog is modified by a thermal point source applicable to a model of a stationary radiation fog. The thermal modification effect is investigated using the results of computations. Field perturbations are analyzed and the effectiveness of the thermal effect on a fog is evaluated. As in [4], the authors of these studies note the existence of the optimum height at which the maximum modification effect is attained.

Summary

All the investigations carried out in the world in the course of 30 years indicate that thermal systems are capable of dispersing a warm fog over a runway to the operational level.

The use of jet engines or burners as heat sources has its positive and negative aspects. The use of jet engines generating both thermal and kinetic energy makes it possible to obtain a more uniform heat distribution over the runway. However, strong artificial turbulence, caused by jet engines in the lower layer of the atmosphere, causes additional difficulties during the landing of relatively light aircraft and has a negative effect on especially sensitive automatic landing systems. In addition, a system using jet engines for the time being is capable of creating a clearing in a fog not higher than the conditions corresponding to an automatic landing of categories II and IIIA.

When using burners as the heat sources the created artificial turbulence does not cause additional difficulties during the landings of any aircraft. However, in this case another problem arises -- the problem of achieving a uniform heat distribution in the volume being cleared. In this case the geometry of the system and the intensity of the sources are highly dependent on meteorological conditions.

The proposal by Doctor W. Vickers (modification team of Mitre Corporation) [32] on the simultaneous use of four jet engines and 75 propane burners is interesting from the point of view of making use of the positive qualities of each type of heat source. The principal function of the engines should be movement of the warm air, although they will also serve as additional heat sources. Another approach is the generation of thermokinetic energy by means of burners, as, for example, in the MAT (Momentum Augmented Thermal) [36] system and in the thermal system at Otis Air Force Base [24].

These investigations indicated that the energy efficiency of the thermal systems is considerably less than 100% due to the nonuniform distribution of heat in the volume to be cleared, heat loss as a result of the wind and edge effects, and also due to the fact that a heat excess is always required in order to clear a fog during a quite short time interval. In order to increase the efficiency of the thermal system it is necessary to seek methods for a more uniform heat distribution in the volume to be cleared and to reduce losses due to edge effects.

In order to create and develop an operational thermal system dispersing fog to an operational level, for selecting its optimum operating regime and evaluating the necessary energy expenditures, in each specific case it is necessary to carry out field experiments in a specially equipped polygon.

The creation of physicomathematical models capable of reproducing a full-scale experiment adequately well would assist in working out an optimum regime of the thermal system with different external conditions, including not only background meteorological fields, but also fog characteristics.

BIBLIOGRAPHY

1. Andreyev, V. M., "Evaluation of the Effectiveness of Fog Modification by a Thermal Point Source," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 6, 1978.

2. Andreyev, V. M., "Perturbation of Meteorological Elements in the Surface Layer of the Atmosphere Using Regulated Effects," Author's Summary of Dissertation for Award of the Academic Degree of Candidate of Physical and Mathematical Sciences, London, 1978.

3. Buykov, M. V., Khvorost'yanov, V. I., "Modeling of Artificial Modification of a Radiation Fog Using the Thermal Method," TRUDY UkrNIGMI (Transactions of the Ukrainian Scientific Research Hydrometeorological Institute), No 161, 1978.

4. Zakharova, I. M., "Modification of the Process of Formation of a Radiation Fog Using Artificial Heat Sources," TRUDY IEM (Transactions of the Institute of Experimental Meteorology), No 12 (31), 1976.

5. Kachurin, L. G., FIZICHESKIYE OSNOVY VOZDEYSTVIYA NA ATMOSFERNYYE PROTSESSY (Physical Principles of Modification of Atmospheric Processes), Leningrad, Gidrometeoizdat, 1973.

6. Kerber, L. L., KOMPONOVKA OBORUDOVANIYA NA SAMOLETAKH (Layout of Instrumentation Aboard Aircraft), Moscow, Mashinostroyeniye, 1976.

7. Polovina, I. P., VOZDEYSTVIYE NA VNUTRIMASSOVYYE OBLAKA SLOISTYKH FORM (Modification of Air-Mass Stratiform Clouds), Leningrad, Gidrometeoizdat, 1971.

8. Simonov, V. V., Nikandrova, G. T., "Evaluations of Energy Expenditures in Fog Dispersal Over an Artificially Heated Zone," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 262, 1971.

9. Solov'yev, A. D., "Fog Dispersal at Positive Air Temperatures," TRUDY TsAO (Transactions of the Central Aerological Observatory), No 65, 1965.

10. Accola, J. P., "Breaking the Fog Blanket. The AWS Entry into Weather Modification," THE MAC FLYER, Vol 15, No 9, 1968.

11. Anonymous. "Potential Economic Benefits of Fog Dispersal in the Terminal Area. Reports FAA-RD-71-44-1 (Part I) and FAA-RD-71-44-11 (Part II). FINAL REPORT TO DEPT. OF TRANSPORTATION, Washington, D. C.

12. Appleman, H. S., FIRST REPORT OF THE AIR WEATHER SERVICE. WEATHER MODIFICATION PROGRAM. TECHNICAL REPORT 203, April 1968.

13. Appleman, H. S., Coons, F. G., "The Use of Jet Aircraft Engines to Dissipate Warm Fog," J. APPL. METEOROL., Vol 9, No 3, 1970.

14. Brooks, C. F., WHY THE WEATHER? London, 1935.

15. Choji Magono, "A Warm Fog Dissipation Experiment Utilizing Burning Propane Gas," J. DE RECHERCHES ATMOSPHERIQUES, Vol VI, No 1-2-3, 1972.

16. Cot, P. D., Serpolay, R., "Les recherches de dissipation thermique des brouillards realisees a l'aeroport d'Orly," J. RECH. ATMOSPH., Vol 2, No 2-3, 1966.

17. "Defoggers and Defrosters Keep Airports Open in Bad Weather," PRODUCT ENGINEERING, Vol 40, No 16, 1969.

18. Downie, C. S., Smith, B. B., "Thermal Techniques for Dissipating Fog from Aircraft Runways," AFCRL-TN-58-477, AIR FORCE SURVEYS IN GEOPHYSICS, No 106, 1958.

19. Facy, L., "Fog Dispersal Physical and Technological Aspects," PROCEEDINGS OF THE WMO/IAMAP SCIENTIFIC CONFERENCE ON WEATHER MODIFICATION, Tashkent, 1-7 October 1973. WMO No 399.

20. "French Fog Dispersal System Tested," AVIATION WEEK AND SPACE TECHNOLOGY, Vol 28, 1974.

21. Kunkel, B. A., Silverman, B. A., Weinstein, A. I., Price, C., "The Design of an Efficient Thermal Fog Dispersal System for Airports," THIRD CONF. WEATHER MODIFICATION, Rapid City, S. D., Amer. Meteorol. Soc. June 26-29, 1972.

22. Kunkel, B. A., Silverman, B. A., Weinstein, A. I., "Thermal and Chemical Fog Dissipation -- Results of Field Experiments at Vandenberg AFB, California, During July 1972," AFCRL-TR-73-0502, ENVIRONMENTAL RESEARCH PAPERS No 454, 1973.

23. Kunkel, B. A., Silverman, B. A., Weinstein, A. I., "An Evaluation of Some Thermal Fog Dispersal Experiments," J. APPL. METEOROL., Vol 13, No 6, 1974.

24. Kunkel, B. A., "The Design of a Warm Fog Dispersal System," SIXTH CONF. ON PLANNED AND INADVERTENT WEATHER MODIF., Oct. 10-13, 1977, Champaign-Urbana, Illinois, Boston, 1977.

25. Murray, F. W., "Numerical Models of a Tropical Cumulus Cloud With Bilateral and Axial Symmetry," MON. WEATHER REV., Vol 98, 1970.

26. Murray, F. W., Koenig, L. R., "Numerical Experiments on the Relation Between Microphysics and Dynamics in Cumulus Convection," MON. WEATHER. REV., Vol 100, 1972.

27. Rogers, C. W., Mack, E. J., Pilie, R. J., "Experimental Test of Fog Clearing by Ground-Based Heating-Visibility, Temperature and Fog Microphysics," AFCRL-TR-73-0056, Calspan Corporation, Buffalo, N. Y., 14221, Scientific Rep., No 1, Dec 1972.

28. Sauvalle, E., "Operational Fog Dispersal Systems at Orly and Charles de Gaulle Airport Using the Turboclair Process," PROCEEDINGS OF THE SECOND WMO SCIENTIFIC CONFERENCE ON WEATHER MODIFICATION, Boulder, Colorado, 2-6 Aug., 1976.

29. Silverman, B. A., Weinstein, A. I., "Design of a Modern Thermal Fog Dissipation System for Airports," PROCEEDINGS OF THE WMO/IAMAP SCIENTIFIC CONFERENCE ON WEATHER MODIFICATION, Tashkent, 1-7 October, 1973.

30. Tag, P. M., "Dissipation of Fog Using Passive Burner Lines: Numerical Sensitivity Experiments," SIXTH CONF. ON PLANNED AND INADVERTENT WEATHER MODIF., Oct. 10-13, 1977, Champaign-Urbana, Illinois, Boston, 1977.

31. Tschupp, E. J., "Economic Considerations in Fog Dispersal," SECOND NATIONAL CONFERENCE ON WEATHER MODIFICATION OF THE AMER. METEOROL. SOC., April 6-9, 1970, Santa Barbara, California.

32. "Warm Fog Dispersal Technique Studied," AVIATION WEEK AND SPACE TECHNOLOGY, Vol 99, No 9, 1973.

33. Weinstein, A. I., "Thermal Warm Fog Dissipation -- Heat Requirements and Projected Utilization of a System for Travis AFB, California," AFCRL-TR-73-0367, 18 June 1973, AIR FORCE SURVEYS IN GEOPHYSICS, No 270.

34. Weinstein, A. I., "Projected Utilization of Warm Fog Dispersal Systems at Several Major Airports," J. APPL. METEOROL., Vol 13, 1974.

35. Weinstein, A. I., "Projected Utilization of Warm Fog Dispersal Technology at Major Airports," SIXTH CONFERENCE ON AEROSPACE AND AERONAUTICAL METEOROLOGY, November 12-15, El Paso, Texas, 1974.

36. Weinstein, A. I., "Fog Dispersal: A Technology Assessment," J. AIRCRAFT, Vol 14, No 1, 1977.

37. Weinstein, A. I., Kunkel, B. A., "Fog Dispersal -- an Operational Weather Modification Technology Today," PAPERS PRESENTED AT THE II WMO SCI. CONF. ON WEATHER MOD., Boulder, Colo., 2-6 Aug 1976, WMO, No 443.

REVIEW OF MONOGRAPH BY YE. G. POPOV: GIDROLOGICHESKIYE PROGNOZY (HYDROLOGICAL FORECASTS), LENINGRAD, GIDROMETEOIZDAT, 1979, 256 PAGES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 p 116

[Article by Candidate of Technical Sciences G. N. Ugreninov]

[Text] Eleven years have elapsed since publication of the textbook by Ye. G. Popov entitled OSNOVY GIDROLOGICHESKIKH PROGNOZOV (Principles of Hydrological Forecasts). During this time there was considerable development of hydrological forecasting methods, there is much more initial information and electronic computers have been extensively introduced into the hydrological forecasting service. All these changes are reflected in the new edition of the book.

As in the preceding edition, the textbook is intended primarily for students at hydrometeorological technical schools. In this connection the author has striven for maximum simplicity and care in exposition, emphasizing solution of the most typical prognostic problems. At the same time it should be stressed that the advanced methodology of the author and universality of the presented material broaden the framework of the textbook and constitute a basis for its access to a broader circle of readers, especially to students at colleges and to professional hydrologists.

The undeviating increase in the level of theoretical training of students enabled the author to include in the book information favoring the formation among readers of a materialistic perception of natural phenomena and human activity (for example, see the section "The Regular and Random in Hydrological Forecasts"). Entirely justifiable is the inclusion in the book of a new chapter entitled "General Problems in the Theory of Formation and Computation of Melt and Rainwater Runoff." The joint examination of the most important hydrological processes in the formation of runoff makes it possible to clarify the general regularities in natural phenomena.

The problem of the use of electronic modeling devices is dealt with more specifically in the new edition of the textbook, although this aspect of activity of the hydrological forecasts could have been devoted somewhat more attention. Taking into account the modern approach to methods for carrying out a water inventory, we can only welcome the supplementing of the textbook with material on the storage of data on technical carriers.

The exercises cited at the end of the chapters will be of great profit to students, especially those engaged in correspondence study, but also to specialists independently studying the subject. The problems formulated in the exercises cover the most important variants of application of the methods described in the corresponding chapters and therefore instructors can use these exercises as a basis for carrying out laboratory exercises with students.

As a comment relative to the completeness of the presented material it is possible to mention lack of information on forecasts on the basis of aerospace information. To be sure, such forecasts to a large extent are a matter of the future, but already accumulated experience merits attention and popularization.

Like the other books by Ye. G. Popov, the textbook is characterized by reproachless logic in exposition, rigorously checked terminology and good literary language. The textual material is well supported with corresponding tables and graphs. The extensive appendices make it possible to use the textbook as a reference manual for carrying out many types of work in operational forecasting. The inclusion of a subject index in the new edition is very useful; it facilitates the search for information, especially in the independent study of the course and in preparation for examinations.

The successful printing quality of the book should also be mentioned.

There is every basis for assuming that the new edition of GIDROLOGICHESKIYE PROGNOZY will have a broad circle of readers interested in hydrometeorological problems.

REVIEW OF MONOGRAPH BY YU. I. CHIRKOV: AGROMETEOROLOGIYA (AGROMETEOROLOGY), LENINGRAD, 1979, 320 PAGES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 116-118

[Article by Candidate of Geographical Sciences M. S. Kulik]

[Text] During recent years several monographs, hundreds of articles and dozens of methodological instructions have been published with exposition of the results of agrometeorological investigations made over the course of recent decades and with generalization of achievements in the agrometeorological support of agriculture.

The author of the textbook AGROMETEOROLOGIYA (Agrometeorology) was faced with an extremely difficult task: within the bounds of a restricted volume (20 printer's pages) set forth the principles of meteorology, weather forecasting, climatology, agrometeorology and agroclimatology.

It is particularly difficult to discriminate from the enormous volume of diversified material on agrometeorology that which is most important and do so with the maximum brevity, clarity and care. The author of the textbook was able to do this.

The textbook gives a concise but clear characterization of the atmosphere, radiant energy in the atmosphere and at the earth's surface; the thermal regime of the air and soil is described; data are given on water vapor in the atmosphere, precipitation, snow cover, soil moisture, wind, weather and its prediction. All the mentioned meteorological factors are examined relative to their importance for agricultural production.

A total of 144 of the 320 pages are devoted to agrometeorology. The textbook contains chapters devoted to meteorological phenomena dangerous for agriculture, climate and its importance for agricultural production, agrometeorological observations, use of their data in production and field experiments, agrometeorological forecasts and agrometeorological support of agricultural production.

The textbooks published earlier for students at higher agricultural institutes could not contain the advances in the development of agrometeorology during recent years. Some textbooks (V. I. Vitkevich) have introduced confusion in the definition of the subject of agrometeorology, arbitrarily interpreted the tasks of agrometeorology and extremely poorly taken into account experience in agrometeorological support of agriculture. Yu. I. Chirkov, having much experience in research work in the field of agrometeorology and experience in routine agrometeorological support of agriculture, has created a textbook taking into account the present status of agrometeorological science and the requirements on it imposed by agricultural and planning organizations.

In 1975 a general agreement was concluded between the Main Administration of the Hydrometeorological Service (now the USSR State Committee on Hydrometeorology and Environmental Monitoring) and the USSR Agriculture Ministry on mutual obligations with respect to hydrometeorological servicing of the agricultural industry. The textbook was prepared with this agreement taken into account.

A definition of the subject of agrometeorology is given in the introduction. It can cause no objection. It gives the laws on which agrometeorological science is based. But they are not all illustrated by examples. For example, the essence of the optimum law is not explained, although it was possible to cite certain results of a two-factor experiment in which the following corn yield increments were obtained (grain, centners/hectare): from fertilizers without irrigation -- 5; from irrigation without fertilizers -- 32; from the application of fertilizers and irrigation -- 67, that is, environmental factors exert their influence to the greatest degree when operating jointly, since they not only supplement one another but also interact rigorously with one another.

In examining the principal tasks of agrometeorology the author has not dwelt on the special importance of agrometeorological support of agriculture in the Nonchernozem zone.

It is noted in the subsection entitled "Principal Stages in the History of Agrometeorology" that the Russian Agrohydrometeorological Institute was organized in 1932. But not a word is said about the organization of the Central Scientific Research Institute for the Study of Droughts and Drying Winds or about the director of this institute, Academician R. E. David. R. E. David was the only agrometeorologist elected an academician of the All-Union Agricultural Academy. He was the author of our country's first textbook on agricultural meteorology (SEL'SKOKHOZYAYSTVENNAYA METEOROLOGIYA). R. E. David wrote the monograph PSHENITSA I KLIMAT (Wheat and Climate). He created a new direction in agrometeorology. His agrometeorological validations of measures for contending with droughts and drying winds are classic. P. G. Kabanov, in developing David's ideas, published dozens of studies which still enjoy exceptional popularity. It is true that the studies of Academician R. E. David and P. G. Kabanov are mentioned on pages 314 and 317, but they should be mentioned in the history of agrometeorology. The Agrophysical Institute is not mentioned at all.

It is noted on p. 193 that many researchers as a basis for evaluating the intensity of a drought use the decrease in the yield of grain crops in comparison with the mean long-term value. There was no need to write about this. The author himself refutes the possibility of using this method by data, cited on p. 200. In actuality, during the last decade, due to new varieties, the mean long-term value is becoming nonindicative for an analysis of the yield level and therefore it is not the deviations from the mean long-term value which are analyzed, but instead, deviations from the trend. This should have been discussed in detail.

The chapter entitled "Agrometeorological Forecasts" includes the sections "Scientific Principles of Methods for Agrometeorological Forecasts" and "Types of Agrometeorological Forecasts and Methods for Their Preparation and the Use of Agrometeorological and Agroclimatic Characteristics in Yield Programming." Dozens of studies have been published on each of the mentioned subjects. Despite this, the chapter is allocated only 28 pages. It is not surprising that no place was found for an examination of the effect of meteorological conditions on the effectiveness of mineral fertilizers and for agrometeorological forecasts. But place should be found. "Soviet and foreign experience shows that not less than half the increment of the yield of agricultural crops is usually obtained due to the use of fertilizers" (L. I. Brezhnev, LENINSKIY KURS, Vol 2, p 295).

In describing the method for predicting the yield of winter wheat developed by Ye. S. Ulanova, the textbook author has not cited the multifactor equations for prediction in the ear-formation stage, although a forecast prepared in this phase is used most extensively on a practical basis. Space should be found for specific examples of the practical use of forecasts of the state of crops for contending with predators, diseases and beating-down of crops, determination of the times of soil dessication in spring (beginning of field work) (A. N. Derevyanko), etc. Very few examples are given of the practical use of agroclimatic data.

On the map (Fig. 29) of the mean long-term reserves of productive moisture in spring (prepared by V. A. Sennikov) the isolines in Eastern Siberia and in the Far East were drawn using data for an extremely limited number of stations and therefore are schematic. The dynamic model of the production process developed by O. D. Sirotenko is not considered. The investigations of A. N. Polevoy on this question, having great practical importance, are not included in the textbook.

The section "Frosts" covers 14 pages and the section on "Agrometeorological Support of Agriculture" covers 12 pages, although dozens of studies have been published on these subjects. We should mention the misprints which were noted. On p. 16 the words "molecular weight" are printed instead of "mass." Such errors in books published in 1979 cause perplexity among students. On p. 296 the formula for the humidity index has an irritating misprint.

The table of contents is printed in type which is too small and the titles of the subsections are not included, which makes it difficult to use the table of contents. However, the mentioned shortcomings are not of fundamental importance. In general, the textbook AGROMETEOROLOGIYA, prepared by Professor Yu. I. Chirkov, is an important landmark in the development of agrometeorology. It merits the highest recognition. But when a new edition is published the volume of the textbook must be increased in order to eliminate the present omissions.

SEVENTIETH BIRTHDAY OF PAVEL SAMOYLOVICH LINEYKIN

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 119-120

[Article by staff of the USSR Hydrometeorological Center]

[Text] Professor Pavel Samoylovich Lineykin, Doctor of Physical and Mathematical Sciences, one of the leading theoretical oceanologists, marked his seventieth birthday on 6 April.

The scientific and teaching work of Pavel Samoylovich began in 1930. After graduating from the Physical-Technical Division of Saratov State University he worked at the Lower Volga Hydrometeorological Bureau. There he formed his scientific interests, completely determined while he was a graduate student at the Scientific Research Geophysical Institute. The subject of his first investigations, made in defense of his Candidate's dissertation in 1936, was tidal processes in basins and channels. Since that time the study of problems in geophysics and hydrometeorology has been the basis of the diversified and productive scientific activity of P. S. Lineykin.

An article by Pavel Samoylovich entitled "Determination of Thickness of the Baroclinic Layer in the Sea" was published by Pavel Samoylovich in 1955 in the DOKLADY AN SSSR (Reports of the USSR Academy of Sciences). It constituted a new direction in study of the dynamics of sea currents. The rational formulation of the problem proposed in the article, together with the ways suggested for its solution, constituted the basis of the theory of the main thermocline in the ocean, making it possible to explain the most important characteristics of three-dimensional circulation and the distribution of water density in the ocean. The results of the first stage of investigations in this direction were generalized in the monograph OSNOVNYYE VOPROSY DINAMICHESKOY TEORII BAROKLINNOGO SLOYA MORYA (Principal Problems in the Dynamic Layer of the Sea) (1957), which received wide recognition.

During the years which followed the studies of P. S. Lineykin and his students were devoted to the development of this new approach to the dynamics of sea currents. A nonlinear theory was formulated, taking into account the interaction of the current velocity and density fields of sea water. The influence of bottom relief and ocean depth on the structure of currents was clarified. The role of diffusion and dissipative mechanisms was evaluated. Deep currents whose direction is opposite the circulation of surface waters were discovered. The last of these theoretical results was confirmed brilliantly on the basis of direct measurements in the ocean and numerical experiments.

All the studies of P. S. Lineykin are characterized by a striving for discriminating the main, decisive aspects of complex natural processes and giving them a clear physical interpretation. This was already manifested in early publications devoted to the theory of tides, the theory of monsoons, the theory of free and forced convection in a fluid, the theory of formation of the temperature and salinity fields in the upper layer of the ocean.

The scientific activity of Pavel Samoylovich is not restricted to investigations which are usually regarded as purely academic. He was one of the first to make successful use of the method of numerical integration of the equations of hydrothermodynamics applicable to real physiographic conditions. In 1967 he headed the Sea Dynamics Laboratory organized at the USSR Hydrometeorological Center. The principal objective of the new laboratory was the development of methods for computing and predicting oceanological characteristics on the basis of hydrothermodynamic models of the corresponding processes. In a relatively short time the laboratory under the direction of P. S. Lineykin developed investigations in the field of mathematical modeling, computations and methods for predicting large-scale and local processes in the ocean. As a result the laboratory formulated numerical methods for predicting temperature and the thickness of the upper mixed layer in the ocean, storm-induced level rises in the major ports of the USSR, thickness and distribution of the ice cover in nonarctic seas. On the initiative of P. S. Lineykin it was possible to develop investigations of interaction between the ocean and the atmosphere directed to improvement in methods for long-range weather forecasting.

The teaching activity of P. S. Lineykin is also highly productive. Broad scientific erudition, personal charm and the unusual capability for defining the most timely problems in oceanology have invariably attracted young people taking their first steps in science to Pavel Samoylovich.

P. S. Lineykin performs much public work.

Pavel Samoylovich meets his 70th birthday at the height of creative activity. During recent years he has achieved new results in the study of nonstationary mechanisms of oceanic circulation. A special type of wave movements in the ocean created by the seasonal variation of meteorological conditions and manifested in the form of moving large-scale (with a scale of the order of the earth's radius) circulatory elements of sign-variable vorticity was discovered. It was demonstrated that nonlinear effects in such wave disturbances lead to a distortion of the wave profile and the possible formation of ocean fronts. This laid the foundations for a fundamentally new approach to the prediction of macroscale oceanological fields.

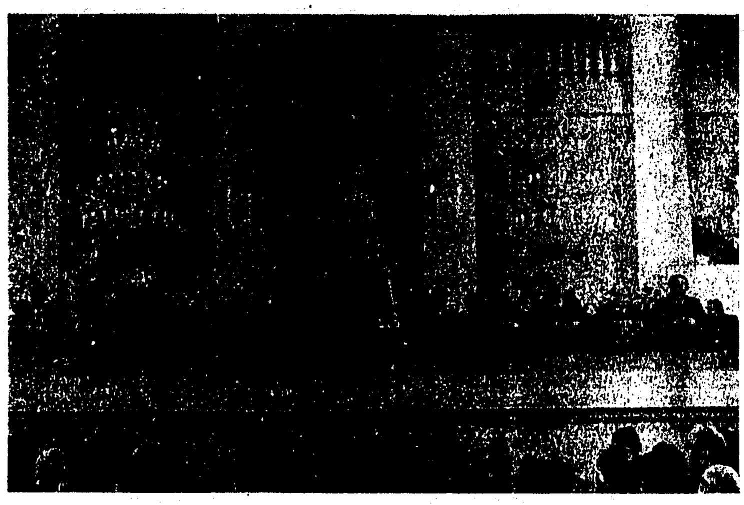
In congratulating Pavel Samoylovich on this memorable birthday we wish him good health and creative successes.

FIFTIETH ANNIVERSARY OF THE USSR HYDROMETEOROLOGICAL CENTER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 120-122

[Article by A. A. Akulinicheva]

[Text] A solemn meeting devoted to the 50th anniversary of the USSR Hydrometeorological Center was held on 8 January in the Columned Hall of the Palace of Unions. The presidium of the solemn meeting included M. V. Zimyanin, Secretary of the Central Committee CPSU, Z. N. Nuriyev, deputy chairman of the USSR Council of Ministers, and a number of key workers of the administrative sector of the Central Committee CPSU, USSR Council of Ministers and the Moscow City Committee CPSU.



Representatives of the ministries and departments closely collaborating with the USSR Hydrometeorological Center gathered to mark this glorious anniversary of the key weather forecasting institute of our country.

The international relationships of the USSR Hydrometeorological Center -- one of the three world meteorological centers -- were broadly represented. The anniversary was attended by the General Secretary of the WMO, Axel W. Nielsen, directors and representatives of the hydrometeorological services and meteorological services of Bulgaria, Hungary, Vietnam, East Germany, Korea, Cuba, Mongolia, Poland, Romania, Czechoslovakia, Yugoslavia and the World Meteorological Center in Washington. The scientific and working relationships of the USSR Hydrometeorological Center were represented by honored guests from a number of institutes of the USSR Academy of Sciences, institutes and administrations of the State Committee on Hydrometeorology.

In his introductory words the Chairman of the USSR State Committee on Hydrometeorology and Environmental Monitoring Yu. A. Izrael' noted the great successes attained by the USSR Hydrometeorological Center in the 50 years of its existence in servicing the national economy of the country with forecasts and information, warmly congratulated the workers and specialists on the anniversary and wished them further successes in implementing the important and responsible national economic tasks.

M. A. Petrosyants, in a report, discussed the principal stages and prospects for development of the USSR Hydrometeorological Center, of which he is the director.

The following spoke with greetings and congratulations to the USSR Hydrometeorological Center: the Chairman of the Central Committee of Trade Unions of Aviation Workers, V. A. Zuyev, the Deputy Minister of the Navy, V. I. Tikhonov, the General Secretary of the WMO A. W. Nielsen, the Deputy Minister of Transportation B. A. Morozov, the President of Regional Association VI (Europe), R. R. Czelnai, the Deputy Minister of Land Melioration and Water Management I. I. Borodavchenko, and in the name of the hydrometeorological services of the socialist countries of Europe, the Director of the Polish Hydrometeorological Service Z. E. Kaczmarek, the Deputy Minister of Electric Power Ye. I. Borisov, the Deputy Chief of the Vietnamese Meteorological Service Nguen Van Ki, the Deputy Director of the Korean Hydrometeorological Service Pak Ok Hen, the Director of the Hydrometeorological Institute of the Meteorological Service of the Republic of Cuba Nunez Rodriguez, and in the name of the scientific research institutes of the State Committee on Hydrometeorology -- the Director of the Arctic and Antarctic Scientific Research Institute, A. F. Treshnikov.

At the conclusion of the solemn meeting the text of a letter was received from the General Secretary of the Central Committee CPSU, Chairman of the USSR Supreme Soviet L. I. Brezhnev.

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An anniversary session of the Scientific Council, dedicated to the 50th Anniversary of the USSR Hydrometeorological Center, was held during the period 9-10 January. In the solemn part of the session, the following speakers extended greetings to the USSR Hydrometeorological Center: the

Director of the Main Geophysical Observatory, Ye. P. Borisenkov, the Director of the Central Asian Regional Scientific Research Hydrometeorological Institute, N. N. Aksarin, the Director of the State Scientific Research Center for Study of Natural Resources, I. P. Vetlov, the Director of the State Oceanographic Institute, F. S. Terziyev, the Director of the Hydrochemistry Institute, A. M. Nikandrov, the Deputy Director of the All-Union Agricultural Academy, Yu. A. Khvalenskiy, from the Leningrad Hydrometeorological Institute — Professor A. R. Konstantinov, and also representatives of other scientific research institutes and administrations of the Hydrometeorological Service. Greetings were presented by foreign guests: from the Czechoslovakian Meteorological Service -- Doctor Richter, from the Polish Meteorological Service -- Doctor Kaczmarek, from the Hydrometeorological Service of the Mongolian People's Republic -- the Director of the Institute of Hydrometeorology Medzhidorzh, from the East German Meteorological Service -- Doctor Kluge, from the Romanian Meteorological Service -- Deputy Director Bachinski, from the Meteorological Service of the Hungarian People's Republic -- Doctor Czelnai, from the Hydrometeorological Service of the Bulgarian People's Republic -- Doctor Betsinski, from the Yugoslav Meteorological Service -- Doctor Gamser Frants, from the Meteorological Service of the Republic of Cuba -- Doctor Rodriguez, from the Korean Meteorological Service -- the Deputy Director Pak Ok Hen, from the Vietnamese Meteorological Service -- the Deputy Director Nguen Van Ki, from the World Meteorological Center in Washington -- Doctor Bedient.

The scientific part of the anniversary session was opened with a report by the Director of the USSR Hydrometeorological Center M. A. Petrosyants in which he discussed the problems facing the institute in the current and forthcoming five-year plans. Other reports presented the history of development of the principal scientific directions at the USSR Hydrometeorological Center and the principal scientific results obtained during recent years.

Corresponding Member USSR Academy of Sciences Ye. N. Blinova gave a review of studies of the hydrodynamic theory of long-range weather forecasting and climate carried out in the USSR.

V. D. Uspenskiy devoted his report to one of the oldest branches -- synoptic investigations -- and described the history of development of work in the field of synoptic weather forecasting, beginning with the work of A. I. Askiaziy and S. P. Khromov -- enthusiasts and initiators of introduction of frontological analysis, the investigations of A. F. Dyubyuk, the head of this branch and who there developed work on the use of pilot balloon observations in weather description and forecasting and on the extrapolation of the surface pressure field.

D. A. Ped' told of three stages in the development of long-range weather forecasts, in particular, seasonal forecasts: the stage of creation under the direction of B. P. Mul'tanovskiy of a qualitative forecasting method, the stage in development of the principal ideas in this method under the direction of S. T. Pagava by the use of pressure pattern charts and the stage of use of the thermal characteristics of the underlying surface and the parameters of stratospheric circulation in seasonal weather forecasts. In particular, the author discussed the problem of drought prediction.

N. I. Zverev reported on the principal stages in improvement in the method for forecasting for a month in advance. He noted that at the present time 70% of the most time-consuming work of the forecaster is automated.

The report of Ye. G. Popov was devoted to investigations directly related to the development and improvement of methods for predicting river runoff and other elements of the water regime carried out in different stages of development of the hydrological forecasts service at the State Hydrological Institute and at the USSR Hydrometeorological Center; he outlined the most important achievements and the immediate goals in the field of hydrological forecasts.

The report of K. P. Vasil'yev was devoted to the present status of marine hydrological forecasts and the prospects for their development. He emphasized the need for the organization of investigations in the ocean for the purpose of obtaining meteorological data for the entire surface of the seas and oceans with an adequate degree of accuracy and spatial-temporal discreteness, as well as the creation of an automated system for the collection, processing and storage of all hydrometeorological information.

Ye. S. Ulanova, in her report, noted that the first agrometeorological forecasts were prepared specifically at the USSR Hydrometeorological Center (USSR Central Weather Bureau) by G. Z. Ventskevich and A. A. Shigolev in 1932-1933. This work is even now concentrated there. The report set forth the general tasks facing agrometeorologists and also the tasks involved in the servicing of regions of irrigated and drained lands and regions in the Nonchernozem zone of the RSFSR.

N. A. Bagrov told of the experience in using statistical procedures in long-range weather forecasts, beginning with the first work done in this direction by V. Yu. Vize in 1925 and enumerated the principal difficulties which are encountered in creating reliable statistical methods for long-range weather forecasting.

A report by Sh. A. Musayelyan and V. P. Sadokov examined the problem of the thermal effect of the ocean on the atmosphere and the possibility of a quantitative long-range weather forecast on the basis of conjugate equations with the use of asynchronous relationships between cloud cover over the ocean and air temperature over the European USSR.

S. L. Belousov analyzed the principal stages in the formation and development of a system for operational hydrodynamic short-range forecasting at the USSR Hydrometeorological Center and examined the present-day configuration and possibilities of this system and the immediate prospects.

In his report I. V. Trosnikov discussed the use of parameterization of radiation processes used in a model of general circulation of the atmosphere developed at the USSR Hydrometeorological Center. This parameterization is based on the use of empirical formulas for radiation fluxes at the upper and lower boundaries of the atmosphere and can be used in climatic modeling.

A report by Ye. G. Lomonosov and P. P. Vasil'yev told of the creation of a unified programmed-technological line for weather forecasting for intermediate times.

It was noted in a report by N. F. Vel'tishev, A. Ya. Zhelnin, V. Z. Kisel'nikova, Ye. M. Pekelis, D. Ya. Pressman and V. M. Losev that the successes attained in the field of numerical modeling of individual mesoscale atmospheric processes make it possible to proceed to the creation of more universal numerical models which in the future can be developed into operational prognostic models.

P. S. Lineykin gave a review of work on the hydrodynamic methods for marine forecasts at the USSR Hydrometeorological Center from 1967 through 1978.

HUNDREDTH ANNIVERSARY OF FERGANA HYDROMETEOROLOGICAL BUREAU

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 p 122

[Article by V. Ya. Syromukova]

[Text] The Fergana Hydrometeorological Bureau of the Uzbek Republic Administration of Hydrometeorology and Environmental Monitoring marked its 100th anniversary.

A hydrometeorological station was organized on 1 May 1880 on the southern margin of Novyy Margilan (now Fergana) on the initiative of the Russian Geographical Society and scientists of the Main Physical Observatory with the participation of the Military Topographic Section of Turkestanskiy Kray.

For a more complete and high-quality servicing of the national economy of Ferganskaya Oblast the Fergana Hydrometeorological Station in late 1971 was reorganized into a prognostic hydrometeorological bureau which now includes an operations group for servicing the national economy, observational and methodological groups, a group of radar men and a group for making observations and monitoring contamination of the environment.

During the past 100 years Fergana station has made a major contribution to study of the climatic resources of the Fergana valley and has trained a great number of meteorologists and agrometeorologists working in different regions of Central Asia.

CONFERENCES, MEETINGS AND SEMINARS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 pp 122-127

[Article by Ye. G. Apasova, Ya. S. Kanchan, A. G. Kovalevskiy, Yu. G. Slatinskiy and A. A. Vasil'yev]

[Text] A working conference on the theme "Development of Stochastic Forecasting Methods" was held at Tashkent during the period from 30 October through 1 November at Tashkent. The conferees examined the status of work carried out by the institutes of the State Committee on Hydrometeorology (All-Union Scientific Research Institute of Hydrometeorological Information -World Data Center (VNIIGMI-MTsD), Main Geophysical Observatory (GGO), USSR Hydrometeorological Center, Central Asian Regional Scientific Research Hydrometeorological Institute (SARNIGMI). In addition, the conference was attended by representatives of regional scientific-research institutes: West Siberian Regional Scientific Research Hydrometeorological Institute (ZSRNIGMI), Kazakh Scientific Research Hydrometeorological Institute (KazNIGMI), Far Eastern Scientific Research Hydrometeorological Institute (DVNIGMI), as well as the Institute of Atmospheric Physics (AFI), Leningrad Hydrometeorological Institute (LGMI), Tashkent State University (TashGU) and other organizations. Nineteen reports were presented on three principal directions of the discussed problem:
-- development of forecasting models;
-- broadening of the information base, selection and parameterization of predictors;
-- evaluation of the quality and economic effectiveness of forecasts.

One of the promising stochastic forecasting methods is forecasting by the analogue method, which theoretically and experimentally has been developed over a number of years and which at the present time has been applied in the form of an automated model with M-222, "Minsk-32" and YeS electronic computers. Studies by specialists of the VNIIGMI-MTsD, SARNIGMI and the USSR Hydrometeorological Center presented the results of experiments with a scheme for predicting the global and regional fields of meteorological elements (five reports). Considerable interest was shown in a report by G. V. Gruza and E. Ya. Ran'kova (VNIIGMI-MTsD, USSR Hydrometeorological Center) entitled "Principles for the Adoption of Decisions in the Use of a Group of Analogues." The report outlined possible ways for optimization of the choice of analogues and it was demonstrated that in connection with the increase in gradients of the fields of monthly temperature anomalies in the northern hemisphere the conditions for prediction by the analogue method have become complicated during the last decade. Data on the predictability of these fields in the territory of the USSR using different sets of predictors were cited in a communication by E. Ya. Ran'kova and L. K. Kleshchenko (USSR Hydrometeorological Center, VNIIGMI-MTsD), who investigated the success of methodological in comparison with ideal, climatic and random forecasts. One of the important conclusions from the study is that in order to improve the method it is necessary to change over to a system of regional predictors; it is possible that the parameterization scales must be varied in accordance with the peculiarities of the initial process for which the analogue is selected. In general, for temperature and precipitation with monthly averaging the forecasts are at the level of climatic forecasts. More successful were forecasts of surface pressure for the European USSR prepared using a system of predictors including the pressure parameters in the Atlantic-European sector and mean pressure in a number of regions of the hemisphere, etc. (report of T. P. Timofeyeva, VNIIGMI-MTsD).

The method of selection of group analogues for predicting temperature for the territory of Central Asia for periods up to 5 days is used for the purposes of local forecasting (G. V. Gruza, A. M. Soldatkina, N. I. Uraganova, L. K. Boyadzhiyeva -- VNIIGMI-MTsD, L. I. Imas -- USSR Hydrometeorological Center, SARNIGMI). The forecasts have been prepared over the course of a number of years and constitute auxiliary material for operational practice. The improvement is made by broadening the set of predictors and a differentiated approach to their inclusion in the model. A method for selecting analogues on the basis of stochastic evaluations of predicted and occurring phenomena was proposed in a report by G. A. Anikina, G. M. Vinogradova and L. N. Romanov (ZSRNIGMI) for increasing the effectiveness of local models for predicting the diurnal variation of temperature and thunderstorms at Novosibirsk.

The conferees gave great attention to a report by D. M. Sonechkin (USSR Hydrometeorological Center) entitled "Symbolic Dynamics -- a Means for Increasing the Advance Time of Reliable Weather Forecasts," devoted to the theoretical basis of one of the possible directions in long-range forecasting.

The problems involved in increasing information content are assuming primary importance in the development of prognostic methods. The information approach described in a report by M. I. Yudin and V. M. Mirvis (GGO) and applicable to the problem of a stochastic forecast is very promising. Computations of the information yield indices and an analysis of the quality matrices enabled the authors, in particular, to confirm the hypothesis of the significance of large-scale components of circulation and inertia of the underlying surface for long-range forecasting.

A number of problems relating to the predictability of atmospheric processes in stochastic forecasting methods were discussed in a report by Yu. V. Zhitorchuk (GGO).

For prediction of the field of temperature anomalies in Kazakhstan G. N. Chichasov (KazNIGMI) proposed a regression model the initial information for which is prepared in two stages: first, using a functionally normal distribution, a normalization of the point values at grid points of intersection is attained. This makes it possible to increase the linear correlation coefficients and then the fields of meteorological elements are represented by Chebyshev polynomials of the first kind, which, according to the author's data, have a greater resolution than natural orthogonal functions.

Some of the reports were devoted to an analysis of the statistical structure and a parameterization of meteorological objects for forecasting purposes. The climatic regime of the field of January precipitation was investigated by Ye. G. Apasova (VNIIGMI-MTsD) using data on anomalies expressed in percent of the long-term mean for 1891-1960 at the points of grid intersection in the northern hemisphere with an interval 2.5° x 2.5°. The report discussed the reality of the ascending precipitation trend, this being ascertained for consolidated regions for the period 1940-1960.

The inertia and predictability of the temperature field for the northern hemisphere in January and July were studied by G. S. Kharmanskaya of the All-Union Scientific Research Institute of Hydrometeorological Information-World Data Center. She demonstrated that temperature autocorrelation has seasonal and regional peculiarities which it is useful to bear in mind when developing prognostic methods. According to the data published by S. I. Tyurebayeva (GGO), the correlation method can be used for determining one of the parameters of the long-range forecasting model -- the limits of the autumn season in the European territory of the USSR.

A. S. Rasulev (SARNIGMI) presented a communication on the possibility of a correlation prediction of the field of anomalies of mean daily temperature with the use of double expansion of the predictors (H_{500} in the European USSR and Western Siberia) and a predictant into natural orthogonal functions.

A study of the temperature regime and altitude of the polar and tropical tropopause (report of B. T. Kurbanov and L. V. Rukhovets (GGO)) was preceded by a report on the development of a hydrodynamic-statistical method for predicting these elements presented by B. T. Kurbanov (GGO).

It is known that methods for evaluating the quality of stochastic forecasts, in contrast to categorical forecasts, have been developed far inadequately. The report of G. V. Gruza and V. T. Radyukhin (VNIIGMI-MTsD) therefore was of special interest. It proposed a method for checking hypotheses on the randomness of forecasts and evaluation of the significance of the conclusion that there is an absence of mastery in this field. The report also gave the results of testing of a method for evaluating the quality of alternative stochastic forecasts. It was demonstrated that with certain assumptions the quadratic and spherical evaluation criteria have a greater effectiveness than the logarithmic criterion. Closely related to the quality evaluation question was the report of Ye. Ye. Zhukovskiy (AFI) on the principles of the strategy of a user when employing stochastic forecasts and calculation of their economic usefulness in a number of situations with alternative forecasts. The investigation of T. M. Brunova (AFI) was devoted to a method for combining forecasts prepared by different methods. In this method a matrix of joint probabilities of initial alternative forecasts is used for increasing success and maximizing the economic effect.

The conference noted that at the present time several methods have been developed in the form of automated models making it possible to prepare stochastic and categorical long-range forecasts, including those prepared on the analogue principle. Encouraging results were obtained in the prediction of the mean monthly air temperature of the northern hemisphere and also temperature and precipitation for 1-5 days in advance for Central Asia. Investigations are being made in a number of central and regional subdivisions of the State Committee on Hydrometeorology, whose efforts must be coordinated in the future.

Ye. G. Apasova

An international seminar for the exchange of experience in the use of a standardized method for computing atmospheric contamination was held at the Main Geophysical Observatory during the period 12-16 November 1979 in accordance with a resolution of the VII (XV) Conference of Directors of Hydrometeorological Services and Meteorological Services of the Socialist Countries. It was attended by representatives of Bulgaria, East Germany, Poland, USSR and Czechoslovakia.

On the recommendation of the working group of the hydrometeorological services and meteorological services of the socialist countries on the meteorological aspects of atmospheric contamination, in the course of preparation for the seminar the participating countries carried out a joint numerical experiment which included computation of the altitude and maximum admissible effluent for a model point source and computation of the fields of maximum and mean annual concentrations of impurity from a group of scattered sources with different parameters.

The communications presented at the seminar and their subsequent working discussion enabled its participants to become acquainted in detail with methods used in computing atmospheric contamination in different countries and to analyze the results of the numerical experiment.

The chairman of the seminar, M. Ye. Berlyand, in his communication discussed the status and the prospects of the method for computing air contamination from many sources. He noted the positive role of models of the

Gaussian type in the initial stage of creation of methods for computing the scattering of impurities in the atmosphere and the existence of difficulties in determining the diffusion parameters of these models in the case of high sources and also in problems of the propagation of impurities under conditions of a nonuniform underlying surface. He pointed out the lack of fundamental difficulties of this type in models based on use of the turbulent diffusion equation, making it possible to take into account diverse meteorological effects, nonuniformity of the underlying surface and the difference in the types of sources. The standard method used in the USSR for computing atmospheric contamination was a result of theoretical work based on use of the turbulent diffusion equation and confirmed by numerous expeditionary investigations in regions with different industrial enterprises. M. Ye. Berlyand gave a brief description of the results of investigations relating to the propagation of impurities under conditions of complex local relief and nonstationary diffusion from surface sources, having great importance when determining air contamination by auto transport, and to the mean annual concentrations and climatology of diffusion parameters. The author pointed out promising directions for research, including determination of change in the wind field behind a building, problems related to the climatology of a city, photochemical transformations of impurities and large-scale transport of impurities.

In Bulgaria, as reported by M. Kolarova, work has been done on a comparison of the results of computations by different methods. The fields of maximum and medium concentrations were determined for two industrial sites of a planned enterprise.

B. Schneider and D. Streicher reported on the status of the method used in East Germany and its implementation program. They told about a method for calculating the effective rising of a plume, the principles for classification of meteorological situations and regionalization of a territory using the parameters of the adopted model.

Studies carried out in Poland in the field of methods for computing atmospheric contamination were discussed by K. Budzinski. He told about a method for approximation of the parameters of the used model, taking into account the influence of roughness of the underlying surface. Great attention was devoted to the reasons for possible differences in the results of computations made by different methods. It was noted that they can be caused not only by the difference in the used diffusion models, but also by the methods for calculating the effective rising of a plume and also the difference in the organization of computations and programs for electronic computers.

F. Hesek and J. Bubnik reported on two methods used in Czechoslovakia for computing atmospheric contamination. In these methods an attempt has been made to take into account the wind shear with altitude in calculating atmospheric contamination from many sources and a method has been proposed for calculating air contamination from an aerial source.

R. I. Onikul and Ya. S. Kanchan told about the fundamental peculiarities of an algorithm widely used in the USSR (at more than 100 planning institutes) for a standardized program for calculating atmospheric contamination from many sources. The program was prepared in such a way that with one and the same volume of initial data and output information the computations require 4-6 times less computer time than for other programs of this type.

Ye. L. Genikhovich and I. G. Grachev reported on the results of investigations at the Main Geophysical Observatory to determine influence of nonuniformity of the underlying surface on the propagation of impurities. The program for an electronic computer, prepared in the course of these investigations, is employed in expert evaluations of the siting of industrial plants in regions with complex relief. The method developed at the Main Geophysical Observatory for computing the mean annual concentrations, taking into account data from gradient observations of wind velocity and temperature in the surface air layer, was described in a communication by S. S. Chicherin. The authors cited examples of computations using observational data from heat balance stations situated in different climatic zones of the USSR.

R. I. Onikul familiarized the seminar participants with a comparison of the results of computations obtained using methods employed in the USSR and the United States with data from observations in the neighborhood of thermal electric power stations in the United States. Noting the good correspondence of the computations by the Soviet method with the experimental data, he noted the possibility of harmonizing different approaches to the evaluation of air contamination.

The seminar summarized the first results of the work done. The analysis of the results of the numerical experiment, in particular, revealed that the basic practical recommendations made with the use of the discussed methods coincide.

It was decided to continue this experiment and carry out computations of air contamination by sources near which the experimental investigations of the field of concentrations were made.

This seminar will facilitate the harmonizing of computation methods used in the socialist countries and the development of general approaches for their further development.

Ya. S. Kanchan and A. G. Kovalevskiy

During the period 1-5 October 1979 an All-Union Conference-Seminar of Section Heads of Expeditions and Bases of the Expeditionary Fleet of the State Committee on Hydrometeorology was held at Odessa. It was attended by representatives of a number of scientific-research institutes (State Oceanographic Institute (GOIN), Arctic and Antarctic Scientific Research Institute (AANII), Far Eastern Scientific Research Hydrometeorological Institute

(DVNIGMI), All-Union Scientific Research Institute of Hydrometeorological Information-World Data Center (VNIIGMI-MTsD), Central Aerological Observatory (TsAO), Main Geophysical Observatory (GGO), Sevastopol', Odessa and Leningrad Divisions of the GOIN) and most of the marine administrations of the hydrometeorological service. Reports and communications were presented by 26 persons.

The conference-seminar was opened with brief introductory words of the director of the Odessa Division of the State Oceanographic Institute Ye. A. Sobchenko. A report on the results of operation of the expeditionary fleet in the tenth five-year plan and tasks for the coming years was presented by V. F. Dmitriyev (Marine Administration of the State Committee on Hydrometeorology). He noted that the conference-seminar was called for the purpose of an exchange of work experience in the field of planning and organization of the operation of marine expeditions, formulation of recommendations on the further improvement of investigations of the world ocean, internal and marginal seas, an increase in the effectiveness of operation of the scientific-research fleet and ensuring the needs of the national economy with oceanographic information. The report emphasized that each year the scientific research fleet of the State Committee on Hydrometeorology is carrying out a great volume of work for study of the world ocean, Soviet seas and the sea mouths of rivers, and also the shelf zone. The research materials are used in the practical work of hundreds of scientific research, planning and other organizations and institutes related to the sea.

In order to improve the direction of the fleet it was necessary to revise or rework a whole series of norm-setting documents. In particular, during the time elapsing from the time of carrying out the preceding conference-seminar a new instruction has been introduced at all subdivisions of the State Committee on Hydrometeorology on the sequence for the planning of expeditionary work; methodological regulations on computation of the efficiency of operation of ships have been published; a list of standard types of work and observations which are to be carried out on all ships with a great navigational range, regardless of the work region and the specific tasks of each individual voyage, has been prepared. A new report form should play an important role in systematizing the data collected in the expeditionary work of low-tonnage vessels.

It was noted in the report that for the purpose of accelerating the processing and analysis of materials from expeditionary investigations it must be arranged that all the results of the observations are routinely registered on a long-term technical carrier (magnetic tape) and presented to the data processing center completely prepared for further analytical processing. This will make possible a considerable acceleration of the formation of a branch bank of oceanographic data.

The report noted the initiative of the Northwestern Administration of the Hydrometeorological Service and the Leningrad Division of the State Oceanographic Institute in the development of the program for complex studies of the Baltic Sea and emphasized the insistent necessity in future years to have similar programs for all marine basins of the country.

V. M. Rokogon (Odessa Division of the State Oceanographic Institute) in his report told of experience in the planning of expeditionary investigations and participation of ships of the State Oceanographic Institute in supporting the system of ocean stations in the North Atlantic. It was noted that in accordance with international obligations assumed under the WMO the scientific-research vessels of the State Oceanographic Institute are actively participating in the support of regular observations at oceanographic station "C" situated to the north of the 52d parallel. A complex of oceanographic, meteorological and aerological observations is being carried out. The collected information is used extensively for operational purposes and also in developing long-range forecasting methods.

I. N. Davidan (Leningrad Division of the State Oceanographic Institute) discussed some problems in the organization and implementation of interdepartmental expeditions for studying the Baltic Sea and analyzed the results of the second interdepartmental expedition (October-November 1978), which collected extensive experimental data.

A report by Yu. G. Slatinskiy and A. P. Zhilyayev (Sevastopol' Division of the State Oceanographic Institute) examined the problem of the effectiveness of use of low-tonnage vessels of the State Committee on Hydrometeorology. It was noted that low-tonnage vessels play an important role in carrying out monitoring work and also in implementing a major program of water balance investigations, primarily in the mouth sectors of rivers. On the average, during a year low-tonnage vessels occupy about 5,500 individual stations and 50-60 multihour stations, that is, approximately a thousand series of observations. The annual goal for each vessel is established on the basis of the approved research plan and for ships of the SChS type is not less than 170-190 days with a duration of the navigation season of about 240-250 days. In order to increase the effectiveness of use of the low-tonnage fleet it is recommended that permanent shipboard stations with a staff of two or three persons be formed on ships of the SChS and RK-376 type by all administrations in the basin. It is also desirable to have a radical change in the method for technical servicing of small ships and for this it is necessary that there be at least one permanent repair base in the basin with centralized allocation of the necessary materials, spare parts, etc.

Also of exceptional importance is the problem of technical support of research carried out aboard small ships. Taking into account the size of the vessels, it is necessary to have special small-sized apparatus, usually with an autonomous current supply from storage batteries. Insofar as possible the sensors used must be multipurpose.

It was emphasized in the report that a decisive role in increasing the effectiveness of operation of low-tonnage vessels must be played by systematic renewal of the fleet.

The report of V. M. Nebesnyy (Odessa Division of the State Oceanographic Institute) dealt with the use of satellite navigational systems on the ships of the State Oceanographic Institute and the prospects for their use in oceanography. L. N. Ryazanov (Central Aerological Observatory) reported on the results of use of rocket sounding data from scientific research weather ships for operational and scientific purposes. B. A. Maksimov (Technical Administration of the State Committee on Hydrometeorology) discussed plans for the technical reoutfitting of marine expeditions and told about the development of new instruments and equipment for the outfitting of sea ships, autonomous buoy stations and pile bases.

I. A. Dyubkin (GGO), in his report dealt with the problem of the representativeness of some types of observations carried out on the scientific research ships of the State Committee on Hydrometeorology. The report gave an evaluation of systematic distortions of air temperature, precipitation, atmospheric pressure and other elements as a result of the influence of the ship's hull. Data were given on the difference in instrument readings on different ships and the corresponding readings on the flagship.

R. R. Belevich (Odessa Division of the State Oceanographic Institute) told of experience acquired in 1979 in the First Global Experiment GARP and the preliminary results of investigations. The work was carried out in two stages: January-March and May-June. Ships of the USSR Academy of Sciences and other departments participated in addition to the ships of the State Committee on Hydrometeorology. An exceptionally great volume of experimental data was collected, in particular, there were 9,500 hourly meteorological observations alone. The ships of the State Committee on Hydrometeorology occupied about 2,000 abyssal stations, launched a great number of radiosondes and placed several autonomous buoy stations. The collected data will be used in developing methods for long-range weather forecasting.

S. F. Sorokolet (GOIN) discussed some problems involved in the use of the interim methodological instructions on evaluating the effectiveness of use of scientific-research ships in the system of the State Committee on Hydrometeorology.

The reports of N. D. Klevtsova (Azerbaydzhan Administration of the Hydrometeorological Service), Ye. V. Fridrik (Northwestern Administration of the Hydrometeorological Service), I. M. Baushis (Lithuanian Administration of the Hydrometeorological Service) and others dealt with proposals for improving the organization and planning of expeditionary investigations in the coastal zone. In particular, attention was given to the need for the standard production of instruments and equipment specially for investigations in the coastal zone.

The participants in the conference-seminar visited the scientific research weather ship "Ernst Krenkel'" of the Odessa Division of the State Oceanographic Institute where they became familiar with the automated subsystems for the collection and processing of hydrometeorological information.

In the adopted resolution of the conference-seminar there was formulation of a number of specific proposals on further improvement of operation of the scientific-research fleet of the State Committee on Hydrometeorology. Particular attention is being given to the need for a clearer coordination of the efforts of all scientific-research institutes and administrations of the Hydrometeorological Service in implementation of major complex programs under interdepartmental and international projects. It was deemed desirable that increased attention be given to the meteorological support of expeditionary work, that there be a broadening of exchange of specialists during the period of voyages for the purpose of mastery of new methods and apparatus, and that there be an improvement in the dissemination of scientific information on the most important attainments in the field of study of the world ocean.

Yu. G. Slatinskiy

A scientific-technical conference on aviation meteorology was held during the period 5-9 November 1979 in Geneva. It was organized for the purpose of exchange of the results of investigations and opinions on the principal problems involved in aviation meteorology among meteorologists and the users of meteorological information. The organizing committee of the conference included: the vice president of the Commission on Aviation Meteorology of the WMO D. Casteline (Netherlands), a representative of the WMO Secretariat A. Mastranchelli, and also members of the Consultative Working Group of the Commission on Aviation Meteorology V. M. Kosenko (USSR), P. Paridier (United States) and J. Renard (France).

The conference was attended by 102 persons from 52 countries and five international organizations (ICAO, IATA, IAOPA, ASECNA, WMO). Forty-five reports were presented, including 7 from the USSR (USSR Hydrometeorological Center, Central Aerological Observatory, Main Geophysical Observatory, Institute of Experimental Meteorology, OLAGA). Although the texts of all the reports were duplicated and disseminated to the conferees in the form of working documents, for the purpose of saving time 32 reports (four of them reports from the USSR) were included in the agenda. Depending on subject matter, the reports were distributed in four sections: weather observations at airports, flight conditions at low levels, telecommunication and processing of data, application of meteorology to aerial navigation.

Eight reports were presented in the first section. These were devoted to the development of weather observation systems (France), monitoring the quality of meteorological observations (United States), and methods for measuring wind and visibility for meteorological servicing of aircraft takeoffs and landings (Sweden, United States, Denmark, Great Britain). In the discussion great interest was shown in a method for measuring slant visibility by means of a lidar developed in France and also in investigations of the vertical structure of visibility in a fog carried out in Great Britain.

The reports of the second section (8 reports) were devoted primarily to the problems involved in measuring and determining wind shear in the lower layer and its influence on takeoffs and landings of aircraft, work done by specialists of the USSR, Finland, Italy and the United States.

Two review reports were presented in the third section. These were devoted to the prospects for the development of a global network of telecommunication and problems involved in short-range weather forecasting. Five reports dealt with special problems (uses of satellite data, data from radar observations, etc.).

The subjects of the reports in the fourth section dealt with the problems involved in the effectiveness of meteorological support of aviation (IATA), studies of a system of zonal forecasts (ICAO), prediction of clear-sky turbulence (USSR, Great Britain), meteorological support of flights of supersonic passenger aircraft (France), aspects of meteorological support of flights in the tropical zone (Senegal, India), etc.

It should be noted that most of the reports were characterized both by well-defined practical applicability and a high scientific level. Accordingly, the conference materials can be useful to a broad range of specialists involved with problems relating to aviation meteorology. Those interested in the text of reports presented at the conference (in English) can familiarize themselves with these in the scientific-technical library at the USSR Hydrometeorological Center.

A. A. Vasil'yev

NOTES FROM ABROAD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 80 p 128

[Article by B. I. Silkin]

[Text] As reported in SCIENCE NEWS, Vol 115, No 24, 1979, according to the opinion adopted among specialists, in formulating a meteorological forecast for one week in advance it is possible to ignore processes transpiring in the air envelope on the other side of the equator. For example, in analyzing the short-range prospects for macroscale circulation in the northern hemisphere forecasters usually have not consciously taken into account the meteorological conditions prevailing in Australia and in South America at the time the forecast is being prepared.

Such an approach may be modified as a result of a report presented by Richard C. J. Somerville, a scientific specialist at the National Center for Study of the Atmosphere at Boulder, Colorado, in the United States, at the annual conference of the American Geophysical Union held in Wasington in June 1979.

According to his conclusions, the medium-scale atmospheric systems in actuality have little dependence on the conditions in remote regions, but the largest atmospheric waves (only three to six such waves are sufficient in order to cover the entire earth) exert a decisive influence on long-range forecasts.

The natural "information" contained in these waves and transported by them in the long run is imparted to short atmospheric waves with which diurnal effects of local significance are associated. Accordingly, macroscale circulation, in the opinion of the speaker, is the key to a 24-hour forecast.

R. C. J. Somerville drew all these general conclusions by means of a comparative analysis of several differing models for long-range forecasting. Comparing these with the meteorological conditions actually prevailing in the Boulder region, he was able to select one of these models as the most effective. This model specifically took into account data collected on a global scale and made it possible to formulate extremely precise forecasts five days in advance.

The model, which made use for the most part of conditions in the northern hemisphere and also included some data for the southern hemisphere, made it possible to give confirming forecasts for three days in advance. This same model, which was based exclusively on data obtained to the north of the equator and even omitted tropical data, led to a more or less precise forecast with an advance time of not more than 1-2 days.

Moreover, the most effective of the enumerated models could dispense with such physical factors as the influence of clouds, solar radiation and latent heat and with respect to its advance time could surpass forecasts based on other models, even with use of the enumerated factors.

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As reported in NATURE, 22 February 1979 and SCIENCE NEWS, Vol 115, No 16, 1979, Academician A. B. Severnyy and his colleagues V. A. Kotov and T. T. Tsap (Crimean Astrophysical Observatory USSR Academy of Sciences) reported on their discovery of oscillations of solar matter with a period of about 160 minutes. This so contradicted the theoretically accepted concepts that many theoreticians resolutely refuted such an assertion.

Then the specialists of the Crimean Astrophysical Observatory USSR Academy of Sciences carried out joint investigations with specialists of the solar observatory at Stanford University in the United States P. H. Scherer and J. M. Wilcox for checking such facts. Their coordinated observations lasted about three years.

The period of the postulated pulsation -- 160 minutes -- is precisely 1/9 of a day. This forced some specialists to insist that the phenomenon does not occur on the sun but is the result of some terrestrial (hypothetically -- atmospheric) effect repeating with the earth's rotation. In such a case it should not be at one and the same time in one and the same phase at two points on the earth remote from one another. But three-year observations in the Crimea and California indicated a close coincidence of these phases.

The postulated vibration meant that the solar surface alternately rises and falls. This should be particularly evident at the limb of the visible solar disk. There, as a result of such vibration some velocity caused by the pulsation should be added to the known velocity of the solar surface associated with its rotation.

For this reason it was necessary to measure the true velocity of solar rotation with a great accuracy. This was done by measurement of the Doppler shift of the spectrum of solar radiation with a frequency of 5124 A (Fe emission line).

As a result it was found that the velocity of the sun's rotation each 160 minutes exceeds that which is associated with its rotation by approximately 1 m/sec. The existence of the pulsations was thereby confirmed.

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At the same time the fact was discovered that there is a phase shift of the pulsation over the course of three years of observations. It was noted at both observatories. Evidently, the precise period of the pulsations is about 160.01 minutes, that is, it is not equal to 1/9 day.

The now discovered vibrations evidently do not arise at the surface, but in the interior of the sun. They play an important role in the transfer of energy from the internal regions of the sun to the surface, which in no way was foreseen by existing theories. All this can lead to the need for a serious reexamination of the accepted ideas concerning the thermodynamics of the solar interior and its clearly stratified structure and the theory of the thermonuclear processes transpiring there.

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