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USSR Report

METEOROLOGY AND HYDROLOGY

No. 11, November 1979

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MOISTENING OF THE CONTINENTS AND INTENSITY OF SUMMER MONSOONAL CIRCULATION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 5-11

[Article by Corresponding Member USSR Academy of Sciences G. P. Kurbatkin, Professor S. Manabe and Doctor D. G. Hahn, Computation Center Siberian Department USSR Academy of Sciences and Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, submitted for publication 25 June 1979]

Abstract: Using the spectral model of the atmosphere developed at the Geophysical Fluid Dynamics Laboratory (Princeton, New Jersey), a study was made of the influence of changes in moistening of the continents on the intensity of summer monsoonal circulation in the middle latitudes. The model includes the annual cycle of climate, the hydrology of the atmosphere and continents. An analysis of the numerical experiments indicated that the drying out of the continents can lead to a decrease of precipitation not only over the continents, but also over the ocean; drying-out of the continents simultaneously can intensify planetary summer monsoonal circulation in the middle latitudes, which can be an important condition in the annual cycle of climate for summer radiation heating of the ocean.

[Text] Without allowance for the annual variation of solar radiation it is evidently impossible to detect and understand the relative importance of different interacting physical processes determining stable and unstable "weather systems" and in the long run -- the forming climates. The annual cycle of climate can be quantitatively explained by solution of the problem of interaction between the atmosphere, continents and ocean in accordance with the characteristic times of the processes participating in this interaction. But how and why the physical processes forming the annual cycle of climate interact with one another to produce climatic, seasonal and year-to-year fluctuations is almost unknown. For example, one of the unstudied aspects of this problem is the influence of changes in the moistening of the continents on the intensity of summer atmospheric circulation.

As is well known, planetary monsoonal circulation is secondary circulation of the convective type. It is not described by the stream function, but is manifested only in the wind velocity potential field -- a small-scale component of large-scale horizontal motion of the atmosphere, not subject to direct instrumental measurements. At the present time it is unknown to what extent there is a change in summer planetary monsoonal circulation in the middle latitudes from year to year and what the reasons for these changes are. It is postulated that the reason for its changes may be a change in the moistening of the continents. However, at the present time not even mean seasonal maps of moistening of the continents for each year are being compiled. We have only mean long-term (climatic) seasonal maps of moistening of the continents [1]. Moreover, at the present time mean seasonal maps of the wind velocity potential field are also not being compiled. This does not make it possible to judge the nature of the changes in summer monsoonal circulation of each year.

Thus, at the present time it is virtually impossible to investigate this problem by means of a diagnostic analysis of observational data.

For studying summer planetary monsoonal circulation in the middle latitudes we used a complex spectral model of general circulation of the atmosphere developed at the Fluid Dynamics Laboratory located at Princeton University in the United States [2].

Spectral models differ from grid (finite-difference) models in that the dynamic variables in them are represented by a synthesis of a finite sum of spherical harmonics, and not by the values in a grid of discrete points. The equations of the model predict the spectral components, and not the variables at the grid points.

The predicted variables in this model are the following: ∇^2 of the stream function, ∇^2 of wind velocity potential (∇^2 is the horizontal Laplace operator), temperature, mixture ratio and logarithm of pressure at the level of the earth's surface. These variables are scalars (the spectral representations of vector values introduce singularities at the poles). In the model use was made of a hydrostatic approximation and in the vertical direction use is made of the σ coordinate, equal to the ratio of pressure to pressure at the earth's surface in order to introduce topographic effects. Simple horizontal viscosity was introduced by attenuation of the model variables by a constant multiplied by ∇^4 of the hydrothermodynamic elements. A simple diffusion scheme with the mixing length is used vertically.

The model has nine vertical levels (σ = 0.025, 0.095, 0.205, 0.350, 0.515, 0.680, 0.830, 0.940, 0.990). These were selected in such a way as to describe the lower stratosphere and the Ekman boundary layer. The horizontal rhomboidal resolution of the model is M = 21. The prognostic equations of the model are integrated in time using a quasi-implicit scheme: the linear and nonlinear components of the trends are split and integrated in time implicitly and explicitly respectively. Use is made of temporal smoothing with $\alpha = 0.01$ in each time interval.

The model includes the annual cycle, the hydrology of the atmosphere and continents. In order to compute the flux of solar radiation there is stipulation of the seasonal change in insolation at the upper boundary of the model atmosphere. The attenuation of solar radiation and the transfer of long-wave radiation emitted by the earth and atmosphere are computed taking into account the effects of clouds, water vapor, carbon dioxide and ozone. The carbon dioxide mixing ratio is everywhere assumed to be constant. The zonally homogeneous distribution of ozone is stipulated as a function of latitude, altitude and season. The time-dependent spatial distribution of water vapor is found as a result of integration in time for the prognostic equation for water vapor, including: three-dimensional advection of water vapor, vertical mixing of water vapor in the planetary boundary layer, evaporation, nonconvective condensation and moist convective adaptation. In computing radiation fluxes an allowance is made for the time-variable distribution of cloud cover at three levels in dependence on the change in water vapor and air temperature.

The temperature of the earth's surface over the continents is determined by the boundary condition expressing the accumulation of heat in the soil (that is, the fluxes of solar and long-wave radiation and the turbulent fluxes of apparent and latent heat locally together are equal to zero). Over the oceanic part the seasonal change in temperature of the ocean surface is stipulated. It is determined by interpolation in time between the four observed distributions of the mean monthly temperature fields of the ocean surface. In order to compute the descending flux of solar radiation the albedo of the earth's surface is stipulated as a function of latitude over the ocean and as a function of latitude and longitude over the continents; in places where as a result of the computations there is a reproduction of snow cover or sea ice, the albedo is replaced by higher values. The rates of change in moistening of the continents and thickness of the snow cover are determined by the budget of water, snow and heat at the land surface.

Numerical integration in time was carried out for two years and eight model months. In this control variant the distribution of moistening of the continents was determined at each moment in time from the budget of evaporation, precipitation, melting of snow and river runoff.

The model quite precisely reproduces climate and its seasonal changes. Figure 1 shows the field of atmospheric pressure at sea level (a) and the field of moistening of the continents (b) reproduced by this model in the control variant, averaged for July and August (here the moistening values beyond the continents must not be taken into account). They can be compared with the corresponding fields constructed on the basis of long-term observations [1, 3], which, unfortunately, are not cited here in order to save space.

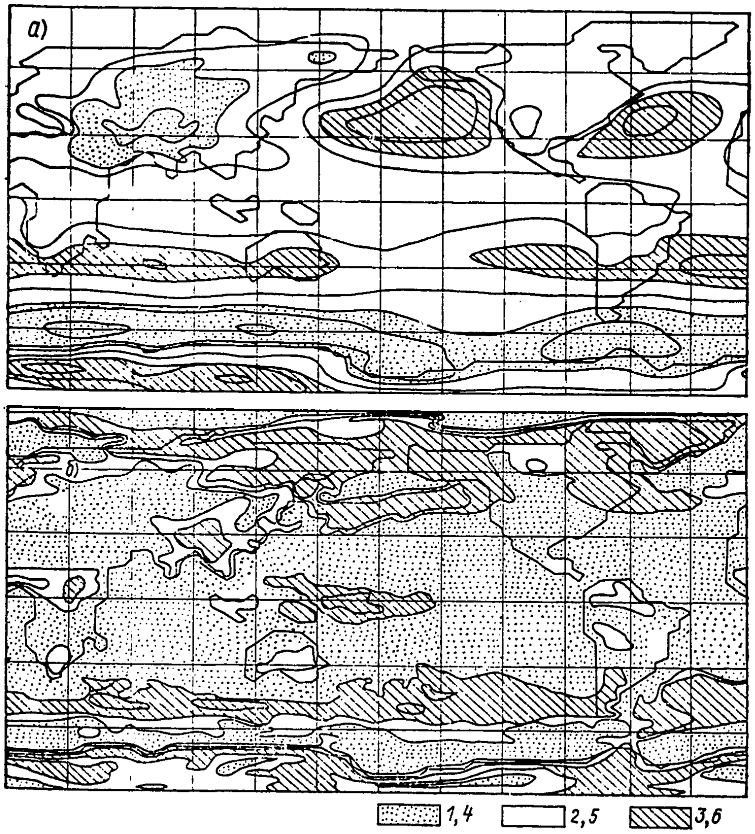

Fig. 1. Atmospheric pressure at sea level (a) and moistening of the continents (b), reproduced by Geophysical Hydrodynamics Laboratory model (Princeton, United States). Isolines are drawn each 10 mb (a) and each 4 cm (b). 1) less than 1000 mb, 2) 1000-1020 mb, 3) more than 1020 mb, 4) less than 2 cm, 5) 2-10 cm, 6) more than 10 cm

From an analysis of these maps it is possible to note a coincidence of the principal regions of high and low pressure. However, they are more strongly expressed in the model climate than in the real climate. In an analysis of the maps for moistening of the continents it is possible to note a coincidence in the control variant with the real climate of extensive regions of quite high moistening (more than 10 cm, shaded regions) in the tropical zone of Africa, in India, on the islands of Indonesia and in the middle latitudes of the Eurasian continent.

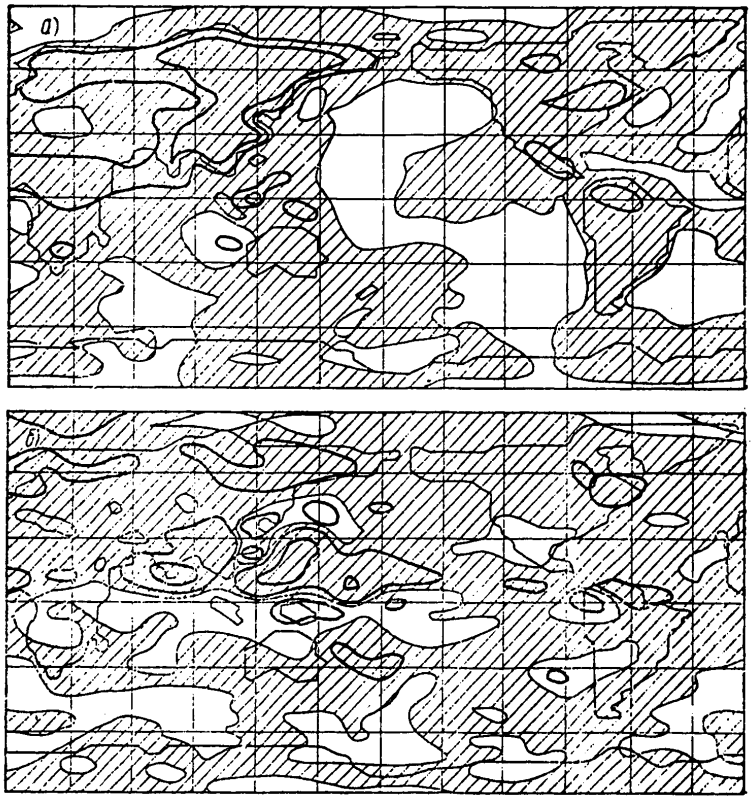

Fig. 2. Difference in rate of evaporation (a) and in rate of precipitation (b) between "Arid" and control variants.

Of the two simplest numerical experiments with a change in moistening of the continents -- total moistening of the continents or their total dessication -- it was the second which could be favorable for a quantitative study of the hydrothermodynamic interactions between the atmosphere and the continents in the middle latitudes. Therefore, after carrying out and analyzing the control experiment the last three model months (June, July and August) were recalculated with the restriction that the continents remained completely waterless during the entire three-month summer period ("Arid" variant).

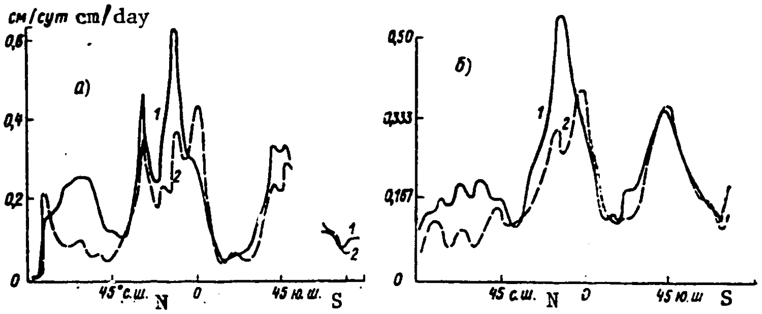

Fig. 3. Total quantity of precipitation per day, averaged for July-August over the continents (a) and over the ocean (b).

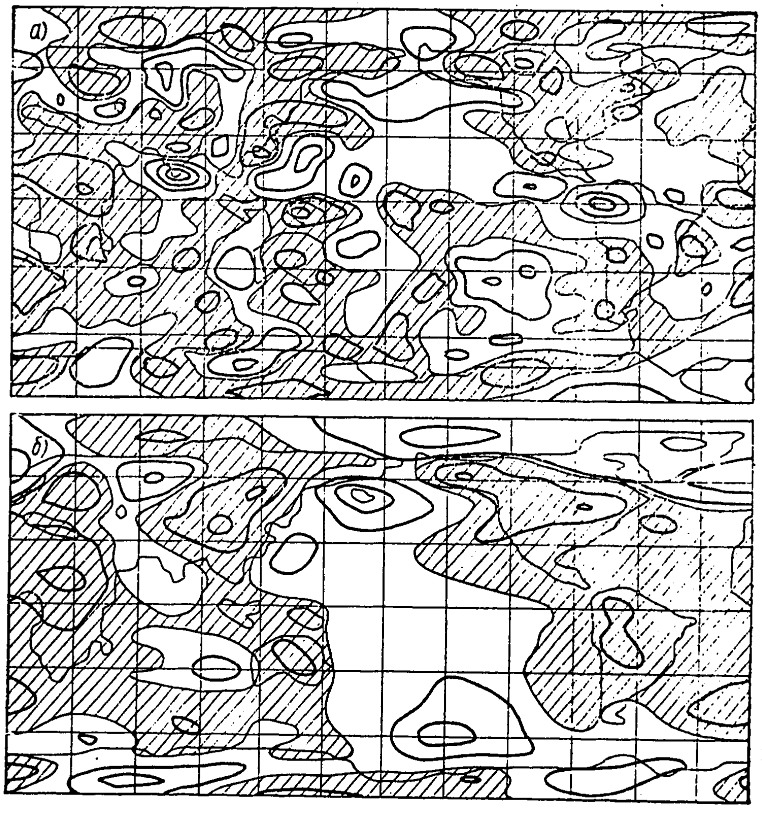

Fig. 4. Difference between "Arid" and control variants of horizontally smoothed vertical velocities in isobaric coordinate system at 500-mb level (a) and atmospheric pressure at sea level (b), averaged for July-August.

The dessication of the continents naturally led to a decrease in evaporation from the surface of the continents and accordingly to a decrease in precipitation. Figure 2a shows the differences in the rate of evaporation between the "Arid" and control variants, whereas Fig. 2b shows similar differences in the rate of precipitation. (In Fig. 2 shaded regions correspond to negative differences, whereas regions without shading correspond to positive differences; the isolines are drawn at a logarithmic scale: ±0.2 and ±1 cm/day).

However, precipitation decreased not only over the continents, but also over the oceans. (Figure 3 shows the total quantity of precipitation per day, averaged during July-August over the continents (a) and over the ocean (b); 1) control variant, 2) "Arid"). This is associated with an intensification of descending vertical movements over the ocean in the "Arid" variant. Figure 4a shows the differences in vertical velocities in an isobaric coordinate system at the 500-mb level between the "Arid" and control variants; the unshaded areas show regions of intensification of descending (or weakening of ascending) vertical movements. Figure 4a shows an intensification of ascending (or weakening of descending) movements over the continents in the "Arid" variant (shading; the isolines are drawn each 20 mb/day).

The intensification of ascending vertical currents over the continents in the "Arid" variant caused a pressure decrease over the continents as a result of an increase in the temperature of the continental surfaces (and the lower troposphere over them) due to a decrease in the heat loss on evaporation and a simultaneous decrease in the cloud cover, increasing the radiation heat influx. Figure 4b shows the difference in atmospheric pressure at sea level between the "Arid" and control variants (shading -- regions of pressure decrease; isolines drawn each 4 mb).

The intensification of ascending vertical currents over the continents in this "Arid" variant must not only intensify the descending vertical currents over the ocean and the inflow of moister air onto the continents from the ocean (intensification of planetary monsoonal circulation in the middle latitudes), but also somewhat increase precipitation over the continents. However, a decrease in evaporation over the continents led to both an increase in air temperature and to a decrease in specific humidity and both factors decreased relative humidity to such an extent that this effect exceeded the preceding effect of a possible increase in precipitation over the continents as a result of an intensification of ascending vertical currents over the continents and led to a general decrease in precipitation. Figure 5 shows a map of the influence of drying-out of the continents on the intensification and weakening of different interacting processes.

This numerical experiment demonstrated that the drying-out of the continents can lead to a decrease in precipitation not only over the continents, but also over the ocean; the drying-out of the continents can simultaneously intensify the planetary summer monsoonal circulation in the middle latitudes, which can be an important condition in the annual cycle of climate for summer radiation heating of the ocean.

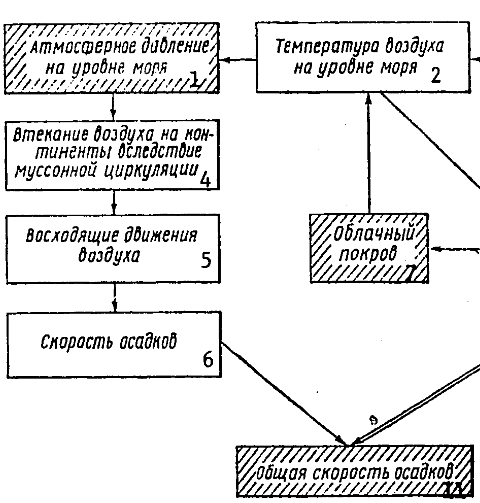

Fig. 5. Diagram of influence of drying-out of the continents on intensification (unshaded rectangles) and weakening (shaded rectangles) of different interacting processes.

KEY:
1. Atmospheric pressure at sea level
2. Air temperature at sea level
3. Rate of evaporation from surface of continents and ocean
4. Inflow of air onto continents as a result of monsoonal circulation
5. Ascending air movements
6. Rate of precipitation
7. Cloud cover
8. Absolute humidity
9. Relative humidity
10. Rate of precipitation
11. Total rate of precipitation

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UDC 551.510.522(-062.4)

CONSTRUCTION OF A MODEL OF THE ATMOSPHERIC BOUNDARY LAYER FOR THE EQUATORIAL ZONE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 12-22

[Article by Professor Ye. M. Dobryshman, Institute of Atmospheric Physics, submitted for publication 22 May 1979]

Abstract: The author analyzes the difficulties involved in constructing a model of the planetary boundary layer for a narrow equatorial zone. The well-known Kuo model of a plane boundary layer is refined and a model of the three-dimensional boundary layer is constructed within the framework of the linear theory. In the latter case the vertical velocity maximum is in the layer 1.5-3.0 km, which agrees with observational data: the angle between the outer zonal flow and the wind velocity vector near the surface is less (31°) than according to the classical Ekman formula (45°).

[Text] The classical formula for the thickness of the planetary boundary layer (PBL), determined from the ratio of the viscosity coefficient ν to the main Coriolis parameter ℓ_1, loses sense at the equator. This occurs because the values $\ell_1 = 2\omega\sin\varphi$ with $\varphi = 0$ become equal to zero, which reflects, in particular, the fact of an impossibility of using the quasi-geostrophic approximation in a narrow equatorial zone with a width of approximately 500 km on each side of the equator [3, 4] ($\omega = 7.29\cdot10^{-5}$ sec^{-1} is the angular velocity of the earth's rotation, φ is geographic latitude). In the equatorial zone the relationships between the wind field and the pressure gradient are extremely complex, not fitting within the framework of such a simple linear operator as the operator of geostrophic correspondence. The fundamental difficulties in formulating a model of the boundary layer (BL) for the equatorial zone are as follows: first, it is necessary to be able to "splice" the model with the Ekman model of the PBL; second, the model must take into account all three wind velocity components in the equatorial zone. The latter circumstance indicates the necessity for drawing upon models of the three-dimensional BL, which, as is well known, is more complex, since these have a number of specific peculiarities [11]. In this article we will refine one of the models of a plane BL and will examine a variant of a model of a spatial BL.

In attempts to formulate a PBL model for the low latitudes using both analytical methods [13] and numerical methods [10], emphasis is on allowance for the vertical wind velocity component w -- one of the principal factors in virtually any circulation mechanism in the equatorial zone. "Qualitative" considerations on the role of w can lead to contradictory results. For example, if we use as a point of departure the general idea of a PBL in which the wind changes with altitude in such a way that there is "pumping" of air, it must be assumed that on the BL boundary near the equator there is a positive vertical velocity component (it gives rise to or favors the convection process). On the other hand, a very simple model of a one-dimensional BL [13], not taking into account the principal peculiarities in the dynamics of the equatorial atmosphere, leads to a solution with general descending movement. The idea behind the formulation of such models is as follows. We will examine a constant zonal flow in the free atmosphere ($u = U_0 = \text{const}$). The system of equations for the BL is taken in the form

$$w \frac{\partial u}{\partial z} = \nu \frac{\partial^2 u}{\partial z^2}; \quad w \frac{\partial v}{\partial z} + 2\omega \frac{y}{r_0} u = \nu \frac{\partial^2 v}{\partial z^2}; \quad \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0; \qquad (1)$$

Here z is the vertical coordinate; y is the horizontal component, reckoned from the equator to the north; $r_0 = 6.37 \cdot 10^6$ m is the earth's mean radius.

System (1) must describe the process in the three-dimensional boundary layer because all three wind velocity components are present. In order to reduce the problem to a plane BL system (1) is integrated for y from the equator (y = 0) to some value y = L ($\approx$500-1,000 km), where the BL structure is close to the structure of the Ekman BL. With y = L the zonal component of wind velocity outside the BL can be determined approximately from the geostrophic relationship. By postulating the nondependence of each of the averaged components on y, we find that the nonlinear terms of the equations of system (1), integrated for y, remain unchanged in form. Thus, for the values

$$\bar{u} = \frac{1}{L}\int_0^L u\,dy; \quad \bar{v} = \frac{1}{L}\int_0^L v\,dy; \quad \bar{w} = \frac{1}{L}\int_0^L w\,dy$$

we obtain the system of equations (the lines over u, v and w have been dropped)

$$w \frac{du}{dz} = \nu \frac{d^2 u}{dz^2}; \quad w \frac{dv}{dz} + \frac{2\omega L}{r_0}\alpha u = \nu \frac{d^2 v}{dz^2}; \quad L \frac{dw}{dz} + v = 0. \qquad (2)$$

The α parameter has been introduced for the sake of universality. Its value is dependent on the hypothesis determining the "averaged" value of the zonal velocity component. In [13] it is assumed that $\alpha = 1$. A more accurate value is $\alpha = 1/2$; in this case the procedure of removing the mean values from the integral sign is identical for all the terms in system (1).

If we exclude u and v, we obtain one nonlinear equation for w in the form

$$\nu \frac{d^2}{dz^2}\left[w \frac{d^2w}{dz^2} - \nu \frac{d^3w}{dz^3}\right] = w \frac{d}{dz}\left[w \frac{d^2w}{dz^2} - \nu \frac{d^3w}{dz^3}\right]. \tag{3}$$

It must be solved with the following boundary conditions:

$$\left.\begin{array}{l} z=0,\quad w=\frac{dw}{dz}=\frac{d^3w}{dz^3}=0 \text{ this is equivalent to } u = v = w = 0). \\ z\to\infty \quad v=0 \Longrightarrow \frac{dw}{dz}=0 \\ u=U_\infty \Longrightarrow \frac{\nu d^3w}{dz^3} - W_\infty \frac{d^2w}{dz^2} + 2\,\omega \frac{\alpha}{r_0} U_\infty = 0. \end{array}\right\} \tag{4}$$

where we use W_∞ to denote the w value when $z \to \infty$; this value is determined from the expression

$$W_\infty = \frac{2\frac{\omega}{r_0}\alpha U_\infty + \nu \left.\frac{d^3w}{dz^3}\right|_{z\to\infty}}{\left.\frac{d^2w}{dz^2}\right|_{z\to\infty}}. \tag{5}$$

(The operator

$$\nu \frac{d^3w}{dz^3} - w \frac{d^2w}{dz^2}$$

is typical for boundary layer problems [11]). Equation (3) cannot be precisely integrated; it is reduced to a nonlinear integrodifferential equation

$$\nu \frac{d^3w}{dz^3} - w \frac{d^2w}{dz^2} = C_1 \int e^{\frac{1}{\nu}\int w dz} dz + C_2^*. \tag{6}$$

[* When $C_2 = 0$ and $C_1 = 80\nu$ equation (6) has the partial solution $w = -5\nu/z$.]

It can be seen from this form of the formula that when $w<0$ equation (6) is conveniently integrated approximately, for example, by iterations.

In the case of westerly flow ($u>0 \Longrightarrow du/dz>0$ in the lower layer of the atmosphere) the turbulence is compensated by the vertical flow u, as follows from the first equation of system (2) or (1). This means that with $u>0$ we should have $w<0$.

As a first approximation it is proposed in [13] that it be assumed that $w = -w_0 = \text{const}$, which after substitution into system (2) reduces it to an easily integrable linear equation. The general integral for the derived equation has the form

$$w = (C_1 + C_2 z)\, e^{-\frac{w_0}{\nu} z} + C_3 + C_4 z + C_5 z^2.$$

If there is rigorous satisfaction of all the conditions (4), then $C_4 = C_5 = 0$; $C_3 = -W$ and for the remaining two arbitrary constants a contradictory system is obtained. Accordingly, Kuo [13] satisfies only one of the conditions and a "correction" is introduced into the second. As a result, for w a solution is obtained which in the adopted notations can be written as follows:

$$w = W_\infty \left\{ \left(1 + \frac{w_0}{\nu} z\right) e^{-\frac{w_0}{\nu} z} - 1 \right\}. \tag{7}$$

In this case w_∞ must be expressed through the parameters of the problem, not depending on the zero approximation ($-w_0$), and specifically U_∞, ν, $2\omega/r_0$. Using the methods of dimensionality theory [1], it can be shown that W_∞ is not uniquely determined through these parameters. In actuality, the combination

$$U_\infty^{1-3p} \nu^{2p} \left(\frac{2\omega}{r_0}\right)^p \tag{8}$$

for any p has the dimensionality of velocity, which in this case can be interpreted as w_∞. In [13] a value was adopted for w_∞ corresponding to p = 1/4 in formula (8). This gives

$$W_\infty = \left[\frac{2\omega}{r_0} U_\infty \nu^2\right]^{\frac{1}{4}}. \tag{9}$$

Assuming $\nu = 10$ m^2·sec^{-1}; $U_\infty = 4$ m·sec^{-1} we obtain $W_\infty \sim 10^{-2}$ m·sec^{-1}.

It is easy to see that

when $p = \frac{1}{5}$ $W_\infty = \sqrt[5]{(U_\infty \nu)^2 \frac{2\omega}{r_0}} \approx 4 \cdot 10^{-2}$ m·sec^{-2};

when $p = \frac{1}{6}$ $W_\infty = \sqrt{U_\infty} \sqrt[3]{\nu} \sqrt[6]{\frac{2\omega}{r_0}} \approx 5 \cdot 10^{-2}$ m·sec^{-1}.

With other "reasonable" assumptions the W_∞ value is unnaturally small (when p = 1/2 $W_\infty \sim 2 \cdot 10^{-5}$ m·sec^{-1}, when p = 1 $W_\infty \sim 10^{-10}$ m·sec^{-1}, etc.).

The continuous curves in Fig. 1 reproduce the results from [13] for u, v, w; the last two functions are easily found from system (2) after substitution there of the zero approximation for w:

$$u = U_\infty \left(1 - e^{-\frac{w_0}{\nu} z}\right); \quad v = L \left(\frac{2\omega}{r_0} U_\infty\right)^{\frac{1}{2}} \frac{w_0}{\nu} z e^{-\frac{w_0}{\nu} z}. \tag{10}$$

The structure of these formulas is similar to the Ekman formulas for the PBL. However, it must be remembered that they were derived at the expense of "coarsening" of both the physical model and the mathematical methods for analysis of the initial system of equations. In addition, the model does not take into account the dynamics of the processes transpiring in the equatorial zone, it is unsuitable with $U_\infty < 0$ -- an easterly flow, which is typical for the equatorial zone [6, 12]. The Kuo model is not cited for critical purposes, but as an illustration of the difficulties arising in formulating a BL model in the low latitudes in general and in the equatorial zone in particular.

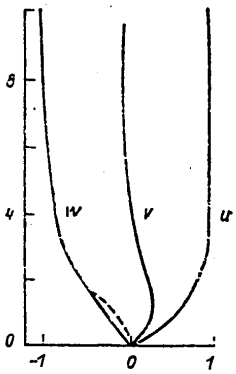

Fig. 1. Vertical profiles of wind velocity components in dimensionless form using the Kuo model [13]. The dashed curve shows the proper value w for small z.

The model can be made more precise, for example, by introducing a parametric dependence on y and stipulating the zero approximation for w not in the form of a constant, but selecting a function of altitude which is more real for the lower layer, for example, a power-law function. We will assume

$$w = -w_0\left(\frac{z}{h}\right)^r, \tag{11}$$

where h is the characteristic height which must be determined proceeding on the basis of dimensionality considerations. As in the case of velocity, the representation of h is unambiguous through the parameters of the problem $2\omega/r_0$; ν; U_∞. Specifically for any p

$$h = \left(\frac{2\omega}{r_0}\right)^p \nu^{1+2p} U_\infty^{-1-3p}.$$

The h values "reasonable" from the point of view of interpretation of BL theory are obtained, for example, for

$p = -\frac{1}{4}$ $h = \sqrt[4]{\frac{r_0}{2\omega}\nu\frac{1}{U_\infty}} \approx 10^3$ м; for $p = -\frac{1}{5}$ $h = \sqrt[5]{\frac{r_0}{2\omega}\nu^3\frac{1}{U_\infty^2}} \approx$ $\approx 0.3\cdot10^3$ m. Nonallowance for the Rossby parameter (p = 0) leads to the unexpected result: $h = \nu/U_\infty \approx 2$ m. It is probably possible to interpret this result as follows: this is the characteristic thickness of the Prandtl boundary layer, which is unrelated to the macrocirculation mechanism. Here the scales are completely different: $W \sim O(u)$.

Then, the parameter $r > 1$. In actuality, from the continuity equation

$$w = -\int_0^z \frac{\partial v}{\partial y}\, dz$$

and by virtue of the condition $v|_{z=0} = 0$ for the function w the point $z = 0$ must be zero of a higher order than for v; $\Longrightarrow r > 1$.

Substituting (11) into the first equation of system (1), we obtain

$$-\frac{w_0}{h^r} z^r \frac{\partial u}{\partial z} = \nu \frac{\partial^2 u}{\partial z^2} \Longrightarrow u = C_1 + C_2 \int_0^z e^{-\frac{w_0 z^{1+r}}{\nu h^r (1+r)}}\, dz.$$

Satisfying the boundary conditions, we find u in the form

$$u = U_\infty(y) \frac{\gamma\left(\frac{w_0}{\nu h^r (1+r)} z^{1+r}, \frac{1}{r+1}\right)}{\Gamma\left(\frac{1}{r+1}\right)}, \tag{12}$$

where $\gamma(p, q)$ and $\Gamma(p)$ are the incomplete and complete Euler gamma functions respectively [2].

Substituting (11) and (12) into the second equation of system (1), we obtain for v a linear inhomogeneous equation whose solution can be represented in the form

$$v = [V_\infty(y) - A(y)] \frac{u(y, z)}{U_\infty(y)} + \int_0^z e^{-\frac{w_0 z_1^{r+1}}{\nu h^r (r+1)}}\, dz_1 \times \tag{13}$$

$$\times \int_0^{z_1} Q(z_2, y)\, e^{\frac{w_0}{\nu (rH) h^r} z_2^{r+1}}\, dz_2,$$

where, for the sake of brevity, we have introduced the notations

$$V_\infty(y) = v(y, z)|_{z \to \infty};$$

$$A(y) = \int_0^\infty e^{-\frac{w_0 z_1^{r+1}}{\nu (r+1) h^2}}\, dz_1 \int_0^{z_1} Q(z_2, y)\, e^{\frac{w_0}{\nu h^2} \frac{z_2^{r+1}}{r+1}}\, dz_2; \tag{14}$$

$$Q(z, y) = -2 \omega \frac{y}{r_0} u(y, z).$$

(It is easy to confirm that all the integrals entering into (13) and (14) converge: w_0, h, ν, $r - 1 > 0$).

Differentiating (13) for y and then integrating for z, we obtain a more precise formula for w(z) than (11):

$$w = -\frac{V'_\infty(y) - A'(y)}{\Gamma\left(\frac{1}{r+1}\right)} \int_0^z \gamma\left(\frac{w_0 z_1^{r+1}}{\nu h^r (r+1)}; \frac{1}{r+1}\right) dz_1 - \tag{15}$$

$$-\int_0^z \int_0^{z_1} e^{-\frac{w_0 z_2^{r+1}}{\nu h^r (r+1)}} \int_0^{z_2} \frac{dQ(z_3, y)}{dy}\, e^{\frac{w_0 z_2^{r+1}}{\nu h^r (r+1)}}\, dz_3\, dz_2\, dz_1.$$

An analysis of formulas (12), (13) and (14) shows that with small z $u \sim z$; $v \sim z$; $w \sim z^2$. Therefore, evidently, as a zero approximation it is natural to take $w = -w_0(z/h)^2$, that is, assume $r = 2$. In this case the gamma functions will be of the parameter 1/3.

Strictly speaking, the dependence of the functions on y is not "purely" parametric -- the derivatives of y enter into the expression for (15).

As U_∞ and V_∞ it is possible to take a suitable solution corresponding to a stationary model of circulation; in the simplest case it is possible to obtain a solution, for example, from [3]:

$$U_\infty = u_0 - \omega \frac{y^2}{r_0}; \quad V_\infty = \sqrt{-\frac{2\omega}{r_0} u_0}\sqrt{1 - \frac{2\omega}{r_0 u_0} y^2}$$

($u_0 < 0$ is easterly flow).

As can be seen from the solution found (13)-(15), allowance for the nonlinear terms, even in very approximate form, by the stipulation of w in the form (11), which actually brought about linearization, to some degree made it possible to reflect the interrelationship between the boundary layer and the external circulation mechanism.

Now we will proceed to an examination of another model in which the spatial structure of the BL is manifested more clearly than in the case considered above. This linear model is based on the same Ekman idea -- a correspondence between dissipative forces and Coriolis accelerations with a stipulated pressure gradient $\partial\Phi/\partial y$. We will write the initial system of equations in the form

$$\left.\begin{aligned} &\nu \frac{\partial^2 u}{\partial z^2} + 2\omega w = 0 \\ &\nu \frac{\partial^2 v}{\partial z^2} + 2\omega \frac{y}{r_0} u + \frac{\partial \Phi}{\partial y} = 0 \\ &\frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \end{aligned}\right\}. \qquad (16)$$

Here in the first equation we have omitted the term $-2\omega y/r_0\, v$ for two reasons. The basic reason is a peculiarity characteristic for any BL: the basic wall (underlying surface) effect is the appearance of a mass flow in the direction perpendicular to the wall. Accordingly, in the BL the terms with w are more important than the terms with v -- velocity "across" is less than the velocity "along" the main external flow $|v| < |u|$. Second, allowance for the discarded term complicates the algebraic part of formulation of the model, which is scarcely justified in such a rough (linear) model, presented for the most part to illustrate the overall qualitative picture and the difficulties in formulating a good model. This simplification should not have a strong effect on the characteristic of particular interest -- w. We can formally introduce a small parameter in front of the term

$$-2\omega \frac{y}{r_0} v$$

and seek a solution in the form of a series in powers of this small parameter: in the zero approximation this term disappears.

Excluding v and w from system (16), we obtain one equation for u

$$\nu \frac{\partial^5 u}{\partial z^5} + 4\,\omega^2 \frac{\partial}{\partial y} \frac{y}{r_0}\, u = -2\,\omega \frac{\partial^2 \Phi}{\partial y^2}. \tag{17}$$

In the BL the pressure gradient is naturally considered to be independent of altitude. Assuming that the solution (17) can be represented in the form of the product

$$u = u_1(y)\, u_2(z), \tag{18}$$

we find

$$u_1 = C y^{-(1-\lambda r_0)^*} \tag{18'}$$

[It will be assumed that u_1 is a dimensionless function and u_2 and thereafter v_2 and w_2 are functions having the dimensionality of velocity.]

where λ is the separation constant. We will determine it from the condition that outside the BL the velocity of the zonal flow should be dependent on y in the same way that this is determined in the problem of the circulation mechanism without taking dissipative forces into account. In the simplest case, with a symmetric distribution of pressure $u \sim y^2$. Hence $\lambda = -3/r_0$.

This means,

$$u_1 = \frac{y^2}{L^2}, \tag{19}$$

where L corresponds to the latitude at which u can be determined from the geostrophic relationship. As is easily checked, in this case the pressure gradient will be a function of the type

$$\frac{\partial \Phi}{\partial y} \sim y^3.$$

For $u_2(z)$ we obtain the equation

$$\frac{d^5 u_2}{dz^5} + \frac{12\,\omega^2}{\nu^2 r_0}\, u_2 = \frac{\mu}{\nu}. \tag{20}$$

The roots of the characteristic equation are $S^5 + 12\,\frac{\omega^2}{\nu^2 r_0} = 0$.

$$S_k = \sqrt[5]{\frac{12\,\omega^2}{\nu^2 r_0}} \left[\cos\frac{\pi}{5}(2k-1) + i \sin\frac{\pi}{5}(2k-1)\right],\ k = 1, 2, 3, 4, 5. \tag{21}$$

It can be seen from this formula that S_1 and S_5 have a positive real part. Accordingly, the arbitrary constants with these solutions must be assumed equal to zero.

Thus, the solution (20) can be written in the form

$$u_2(z) = U_\infty + C_2 e^{S_2 z} + C_3 e^{S_3 z} + C_4 e^{S_4 z},$$

where U_∞ corresponds to a partial solution of the inhomogeneous equation. Hence we find μ:

$$\frac{12\,\omega^2}{\nu^2 r_0} U_\infty = \frac{\mu}{\nu} \Longrightarrow \mu = \frac{12\,\omega^2}{\nu^2 r_0} U_\infty.$$

In order to determine the integration constants it is necessary to stipulate three conditions:

1)

$$z=0 \quad u=0 \Longrightarrow u_2=0,$$

which gives

$$C_2+C_3+C_4=-U_\infty.$$

2)

$$z=0 \quad w=0 \Longrightarrow \frac{d^2 u_2}{dz^2}=0,$$

we obtain

$$C_2 S_2^2 + C_3 S_3^2 + C_4 S_4^2 = 0.$$

3) From the continuity equation

$$\left.\frac{\partial v}{\partial y}\right|_{z=0} = 0 \Longrightarrow$$

$$\left.\frac{\partial w}{\partial z}\right|_{z=0} = 0 \Longrightarrow \left.\frac{d^3 u_2}{dz^3}\right|_{z=0} = 0.$$

Thus, the third equation will be

$$C_2 S_2^3 + C_3 S_3^3 + C_4 S_4^3 = 0.$$

Solving a system of three equations relative to C_2, C_3, C_4, taking into account the values of the roots S_k, we find their powers S_k^j and make use of the Euler formulas

$$e^{\pm ix} = \cos x \pm i \sin x$$

$$C_2 = C_4 = -U_\infty \frac{\sin\frac{\pi}{5}}{2\sin\frac{\pi}{5} + \sin\frac{3\pi}{5}} \approx -0{,}276\ U_\infty,$$

$$C_3 = -U_\infty \frac{\sin\frac{3\pi}{5}}{2\sin\frac{\pi}{5} + \sin\frac{3\pi}{5}} \approx -0{,}447\ U_\infty.$$

Combining the results, we write u_2 in the form

$$u_2(\zeta)=U_\infty\left\{1-\frac{1}{2\sin\frac{\pi}{5}+\cos\frac{\pi}{10}}\left[e^{-\zeta}\cos\frac{\pi}{10}+\right.\right. \tag{22}$$

$$\left.\left.+2e^{-\zeta\sin\frac{\pi}{10}}\sin\frac{\pi}{5}\cos\left(\zeta\cos\frac{\pi}{10}\right)\right]\right\},$$

where, for the sake of brevity, we introduce the notation

$$\zeta=\sqrt[5]{\frac{12\,\omega^2}{\nu^2 r_0}}\,z.$$

Assuming the value $\nu = 10\ \mathrm{m^2 \cdot sec^{-1}}$ to be usual for the turbulence coefficient, we obtain

$$\zeta\approx 10^{-3}z\quad (z \text{ in m}).$$

The working formula for computing $u(y, z)$ can now be represented as

$$u=U_\infty\frac{y^2}{L^2}\left\{1-0{,}447\,e^{-z}-0{,}553\,e^{-0{,}309\,z}\cos(0{,}951\,z)\right\},$$

where z, y are in km, $L \sim 500$ km.

From the first equation in system (16) we find

$$w=-\frac{\nu}{2\omega}\frac{\partial^2 u}{\partial z^2}.$$

This means that the dependence of w on altitude will be determined using the formula

$$w_2=U_\infty\frac{\nu}{2\omega}\sqrt[5]{\left(\frac{12\,\omega^2}{\nu^2 r_0}\right)^2}\frac{1}{2\sin\frac{\pi}{5}+\cos\frac{\pi}{10}}\left\{\cos\frac{\pi}{10}\cdot e^{-\zeta}-\right. \tag{23}$$

$$\left.-2\sin\frac{\pi}{5}\,e^{-\zeta\sin\frac{\pi}{10}}\cos\left(\frac{\pi}{5}+\zeta\cos\frac{\pi}{10}\right)\right\}.$$

From the continuity equation we find the dependence of v on altitude:

$$v_2(\zeta)=U_\infty L\sqrt[5]{\frac{54\,\omega}{\nu r_0^3}}\frac{1}{2\sin\frac{\pi}{5}+\cos\frac{\pi}{10}}\left\{-\cos\frac{\pi}{10}\,e^{-\zeta}+\right. \tag{24}$$

$$\left.+2\sin\frac{\pi}{5}\,e^{-\zeta\sin\frac{\pi}{10}}\sin\left(\frac{3\pi}{10}+\zeta\cos\frac{\pi}{10}\right)\right\}.$$

Expanding (22), (23) and (24) into a series of powers of z it is easy to show that with small z we will have

$$u_2 \sim z; \qquad v_2 \sim z; \qquad w_2 \sim z^2.$$

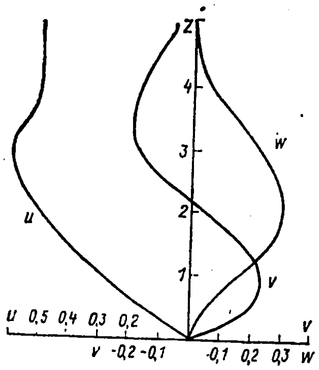

Fig. 2. Vertical profiles of wind velocity components in dimensionless form using model (16). In order to facilitate reading of the diagram the positive direction for u is indicated to the left.

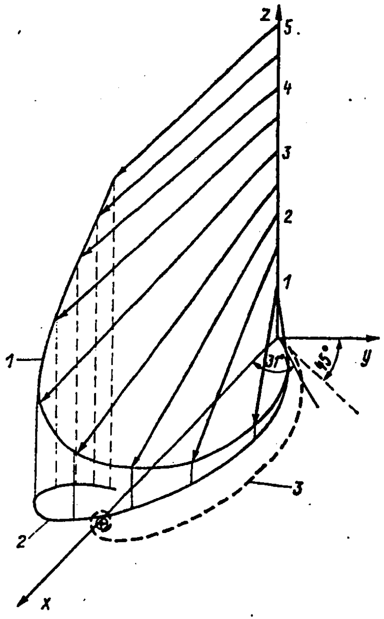

Fig. 3. Hodograph of wind velocity (1), its projection onto the horizontal plane (2) and the Ekman spiral (3). The small cross indicates the limiting value (with $z \to \infty$) of the velocity hodograph projection. It can be seen that in accordance with model (16) a tendency to the limiting value occurs far more slowly than according to the Ackerblom model.

With respect to the dependence on y, for w it evidently will be the same as for u, but for

$$v \sim \frac{y^3}{3L^3}.$$

In general, from the point of view of BL theory the function $U_\infty(y)$ is considered stipulated and it can be selected, to a certain degree, arbitrarily. If in (18') it is assumed that $1 - \lambda r_0 = 0$, that is, if it is assumed that U_∞ = const, then only the one function v will be dependent on y. (In this case $\partial\Phi/\partial y \sim y$). The dependence of the solutions on z does not change. Such a model is justified by the fact that when y = 0, that is, on the equator, the boundary layer does not disappear: the components u and w are not different from zero.

In such models $w \to 0$ when $z \to \infty$, which cannot be the case for a plane boundary layer: in a three-dimensional case there is a possibility for compensating the vertical flow due to a change in the second component of horizontal velocity. In these models u can be of any sign. Figure 2 shows the $u_2(\zeta)$, $v_2(\zeta)$ and $w_2(\zeta)$ profiles in dimensionless values. Normalization was carried out for the corresponding factors

$$U_\infty; \quad U_\infty \frac{\nu}{2\omega} \sqrt[5]{\left(\frac{12\omega^r}{\nu^r r_0}\right)^2}; \quad U_\infty \sqrt[5]{\frac{54\omega}{\nu r_0^3}}.$$

Figure 3 is a velocity hodograph for y = 1 and its projection onto the plane xoy. It can be seen clearly from the figure that $w \to 0$ when $z \to \infty$ due to the fact that aloft v fluctuates near zero with an attenuating amplitude.

It should be noted that the main maximum w falls on the value $\zeta \approx 2.0$. In dimensional values this means that in the layer 1.5 to 3.0 km vertical movements are particularly appreciable. This agrees fairly well with the results obtained during GATE (Atlantic Tropical Experiment - an international program carried out in the summer of 1974 [12]).

One of the characteristics which is usually determined in models of the atmospheric boundary layer is the angle between the isobar and the limiting position of the velocity vector when z = 0, that is, at the earth's surface. In this case it is correct to speak of the angle between the wind direction outside the BL and the limiting value when z = 0, although actually these concepts coincide here: the isobars run parallel to the equator and the principal external flow is zonal. In the classical Ackerblom model [7], as is well known (when ν = const) this angle is $\alpha = 45°$. However, in general it is dependent on the turbulence regime (on stratification) in the boundary layer [9], but it is less than 45°. It is easy to compute this angle for the considered model as well:

$$\operatorname{tg}\alpha = \lim_{z\to 0}\frac{v}{u} = \lim_{z\to 0}\frac{v_2(z)}{u_2(z)} = L\sqrt[5]{\frac{54\omega}{\nu r_0^3}}\,\frac{1-\sin\frac{\pi}{10}}{1+2\operatorname{tg}\frac{\pi}{10}\sin\frac{2\pi}{10}}.$$

Digressing from the dimensionless factor, which with the selected values of the parameters is the value O(1), we find $\alpha \approx 31°$. To be sure, this is only an approximate value whose main sense is that it is less than 45° -- the model value for the PBL characteristic outside the equatorial zone.

Despite a number of shortcomings the considered model of a three-dimensional boundary layer reflects some qualitative aspects of the processes transpiring in the lower layers of the troposphere in the equatorial zone: a maximum of vertical movements in the layer 1.5-3.0 km; a tendency to its limiting values of the wind velocity components with altitude slower in comparison with the PBL; a lesser angle between the main flow outside the BL and flow at the earth's surface.

I consider it my duty to express appreciation to I. B. Kazitskaya for assistance in finalizing the article.

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SMALL OSCILLATIONS OF THE POLYTROPIC ATMOSPHERE AND THE FILTERING ROLE OF THE HYDROSTATIC APPROXIMATION

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[Article by Candidate of Physical and Mathematical Sciences V. M. Kadyshnikov, USSR Hydrometeorological Scientific Research Center, submitted for publication 23 May 1979]

Abstract: The article gives a comparison of the frequency spectra of wave movements of the polytropic atmosphere in nonhydrostatic and hydrostatic cases. In the first case the dependence of the solution on altitude is described by confluent hypergeometric functions, and in the second case -- by Bessel functions. It is shown that the hydrostatic approximation, as in an isothermic atmosphere, filters out acoustic oscillations and considerably distorts the first modes (that is, those changing least with altitude) of gravitational oscillations only with a wavelength shorter than 100 km.

[Text] In [6] the authors obtained an analytical solution of the problem of small oscillations of a nonhydrostatic atmosphere under the condition that the linearization of the equations of hydrothermodynamics is carried out relative to an isothermic state. An analysis of this solution indicated that the atmosphere is characterized by wave processes of different nature, to wit: there are high-frequency acoustic and low-frequency gravitational oscillations. It was also demonstrated that the hydrostaticity hypothesis filters out acoustic waves and the spectrum of gravitational oscillations is distorted the lesser the longer the corresponding wave. In [2] a similar problem was examined for a model of the atmosphere with a real temperature stratification, but the solution obtained to a considerable degree is qualitative. In our article [4] we gave an analytical solution for a neutrally stratified atmosphere. In such an atmosphere there are no gravitational waves. The objective of this article is solution of the problem of small oscillations in a stably stratified, nonhydrostatic, polytropic atmosphere and a quantitative evaluation of the role of a hydrostatic approximation in this case.

As demonstrated in [6], the system of equations in hydrothermodynamics linearized relative to a state of rest has the form

$$u_t = -p_x + lv, \quad v_t = -p_y - lu, \quad w_t = -p_z - \rho g,$$
$$\rho_t = -(u_x + v_y + w_z), \quad p_t = -\Gamma w - c^2 (u_x + v_y + w_z), \tag{1}$$

where u, v, w are $\bar{\rho} u^*$, $\bar{\rho} v^*$, $\bar{\rho} w^*$: $\bar{\rho}$ is the density of the main state (its pressure and temperature are $\bar{p}$ and $\bar{T}$; all these three functions are dependent only on z), and u^*, v^*, w^* are velocity vector components; p and ρ are the deviations of pressure and density from the corresponding values of the main state; l is the Coriolis parameter (constant), g is the acceleration of free falling, $c^2 = \varkappa \bar{p}/\bar{\rho}$, $\varkappa$ is the ratio of heat capacities, $\Gamma = \varkappa R(\gamma_a - \gamma)$ is the stratification parameter, R is the gas constant, γ_a is the dry adiabatic vertical temperature gradient, $\gamma = -d\bar{T}/dz$.

We will solve the problem with initial conditions periodic relative to x, y. Now we will consider formulation of boundary conditions for z. We will assume that the underlying surface is impermeable, that is, at the earth $w^* = 0$. This gives

$$w = 0 \qquad (z = 0). \tag{2}$$

For formulation of the second condition we note that the following formula follows from system (1) [6]:

$$E_t + (u^* p)_x + (v^* p)_y + (w^* p)_z = 0,$$

where the quadratic form (energy) is

$$E = \frac{u^2 + v^2 + w^2}{2\bar{\rho}} + \frac{1}{2\bar{\rho} c^2}\left[p^2 + \frac{g}{\Gamma}(p - c^2 \rho)^2\right]. \tag{3}$$

If, accordingly, from the initial data it is required that

$$\int_0^\infty \left(\iint_D E\, dx\, dy \right) dz < \infty \tag{4}$$

(D is the periodicity region), then with condition (2) and the condition $(w^* P)_{z \to \infty} \to 0$, that is

$$\frac{wp}{\bar{\rho}} \to 0 \ (z \to \infty), \tag{5}$$

the energy of the system will be conserved. Moreover, below we will confirm that if we take (4), rather than (5) for all $t > 0$ as the second condition, condition (5) will be automatically satisfied, that is, from the limitation of energy follows its conservation.

Thus, we will seek a periodic solution of the system of equations (1) under conditions (2) and (5). As already mentioned, the γ value falling between 0 and γ_a is considered constant, so that Γ = const. The altitude of the polytropic atmosphere H is finite and equal to $\overline{T}_0/\overline{\gamma}$, where $\overline{T}_0 = \overline{T}\big|_{z=0}$. We will represent all the functions in the form

$$f(x, y, z, t) = \tilde{f}(z) \exp i(k_x x + k_y y - \lambda t).$$

It follows from the equations of horizontal motion that the amplitude of plane divergence is,

$$\frac{i\lambda k^2}{\lambda^2 - l^2}\tilde{p},$$

where $k^2 = k_x^2 + k_y^2$. We introduce three-dimensional divergence $\chi = u_x + v_y + w_z$. We have

$$\tilde{\chi} = \frac{i\lambda k^2}{\lambda^2 - l^2}\tilde{p} + \tilde{w}_z. \tag{6}$$

The third equation of motion (with the continuity equation taken into account) and the heat influx equation give, respectively

$$-i\lambda\tilde{w} + \tilde{p}_z - \frac{ig}{\lambda}\tilde{\chi} = 0, \tag{7}$$

$$-i\lambda\tilde{p} + \Gamma\tilde{w} + c^2\tilde{\chi} = 0. \tag{8}$$

We have a system of three ordinary differential equations (6)-(8) for the functions $\tilde{\chi}$, $\tilde{p}$ and $\tilde{w}$. We will write an equation for some one of them. Since the coefficients of the system are variable (c^2 is a function of z), for each function there will be a specific equation. It is convenient to examine the equation for $\tilde{\chi}$; its eigenfunctions are single-term functions (it goes without saying that the final solution of the problem is not dependent on the choice).

We will express $\tilde{p}$ from (8). Then we differentiate this expression and we will substitute the $\tilde{p}$ and $\tilde{p}_z$ values into (6) and (7). We will solve the derived system of two equations as an algebraic system relative to $\tilde{w}$ and $\tilde{w}_z$. In particular, we have ($c^2 = s$),

$$\tilde{w} = -\frac{\varkappa R\overline{\gamma}(\lambda^2 - l^2)}{\lambda^2(\lambda^2 - l^2) - k^2\Gamma^2}\left[\left(\frac{g+\Gamma}{\varkappa R\overline{\gamma}} - 1 - \right.\right. \tag{9}$$

$$\left.\left. - \frac{k^2\Gamma}{\varkappa R\overline{\gamma}(\lambda^2 - l^2)}\, s\right)\tilde{\chi} - s\tilde{\chi}_s\right].$$

Differentiating this expression and comparing it with the already determined $\tilde{w}_z$, we obtain

$$s\tilde{\chi}_{ss} - \left(\frac{g+\Gamma}{s_1} - 2\right)\tilde{\chi}_s + \left[-\frac{\lambda^2 k^2}{s_1^2(\lambda^2 - l^2)}s + \frac{\lambda^2}{s_1^2} + \frac{gk^2\Gamma}{s_1^2(\lambda^2 - l^2)}\right]\tilde{\chi} = 0, \tag{10}$$

where

$$s \equiv c^2 = s_0 - s_1 z \qquad (s_0 = \varkappa R\overline{T}_0,\ s_1 = \varkappa R\overline{\gamma}).$$

In the derivation of this equation we had to exclude from consideration the roots of the equation

$$\lambda(\lambda^2-l^2)\,[\lambda^2(\lambda^2-l^2)-k^2\Gamma^2]=0. \tag{11}$$

They must be investigated separately. It is easy to show that the frequency $\lambda = 0$ is the solution of our problem. It corresponds to a geostrophic hydrostatic case. However, the λ values, bringing the terms in parentheses and brackets to 0 in (11), are not solutions: in the first case from (7) and (8) for $\tilde{w}$ and $\tilde{\chi}$ we obtain a homogeneous algebraic system of equations with a determinant different from zero only at the one point where the linear function c^2 is $g\Gamma/\ell^2$, whereas according to the equations of motion $\tilde{p}\equiv 0$; in the second case, from (6)-(8) we obtain a similar system for $\tilde{\chi}$ and $\tilde{\chi}_s$, which can be different from 0 also only at one point where c^2 is Γ^2/λ^2; it therefore follows that there are no continuous nontrivial solutions in the two cases.

The solution of the fundamental equation (10) of the problem is

$$\tilde{\chi}=C_1y_1(s)+C_2y_2(s), \tag{12}$$

where C_1 and C_2 are integration constants and the linearly independent special solutions are [5]

$$\begin{gathered} y_1=e^{-\frac{\alpha_s}{2}}\,\Phi\left(1-\frac{b}{2}-\beta,\ 2-b,\ \alpha_s\right), \\ y_2=s^{b-1}\,e^{-\frac{\alpha_s}{2}}\,\Phi\left(\frac{b}{2}-\beta,\ b,\ \alpha_s\right), \end{gathered} \tag{13}$$

and the function of the three arguments $\Phi(r, m, x)$ is a confluent hypergeometric function (8), determined by a Pochhammer series

$$\Phi=1+\sum_{n=1}^{\infty}\frac{r\,(r+1)\ldots(r+n-1)}{m\,(m+1)\ldots(m+n-1)}\,\frac{x^n}{n!}. \tag{14}$$

Here we have introduced the notations

$$\alpha_s=\frac{2\lambda k}{s_1\sqrt{\lambda^2-l^2}}\,s,\quad \beta=\frac{\lambda^2(\lambda^2-l^2)+gk^2\Gamma}{2\lambda k s_1\sqrt{\lambda^2-l^2}},\quad b=\frac{g+\Gamma}{s_1}. \tag{15}$$

Using (9), and in particular, the fact that when $s\to 0$ $\tilde{w}\sim s\,\tilde{\chi}_s-(b-1)\tilde{\chi}$, and also that $\tilde{p}\sim\tilde{w}$ (this, incidentally, confirms the advantage of reduction of system (6)-(8) to an equation specifically for $\tilde{\chi}$), we substitute the resulting solution into condition (5), in a polytropic atmosphere existing, as already noted, when $s = 0$. Since $\bar{\rho}\sim s^b$, this gives

$$a_1C_1^2+a_{12}C_1C_2+a_2C_2^2=0,$$

and a_1 is a linear combination of the powers s^{2-b}, s^{1-b}, s^{-b}, a_{12} -- the powers s^1, s^0, s^{-1}; a_2 -- the powers s^b, s^{b-1}, s^{b-2}. Since

$$b=\frac{\varkappa}{\varkappa-1}\frac{\gamma_a}{\gamma}-1=\frac{7}{2}\frac{\gamma_a}{\gamma}-1>2,$$

$C_1 = 0$ and the C_2 coefficient can be arbitrary. Thus, with an accuracy to a constant factor the solution of equation (10), satisfying condition (5), has the form

$$\tilde{\chi} = s^{b-1} e^{-\frac{a_s}{2}} \Phi\left(\frac{b}{2} - \beta, b, a_s\right). \qquad (16)$$

If we found the remaining amplitudes from the function $\check{\chi}$, determined by formulas (12)-(15), and formed energy E from formula (3), condition (4) for all $t > 0$ would yield this same solution. Accordingly, we see that its conservation will follow from the condition of restriction on the total energy.

We will make two comments. First: the solution (16) was obtained proceeding on the basis that (13) are special solutions. But the latter is correct under the condition that the difference in the roots of the determining equation [7] for (10), but the roots in this case are $b - 1$ and 0, is not a whole number. Otherwise the second argument of the Φ function for one of y_i, in accordance with (13), is a whole negative number, and in accordance with (14) the eigenfunction does not exist. But, for example, with $\bar{\gamma}$ close to the real value 5.83 K/km, this is a whole number. Nevertheless, in this case the solution of equation (10) under the condition (5) is the function (16). In actuality, in the neighborhood of the regular singularity $s = 0$ in this exceptional case as one independent solution, as before it is necessary to take y_2 (this corresponds to the greater root of the determining equation), and as the other, not y_1, but the expression $P(s) + \tilde{a}y_1 \ln s$, where $\tilde{a}$ is some number and $P(s)$ is a power series with a free term [7]. But only this, and specifically the presence of a free term in the function y_1, was used in the proof that $C_1 = 0$.

The second remark is as follows: we will assume that $0 < \bar{\gamma} < \gamma_a$. When $\bar{\gamma} = \gamma_a$ there is also a solution of the formulated problem [4]. At the same time, oscillations of the isothermic atmosphere with restricted energy are not possible. In actuality, in this case c^2 = const and the equation for p is the same as for $\tilde{\chi}$:

$$\tilde{p}_{zz} + \frac{g+\Gamma}{c^2}\tilde{p}_z + \left[\frac{\lambda^2}{c^2} - \frac{k^2\lambda^2}{\lambda^2 - l^2}\left(1 - \frac{g\Gamma}{c^2\lambda^2}\right)\right]\tilde{p} = 0.$$

We denote $g + \Gamma/2\ c^2$ by r and introduce R in such a way that the characteristic equation assumes the form $x^2 + 2rx + r^2 - R = 0$. There can be three forms of the dependence of $\tilde{p}$ on z:

$$e^{-rz}\left(C_1 \sin z\sqrt{-R} + C_2 \cos z\sqrt{-R}\right) \quad (R < 0),$$
$$e^{-rz}\left(C_1 + C_2 z\right) \quad (R = 0),$$
$$e^{-rz}\left(C_1 e^{z\sqrt{R}} + C_2 e^{-z\sqrt{R}}\right) \quad (R > 0).$$

Taking into account that $\tilde{w} \sim \tilde{p}_z + g/c^2\, \tilde{p}$, and $\tilde{\rho} \sim e^{-2rz}$, we conclude that condition (5) in the first two cases is not satisfied by the two special solutions, and in the third case, although it is satisfied, the lower boundary condition (2) requires from it that

$$\left[\frac{(2-\varkappa)\, g}{2c^2}\right]^2 = \left(\frac{g+\Gamma}{2c^2}\right)^2 - \frac{\lambda^2}{c^2} + \frac{k^2\lambda^2}{\lambda^2 - l^2}\left(1 - \frac{g\Gamma}{c^2\lambda^2}\right).$$

If this condition is satisfied, then $\tilde{w} = 0$. The corresponding λ values can be found. However, it is clear that it is impossible to solve the problem with any general initial conditions.

Now we substitute solution (16) into the lower boundary condition (2). Using (9), we obtain the dispersion expression in the form

$$\left(1 - \frac{2\beta}{b}\right) \Phi\left(\frac{b}{2} - \beta + 1,\ b+1,\ \alpha\right) = \left(1 - \frac{\Gamma}{S_\pm}\right) \Phi\left(\frac{b}{2} - \beta,\ b,\ \alpha\right), \qquad (17)$$

where

$$S_\pm = s_1\beta \pm \sqrt{(s_1\beta)^2 - g\Gamma}, \quad \alpha = \alpha_s|_{s=s_0}. \qquad (18)$$

In this case we considered that, in accordance with (15),

$$\lambda^2 = \frac{\alpha}{2H} S, \quad k = \frac{\alpha}{2H} \frac{\sqrt{\lambda^2 - l^2}}{\lambda}. \qquad (19)$$

Equation (17) determines in the plane of the variables α, β two families of curves corresponding to the values S_+ and S_-. The first family corresponds to acoustic waves because it owes its existence to atmospheric compressibility. In actuality, we will assume that the atmosphere is incompressible, that is, $\varkappa \to \infty$ [6]. This means that the parameters Γ, s_0, s_1 also tend to infinity. This is in no way reflected in determination of the α parameter in (15). At the same time

$$\beta \to \frac{gk(\gamma_n - \bar{\gamma})}{2\lambda\bar{\gamma}\gamma\sqrt{\lambda^2 - l^2}}.$$

Accordingly, in accordance with (18), $S_+ \to \infty$. Thus, in accordance with (19), $\lambda \to \infty$, that is, the assumption made actually filters out oscillations of this family. In this case

$$S_- \to \frac{\lambda\gamma\sqrt{\lambda^2 - l^2}}{k}.$$

The second family corresponds to gravitational waves because it owes its existence to the presence of stratification. In actuality, with $\Gamma = 0$ the parameter $S_- = 0$, so that $\lambda = 0$.

It follows from the conservation of energy that all λ are real. Below it will be demonstrated that $\lambda^2 > l^2$, that is, α and β are also real. It can be seen from (15) that $\alpha\beta > 0$. Now we will first examine the case $\alpha > 0$, $\beta > 0$, and then we will show that the case $\alpha < 0$, $\beta < 0$ does not contain new solutions. According to (18), it is necessary to consider only

$$\beta \geq \frac{\sqrt{g\Gamma}}{s_1}, \quad \text{and with} \quad \beta = \frac{\sqrt{g\Gamma}}{s_1}$$

the curves of both families merge. Since $\lambda^2 > \ell^2$, there is, in accordance with (19), also a restriction on α: acoustic solutions must be considered only for $\alpha > H\ell^2/s_1\beta$, and gravitational solutions -- for

$$\alpha > \frac{4Hs_1\ell^2}{g\Gamma}\beta.$$

In some special cases:

1) $\beta \gg \alpha$, $\beta \gg b$, $\beta \gg 1$; $\alpha \neq 0$,
2) $\alpha \ll 1$,
3) $\alpha \gg \beta$, $\alpha \gg b$, $\alpha \gg 1$,

the solution of the transcendental equation (17) can be found in explicit form using the asymptotic formulas for confluent hypergeometric functions. The corresponding solutions are of interest because they describe important cases of long and short waves of practical interest.

In case 1, in accordance with [1], we have

$$\Phi\left(\frac{b}{2} - \beta,\ b,\ \alpha\right) \approx \frac{(b-1)!}{\sqrt{\pi}}\, e^{\frac{\alpha}{2}} (\alpha\beta)^{\frac{1-2b}{4}} \cos\left(2\sqrt{\alpha\beta} + \pi\,\frac{1-2b}{4}\right). \qquad (20)$$

In this case for acoustic waves $S_+ \approx 2s_1\beta$. Therefore, substituting (20) into (17), we obtain

$$\operatorname{tg}\left(\delta + \pi\,\frac{1-2b}{4}\right) = -\frac{\alpha}{\delta} \quad (\delta = 2\sqrt{\alpha\beta}). \qquad (21)$$

In particular, for

$$\delta \gg 1 \quad \alpha\beta = \left[\frac{\pi}{2}\left(n + \frac{2b-1}{4}\right)\right]^2,$$

where $n > 0$ is a sufficiently large whole number. For gravitational waves $S_- \approx g\Gamma/2s_1\beta$. Accordingly, similar to the preceding,

$$\operatorname{tg}\left(\delta + \pi\,\frac{1-2b}{4}\right) = \frac{s_1\delta}{2g}. \qquad (22)$$

In particular, for $\quad \delta \gg 1 \quad \alpha\beta = \left[\frac{\pi}{2}\left(n + \frac{2b+1}{4}\right)\right]^2,$

where $n > 0$ is a sufficiently large whole number.

We note that the several first solutions of equations (21) and (22) can be parasitic because sufficiently small δ values under the condition $\beta \gg b$ can lead to α values which are too small. The hyperbolic equations approximately following from (21) and (22) can be joined into one:

$$\alpha\beta = \left[\frac{\pi}{2}\left(n + \frac{2o \mp 1}{4}\right)\right]^2 \equiv q_\pm. \tag{23}$$

Here and in the text which follows the subscripts "+" and "-" will relate to the acoustic and gravitational families respectively.

In case 2 we make direct use of the series (14). There are two possibilities: β is limited and $\beta \to \infty$. For the first -- for acoustic waves -- there is no solution, whereas for gravitational waves we obtain $\beta = b/2$. And in general, if $S = S_-$, the entire straight line $\beta = b/2$ formally satisfies equation (17). But the corresponding frequency curve, reducing the bracketed term in (11) to zero, as already noted, is not a solution. With the second possibility for acoustic waves there is again no solution, whereas for gravitational waves we have

$$\alpha\beta = \frac{b(b+1)\Gamma}{g + (b+1)\Gamma}. \tag{24}$$

In this case it is assumed that $\alpha\beta \ll 1$, that is $\Gamma \to 0$.

In case 3, in accordance with [8], we have

$$\Phi\left(\frac{b}{2} - \beta,\ b,\ \alpha\right) \approx \frac{(b-1)!}{\left(\frac{b}{2} + \beta - 1\right)!\,(-\alpha)^{\frac{b}{2} - \beta}} + \frac{(b-1)!\,e^{\alpha}}{\left(\frac{b}{2} - \beta - 1\right)!\,\alpha^{\frac{b}{2} + \beta}}.$$

Therefore, from equation (17) we obtain

$$\frac{(-1)^{\beta - \frac{b}{2}}\,\alpha^{2\beta}}{\left(\frac{b}{2} + \beta - 1\right)!}\,\frac{S - \Gamma}{S + \Gamma} = \frac{e^{\alpha}}{\left(\frac{b}{2} - \beta - 1\right)!}. \tag{25}$$

In order for the right-hand side of equation (25) with $\alpha \to \infty$ to remain, like the left-hand side, finite (the $\alpha^{2\beta}$ factor on the left-hand side cannot ensure the corresponding increase), it is necessary that the denominator on the right-hand side increase without limit, compensating the increase in the numerator. Hence

$$\beta = \beta_n - \varepsilon \quad \left(\beta_n = \frac{b}{2} + n\right), \tag{26}$$

where n is any whole non-negative number and $|\varepsilon| \ll 1$. In this case

$$\left(\frac{b}{2} - \beta - 1\right)! = \frac{(-1)^n}{n!\,\varepsilon}.$$

Substituting (26) into equation (25), we find

$$\varepsilon = \frac{e^{-\alpha}\,\alpha^{b+2n}}{(b+n-1)!\,n!}\,\frac{S - \Gamma}{S + \Gamma}.$$

With $\beta = \beta_n$

$$S_\pm = \frac{g + \Gamma}{2} + s_1 n \pm \sqrt{\left(\frac{g - \Gamma}{2}\right)^2 + s_1 n (g + \Gamma) + (s_1 n)^2}.$$

Therefore, for any n, taking into account that $g > \Gamma$, we have $S_+ > \Gamma$. Since, moreover, the root is a value not less than $g - \Gamma/2 + s_1 n$, for $n \geqslant 1$ we have, on the contrary, $S_- < \Gamma$. This means that when $\alpha \to \infty$ $\beta_+ \to \beta_n - 0$, but $\beta_- \to \beta_n + 0$.

Since the different modes of the long-wave part of the spectrum are characterized by the parameter q, it is convenient to find λ from the equation obtained by multiplying the first two formulas (15). Since k is small, we obtain

$$\lambda_{+}^{2}=\frac{s_1 q_{+}}{H}, \tag{27}$$

$$\lambda_{-}^{2}=l^{2}+\frac{g\Gamma}{\frac{s_1 q_{-}}{H}-l^{2}}k^{3}. \tag{28}$$

In the short-wave part of the spectrum the modes are characterized by a constancy of the parameter $\beta(\beta\approx\beta_n)$; using this parameter, directly from (15) we have

$$\lambda_{\pm}^{2}=\frac{l^{2}}{2}+\sqrt{\frac{l^{4}}{4}+S_{\pm}^{2}k^{2}}\ .$$

If, in particular, n is sufficiently large, then

$$\lambda_{+}^{2}=\frac{l^{2}}{2}+\sqrt{\frac{l^{4}}{4}+(4\,s_1^2\beta_n^2-2\,g\Gamma)\,k^{2}},$$

$$\lambda_{-}^{2}=\frac{l^{2}}{2}+\sqrt{\frac{l^{4}}{4}+\frac{g^{2}\Gamma^{2}}{4\,s_1^2\beta_n^2}\,k^{2}}.$$

We assumed $\alpha>0$, $\beta>0$. It follows from (15) that a simultaneous change in the signs on α and β is equivalent to a replacement of λ by $-\lambda$. Since all our formulas for $\lambda(k)$ contain λ^2 (that is, the frequency was determined with an accuracy to the sign), we evidently obtain no new solutions. We note that the eigenfunction (16) in this case also remains unchanged because $\Phi(r, m, x) = e^{x}\Phi(m - r, m, -x)$ [8].

We also assumed that $\lambda^2>l^2$. We will confirm this. We will assume that this is not so. Then $\alpha = -i\,\alpha_1$, $\beta = -i\,\beta_1$; α_1 and β_1 are real positive numbers. It can be shown that if the wavelength does not exceed several tens of thousands of kilometers, even for very small $\Gamma\neq 0$ $|\beta|\gg|\alpha|$, that is, it is possible to use the asymptotic form (20). We again obtain the equations (21) and (22). Their left-hand side is complex, whereas the right-hand side in the first case is real, but in the second case -- purely fictitious, because $\delta = 2i\sqrt{\alpha_1\beta_1}$. Thus, in actuality, $\lambda^2>l^2$. It was demonstrated in [4] that this inequality also is observed with $\Gamma = 0$.

Now we will proceed to a clarification of the problem of how the frequency spectrum changes if the hydrostaticity hypothesis is adopted. Here it is possible to use the results in [3], where the corresponding spectrum was constructed. However, we will proceed differently and construct it by proceeding directly from equations (1) and the boundary conditions (2), (5).

We will supply the left-hand side of the third equation of motion in (1) with the factor ε_2 so that the transition to hydrostatics will correspond to the limiting transition $\varepsilon_2 \to 0$. First, the frequency $\lambda = 0$ as before is a solution. Second, we will again obtain equation (10) and the dispersion expression (17), but formulas (15) assume the form

$$\alpha_s = \frac{2\lambda\varepsilon_2 k}{s_1\sqrt{\lambda^2 - l^2}}\, s, \quad \beta = \frac{\lambda^2\varepsilon_2^2(\lambda^2 - l^2) + gk^2\Gamma}{2\lambda\varepsilon_2 k s_1\sqrt{\lambda^2 - l^2}}, \tag{15'}$$

that is, λ, seemingly not entering into the combination $\lambda^2 - l^2$, is supplied with the factor ε_2. This means that in any range of wavelengths with $\varepsilon_2 \ll 1$ we have the case 1, that is, we have formulas (21)-(23). Similarly to (27), (28) we obtain

$$\lambda_+^2 = \frac{s_1 q_+}{H\varepsilon_2^2}, \tag{27'}$$

$$\lambda_-^2 = l^2 + \frac{g\Gamma}{\frac{s_1 q_-}{H} - l^2\varepsilon_2^2}\, k^2. \tag{28'}$$

With $\varepsilon_2 \to 0$ the frequencies (27') tend to infinity, that is, the corresponding oscillations are filtered out. Thus, in a hydrostatic polytropic atmosphere all the solutions are given by the formula

$$\lambda^2 = l^2 + \frac{g\Gamma}{\frac{s_1 q_-}{H}}\, k^2. \tag{28''}$$

However, for its derivation it is not necessary to assume a smallness of k. It is sufficient from (15') to form $q = \alpha\beta$, assume $\varepsilon_2 = 0$ and solve the derived formula for λ^2. The q values can be found from equation (22), bearing in mind that $q = \delta^2/4$. However, it is better (at the limit $\alpha \to 0$ and the asymptotic formula (20) even with $\beta \to \infty$, generally speaking, is not true), to discard λ^2, except the combination $\lambda^2 - l^2$, directly in equation (10) and obtain a corresponding solution. Instead of (10), we obtain the Bessel equation

$$s\tilde{\chi}_{ss} - (b-2)\tilde{\chi}_s + \frac{gk^2\Gamma}{s_1^2(\lambda^2 - l^2)}\tilde{\chi} = 0.$$

Its solution, satisfying the upper boundary condition, is

$$\tilde{\chi} = s^{\frac{b-1}{2}} J_{b-1}\left(2\frac{k}{s_1}\sqrt{\frac{g\Gamma}{\lambda^2 - l^2}\, s}\right),$$

and the lower boundary condition gives a dispersion equation in the form

$$J_b(z) = \frac{s_1 z}{2g} J_{b-1}(z) \quad \left(z = \frac{2k}{s_1}\sqrt{\frac{g\Gamma s_0}{\lambda^2 - l^2}}\right). \tag{17'}$$

If, in particular, $z \gg 1$, using the corresponding asymptotic formula [8], from (17') we obtain equation (22) for z. And formula (28") follows from the determination of z.

We see that it virtually coincides with formula (28) for the frequency of long gravitational waves because the parameter l^2 in the denominator of the latter can be neglected: for example, if T_0 = 273 K, $\bar{\gamma}$ = 5.83 K/km, then $s_1 q\_/H = 0.5 \cdot 10^{-4}$ q; $q\_ > 1$, whereas $l^2 = 10^{-8}$. A comparison of formulas (28) and (28") shows that the influence of the hydrostatic approximation decreases not only with an increase in wavelength, but also with an increase in the number of the mode denoting the degree of "vertical" variability of the solution.

All the waves with the frequencies (28"), except the zero mode, which is designated so because β_0 corresponds to its short waves, whereas the long waves of all other modes are described by formulas (23), beginning with n = 1, are gravitational. In actuality, according to (28") with $\Gamma \to 0$ $\lambda^2 \to l^2$, but since these frequencies are not solutions, the corresponding oscillations are filtered out. The zero mode, which in a general case consists of two branches (the short waves are acoustic, the long waves are gravitational) cannot be regarded as purely gravitational: with $\Gamma \neq 0$ it is gravitational, since in the long-wave range it corresponds to gravitational waves in a nonhydrostatic atmosphere, but with $\Gamma \to 0$ it is not filtered out, but passes into a solution corresponding to acoustic waves in a nonhydrostatic atmosphere. Now we will consider how this occurs. If $\Gamma \to 0$, then it also has one value $q \to 0$, and specifically (24). Therefore, it follows from (28") that

$$\lambda^2 = l^2 + \frac{g\bar{T}_0 (\varkappa - 1)}{\varkappa \bar{\gamma}} k^2, \qquad (29)$$

that is, this mode actually exists also when $\bar{\gamma} \to \gamma_a$, but in this case it already becomes acoustic. In actuality, if $\Gamma = 0$, then, in accordance with (15'), the hydrostatic approximation means $\alpha_s \ll 1$, $\beta \ll 1$. It follows from (17), in accordance with (14), that

$$\beta = \frac{b}{4(b+1)} \alpha.$$

Therefore

$$q = \frac{b}{4(b+1)} \alpha^2 = \frac{b}{b+1} \frac{\lambda^2 H^2}{\lambda^2 - l^2} k^2 \varepsilon_2^2.$$

Substituting this into formula (27') for acoustic frequencies, we obtain (29) with the replacement of γ by γ_a. Thus, this mode must be considered acoustic-gravitational.

Thus, the hydrostatic approximation filters out the acoustic waves and the frequencies of the gravitational and acoustic-gravitational waves are distorted the less the longer the wave and the higher the number of the mode.

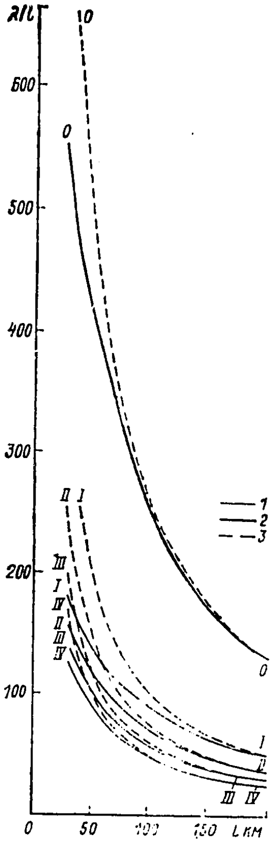

Fig. 1. Wave frequencies of gravitational (1) and (for the zero mode) the acoustic (2) nonhydrostatic oscillations and wave frequencies of hydrostatic oscillations (3) in dependence on wavelength in a polytropic (γ = 5.83 K/km) atmosphere. The figures on the curves denote the mode number.

Figure 1 shows the frequency curves computed using the dispersion equations: (17) -- for a nonhydrostatic atmosphere (acoustic part of the spectrum is not represented) and (17') -- for a hydrostatic atmosphere. In complete accordance with the asymptotic formulas (28) and (28") the difference in the frequency spectrum decreases with an increase in the mode number and an increase in wavelength. Only the zero mode in a considerable part of the spectrum is more hydrostatic than, for example, the first mode. But with the selected $\overline{\gamma}$ (5.83 K/km) it is acoustic to L = 187 km, so that its behavior is not described by formula (28). We see that gravitational waves longer than approximately 100 km with great accuracy are hydrostatic.

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CORRELATION BETWEEN MINIMUM PRESSURE AND MAXIMUM WIND VELOCITY IN TROPICAL CYCLONES

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[Article by Candidate of Physical and Mathematical Sciences V. M. Radikevich and Candidate of Geographical Sciences G. G. Tarakanov, Leningrad Hydrometeorological Institute, submitted for publication 2 April 1979]

The authors propose a model for describing the dependence of maximum wind velocity V_m in a tropical cyclone on the radius of the region with maximum wind velocity r_0, the Coriolis parameter ω_z, pressure P_0 at the center of a tropical cyclone and pressure P_1 at a great distance from the center r_d. In addition to a precise expression for determining V_m, the authors also derived an approximate and simplified expression. The results of the computations agree satisfactorily with observations. The systematic discrepancy between computations and observations falls within the range of discrepancies between the wind in the free atmosphere and the surface wind and varies from 0.78 to 0.65.

[Text] Tropical cyclones develop in the tropical and equatorial zones between 22°S and 35°N, except for a narrow equatorial zone (about 2°N-2°S). However, the main mass of tropical cyclones (87%) is associated with a narrower zone taking in the region between 3 and 20°N and S [2]. Observations show that in each tropical cyclone (TC) there is a so-called ring of maximum wind (if it is sufficiently narrow it is called the maximum wind circle). The maximum wind velocities can attain 80-100 m/sec. It is evident that the instrumental measurement of such velocities involves great difficulties. Measurements and the presently known theoretical models of a tropical cyclone show that pressure decreases toward the center of the cyclone in conformity to a parabolic law. Taking this circumstance into account, and also that pressure measurements are usually inadequate for a precise determination of the pressure gradient in the neighborhood of the maximum wind zone, there have been numerous attempts to relate the maximum wind velocity (V_m) to the pressure drop at the center (P_0) and on the periphery (P_1) of the TC. A physical validation of the correlation between V_m and ($P_1 - P_0$) can be obtained if a TC is regarded as an isolated vortex [3]. With such an approach it is possible to solve either the direct or inverse problem, that is, on the basis of pressure data it is possible to determine the maximum wind velocity in the TC (direct problem) or, using data on wind velocity in the TC it is possible to determine the pressure at its center. A solution of the inverse problem became possible and even necessary with the appearance of meteorological satellites and the development of numerical forecasting methods. On the basis of observation of the cloud cover fields from satellites it is possible to estimate V_m [9] for the free atmosphere and use this evaluation for computing pressure at the center of a TC, which by no means can always be measured.

Already in the early 1930's Takahashi [13] proposed a dependence in the form

$$V_m = k\,(P_1 - P_0)^a, \qquad (1)$$

where k and a are empirical constants. On the basis of observations on ships and island stations he obtained a = 0.5; k = 13.4. Later [14], for the higher latitudes, he proposed k = 11.5. A summary of different modifications of a dependence in the form (1) is given in Table 1.

Table 1 shows that the coefficients k and a are not universal constants and vary in dependence on region. According to [11], for the Atlantic and Pacific Oceans, where P_1 varies relatively slightly, it is possible to use the fixed value P_1, whereas in the Indian Ocean (in the region of the Indian subcontinent) it is necessary to consider the actual pressure P_1 (it can vary in a broad range: from 994 to 1012 mb).

The rather great variability of the coefficient k can be associated with a number of factors which are not directly taken into account in dependence (1) and exert an indirect influence through k (or a). In particular, this is the influence of friction and Coriolis force, and also the characteristic dimensions of the tropical cyclone. The authors of [12] indicate that the difference in the k coefficients in the Fletcher formula and their formula is attributable to the fact that in one case it corresponds to the land, and in another case -- the sea. In a number of studies an attempt is made to take into account the influence of Coriolis force and the characteristic dimensions of a tropical cyclone. A dependence of the following form was proposed in [6]

$$V_m^{н} = 16\,(P_1 - P_0)^{0,5} - 19,6 + 0,57\,r_0. \qquad (2)$$

where V_m^{obs} is the observed maximum wind velocity, r_0 is the distance from the center to the point at which the wind velocity attains a maximum (in miles).

Table 1

V_m -- in knots; P_1, P_0 -- in mb

Автор 1	*k*	*a*	Район исследований 2	Примечание 3
4 Флетчер, 1955, [5]	16	0,5	Прибрежные и островные станции северо-западной части Атлантического океана 10	
5 Муарс, 1957, [11]	11	0,5	Атлантический и Тихий океаны 11	P_1=1010 *мб* 16
6 Крафт, 1961, [11]	14	0,5	то же 12	P_1=1013 *мб*
7 Натаражан, Рамамурти, 1975, [12]	13,6	0,5	Восточная часть Тихого и Атлантического океанов 13	Рассмотрено 42 урагана и тайфуна 17
8 Мишра, Гапта, 1976, [11]	14,2	0,5	Индийский океан 14	Рассмотрено 35 ТЦ в стадии от шторма до урагана 18
9 Аткинсон Холидей, 1977, [4]	6,7	0,644	Береговые и островные станции западной части Тихого океана 15	P_1=1010 *мб* 16

KEY:

1. Author
2. Region of investigations
3. Notes
4. Fletcher
5. Muars
6. Kraft
7. Natarajan, Ramamurthy
8. Mishra, Gupta
9. Atkinson, Holliday
10. Coastal and island stations of NW part of Atlantic Ocean
11. Atlantic and Pacific Oceans
12. Same
13. Eastern part of Pacific and Atlantic Oceans
14. Indian Ocean
15. Shore and island stations of western part of Pacific Ocean
16. mb
17. 42 hurricanes and typhoons were considered
18. 35 tropical cyclones were considered in stage from storm to hurricane

For the gradient wind a different form of the dependence is examined:

$$V_m = 16\,(P_1 - P_0)^{0.5} - \omega \sin \varphi \cdot r_0, \tag{3}$$

where ω is the angular velocity of the earth's rotation.

It is noted in [4] that V_m must be a function of r_0 and this is indicated in a number of studies in which a dependence on latitude was proposed. In 1952 Macnown, et al., on the basis of a study of 230 typhoons, proposed a dependence in the form

$$V_m = \left(20 - \frac{\varphi}{5}\right)(1010 - P_0)^{0,5}. \tag{4}$$

Fortner (1958) obtained the dependence

$$V_m = \left(20 - \frac{\varphi}{5}\right)\left(372 - \frac{h_{700}}{8,54}\right)^{0,5}, \tag{5}$$

where h_{700} is the altitude of the 700-mb isobaric surface in meters, φ is latitude in degrees.

In a number of other studies mentioned in [4] there was modification of the coefficients taking into account the dependence on latitude.

An expression for determining V_m was proposed in [2] in the form

$$V_m = -r_0\,\omega_z + \sqrt{r_0^2\,\omega_z^2 + \frac{P_1 - P_0}{\rho}\,e^{-1/2}}, \tag{6}$$

which, in the opinion of the authors, due to the smallness of r_0 and $\omega_z = \omega \sin \varphi$, is expressed in

$$V_m = 0{,}78\sqrt{\frac{P_1 - P_0}{\rho}}, \tag{7}$$

where P is in mb, ρ is in kg/m^3, V_m is in m/sec.

According to [4], despite the development of different theoretical models of tropical cyclones, at the present time there are no expressions which would stand up with checking with time with use in routine practice and the authors feel it desirable to continue work in the search for empirical relationships.

In this study we propose a simple model relating V_m to $(P_1 - P_0)$, r_0 and φ.

In the approximation of an ideal fluid (for the free atmosphere) in a natural system of coordinates, for a stationary process, the equation of motion for the normal acceleration component can be written as

$$\frac{V^2}{r} = F_n - \frac{1}{\rho}\frac{\partial P}{\partial n}, \tag{8}$$

where V is the velocity component directed along the stream line, F_n is the force component normal to the streamline (related to a unit mass). If the motion is assumed to be horizontal and if gravity is neglected, then $F_n = F_k = -2\omega_z V$.

Using the expression

$$-\frac{\partial P}{\partial n} = \frac{\partial P}{\partial r},$$

(8) can be rewritten as follows

$$\frac{V^2}{r} = \frac{1}{\rho}\frac{\partial P}{\partial r} - 2\,\omega_z V. \tag{9}$$

We will consider a tropical cyclone as an isolated vortex:

$$\begin{aligned} r \leqslant r_0, \quad & V = \Omega r, \\ r \geqslant r_0, \quad & V = c/r^n, \end{aligned} \tag{10}$$

where $c = \Omega r_0^{n+1}$, r_0 is the radius of the "eye," Ω is the angular velocity of rotation, n is an empirical coefficient.

Integrating (9) from r to r_0 and from P to P_*:

$$P = P_* - \frac{\rho\Omega}{2}\,(2\,\omega_z + \Omega)(r_0^2 - r^2). \tag{11}$$

Since the P_* value (with $r = r_0$) is usually difficult to measure (the wind velocities are maximum here), it is desirable that it be expressed through P_1 -- the pressure at a considerable distance from the center of the cyclone (r_d). For this purpose we once again integrate (9) from r_d to r_0 and from P_1 to P_*:

$$P_* = P_1 - \frac{\rho c^3}{2n r_0^{2n}}\left[1 - \left(\frac{r_0}{r_6}\right)^{2n}\right] - \frac{2\rho c\,\omega_z}{(n-1)\,r_0^{n-1}}\left[1 - \left(\frac{r_0}{r_6}\right)^{n-1}\right]. \tag{12}$$

After substitution of (12) into (11) we obtain an expression for the pressure distribution within the "eye" ($r \leqslant r_0$):

$$P = P_1 - \frac{\rho c^2}{2n r_0^{2n}}\left[1 - \left(\frac{r_0}{r_6}\right)^{2n}\right] - \frac{2\rho c\,w_z}{(n-1)\,r_0^{n-1}}\left[1 - \left(\frac{r_0}{r_6}\right)^{n-1}\right] - \tag{13}$$

$$-\frac{\rho\Omega}{2}\,(2\,\omega_z + \Omega)(r_0^2 - r^2).$$

If with r = 0 P = P_0, then

$$P_0 = +P_1 - \frac{\rho\Omega^2 r_0^{2\,(n+1)}}{2\,n\,r_0^{2n}}\left[1 - \left(\frac{r_0}{r_6}\right)^{2n}\right] - \frac{2\,\rho\omega_z\,\Omega\,r_0^{n+1}}{(n-1)\,r_0^{n-1}}\left[1 - \left(\frac{r_0}{r_6}\right)^{n-1}\right] - \tag{14}$$

$$-\frac{\rho\Omega}{2}\,(2\,\omega_z + \Omega)\,r_0^2.$$

We use the notation $k = r_0/r_d$ and employing the condition that $V_m = \Omega r_0$, after the transformations we can write (14) in the form

$$V_m^2 + 2\,\omega_z r_0 D V_m - \frac{2\,(P_1 - P_0)}{\rho}\,A = 0, \tag{15}$$

where

$$A=\frac{1}{n}(1-k^{2n})+1,$$

$$D=\frac{n(n+1-2k^{n-1})}{(n-1)(n+1-k^{2n})}.$$

From (15) we can obtain an expression for V_m:

$$V_m=-\omega_z r_0 D\left[1-\sqrt{1+\frac{2(P_1-P_0)}{\rho A\omega_z^2 r_0^2 D^2}}\right] \qquad (16)$$

(the sign on the root was selected in such a way that with $\omega_z \to 0$ $V_m > 0$).

An evaluation of the order of the terms shows that for practical purposes under the root it is possible to neglect 1.0 in comparison with the second term; in such a case (16) is written as follows

$$V_m=-\omega_z r_0 D+\sqrt{\frac{2}{A}\frac{P_1-P_0}{\rho}}. \qquad (17)$$

Since the presently available data on the value of the n coefficient in expression (10) have not been adequately determined, in accordance with [8, 10, 15] n can vary in the range from 1/2 to 1.0; as a first approximation it makes sense to examine the case n = 1.0.

Taking into account the different reasonings presented above, it is easy to obtain the expression

$$V_m=-\frac{r_0\omega_z(1-2\ln k)}{(2-k^2)}\left(1-\sqrt{1+\frac{P_1-P_0}{\rho}\frac{2(2-k^2)}{r_0^2\omega_z^2(1-2\ln k)}}\right). \qquad (18)$$

Since the second term under the root is considerably greater than 1.0 (its value varies from 10 to 200), it can be written approximately that

$$V_m=-\frac{r_0\omega_z(1-2\ln k)}{2\left(1-\frac{1}{2}k^2\right)}+\sqrt{\frac{P_1-P_0}{\rho}\frac{1}{1-\frac{1}{2}k^2}}. \qquad (19)$$

Table 2

Frequency of recurrence	Gradations Градации 1/2 k^2						
	0,22—0,30	0,17—0,22	0,14—0,17	0,11—0,14	0,09—0,11	0,08—0,09	<0,08
Повторяемость, %	11,9	21,4	8,3	41,7	2,4	8,3	6,0

An analysis of the observational data used for checking these expressions shows that in approximately 60% of all the considered cases the 1/2 k^2 value does not exceed 0.14 (Table 2 shows the distribution of the frequency of recurrence of different 1/2 k^2 gradations).

Taking this circumstance into account, it can be expected that rather frequently the following simplified formula will be correct

$$V_m = -\frac{r_0 \omega_z (1 - 2 \ln k)}{2} + \sqrt{\frac{P_1 - P_0}{\rho}}, \tag{20}$$

which with $\omega_z \to 0$ is transformed into the expression, known from [2]

$$V_m = \sqrt{\frac{P_1 - P_0}{\rho}}. \tag{21}$$

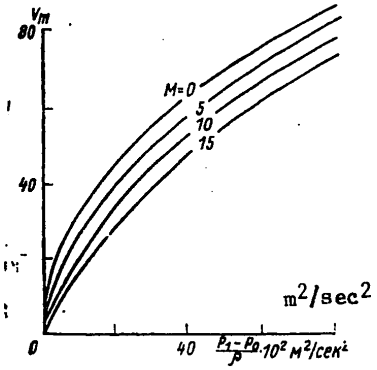


Fig. 1. Nomogram for computing maximum wind velocity V_m(m/sec) as a function of the pressure difference on the periphery -- P_1 and at the center of a TC -- P_0, and also on the parameter $M = \omega_z r_0/2\ (1 - 2 \ln k)$.

For computations with (20) it is possible to use the nomogram (Fig. 1), in which it can be seen that the relative contribution of the parameter $M = \omega_z r_0/2\ (1 - 2 \ln k)$ decreases with an increase in $P_1 - P_0/\rho$. Allowance for M leads to a decrease in V_m by not more than 15 m/sec. The parameter most difficult to determine is r_0. On the basis of available measurements it can be assumed that r_0 approximately corresponds to the radius of the circle occupied by continuous cloud cover [9] and can be determined from satellite photographs of cloud cover. For different categories of TC, in different oceans, this values varies in the range from 25 to 150 km. According to estimates of change in vorticity as a function of distance from the center of the TC, a change in the sign of vorticity (for the 900-mb isobaric surface) occurs at a distance of about 350-500 miles (650-920 km) from the center; these values can evidently be regarded as estimates of r_d. To distances of about 180 miles (330 km) positive vorticity conserves a rather high value (about $1.5\text{-}2.5) \cdot 10^{-5}$ 1/sec) and this region with a certain approximation can be regarded as the "eye" of the vortex r_0 [4]. Taking into account the above-mentioned relatively slight influence of the parameter, the uncertainty in stipulating the parameters r_d and r_0 has rather little influence on the results of computations. This is favored by the logarithmic nature of the dependence on r_d and r_0, and also the "compensated" influence of r_0. Numerical estimates show that in the latitude interval from 15 to 40°, with r_d = 400-600 km, a possible exaggeration of the r_0 parameter by a factor of 2 (with the actual value r_0 = 100 km) leads to an underestimate of V_m by 1.5-3.0 m/sec.

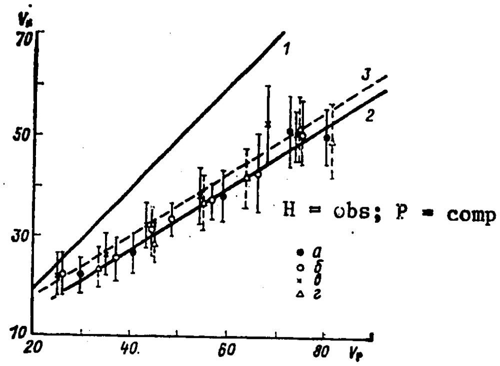
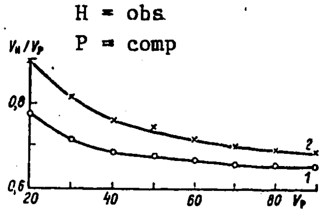


Fig. 2. Comparison of observed (V_{obs}) and computed (V_{comp}) maximum wind velocity in m/sec. a) computed using full formula (18), b) computed using approximate formula (19), c) computed using simplified formula (20), d) computed using empirical formula (4); each dot represents the result of averaging by gradations of V_{comp} of 10 m/sec; the vertical straight lines indicate the standard deviations: 1) bisectrix, 2) straight line drawn through points a and b, 3) straight line drawn through points c



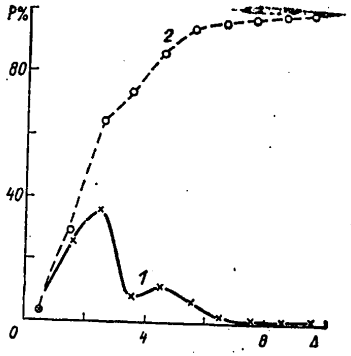


Fig. 3. Dependence of ratio of observed and computed winds (V_{obs}/V_{comp}) on computed value (in m/sec).

Fig. 4. Differential (1) and integral (2) distributions of difference V_m for cases n = 1.0 and n = 0.5, $\Delta = V_{m\,1.0} - V_{m\,0.5}$ (m/sec)

For checking of the dependence (18) or (19) proposed by the authors and comparison with other dependences we used observations of TC in the northwestern part of the Pacific Ocean, Bay of Bengal and Arabian Sea. We examined a total of 84 cases. Pressure at the cyclone center and maximum wind velocity were taken from the ZHURNAL UCHETA TROPICHESKIKH TSIKLONOV (Journal of Inventory of Tropical Cyclones) which is kept at the USSR Hydrometeorological Center. The P_1 values were taken from the synoptic charts at a point situated in the middle of the segment between the last closed isobar of the cyclone and the isobar following it (r_d). The r_0 value was determined as the distance from the center of the cyclone to the last outer closed isobar bounding the region of maximum pressure gradients.

Figure 2 gives a comparison of the observed and computed maximum winds. The filled circles represent computations made using the full formula (18), averaged for gradations each 10 m/sec; the open circles -- using the approximate formula (19); the small crosses -- using the simplified formula (20). The vertical straight lines indicate the standard deviations. We note that computations based on (18) and (19) virtually coincide with one another and can be approximated by the straight line 2, whereas computations made using formula (20) are described by the straight line 3. With sufficient accuracy it is possible to use the following relationship between the maximum velocity, determined using the full or approximate formula $V_{m\ 1}$ or the simplified formula $V_{m\ 2}$.

$$V_{m1} = V_{m2} - 3{,}0 \text{ (in m/sec)} \qquad (22)$$

It is interesting to note that the results of computations using formulas (18) and (19) agree with computations made using empirical formula (4), obtained on the basis of observations of typhoons specifically for the regions considered here.

Figure 3 shows that the ratio between the observed and computed wind velocities is about 0.775-0.650 in computations using the full and approximate formulas and about 0.900-0.700 in computations using the simplified formula; this relationship decreases with an increase in wind velocity. If the computed wind is considered as the wind near the upper boundary of the boundary layer (or in the free atmosphere), and the observed (with certain reservations) is considered as the surface wind, the estimates of the parameters obtained here and the nature of the dependence of V_{obs}/V_{comp} on V_{comp} agree with the estimates following from the model of the planetary boundary layer of the atmosphere [1]. A checking of the Takahashi model (1) which was carried out also supports such an explanation of the reasons for the systematic discrepancy between the observed and computed wind velocities. With approximately the same deviation from the means as in Fig. 2, the V_{obs}/V_{comp} ratio is about 0.77 (we recall that in deriving this empirical formula the author used wind observations made on ships and at island stations).

Bearing in mind the future possible refinement of the values of the n coefficient, on the basis of the initial data considered above we carried out sample computations for n = 0.75, 0.50 and 0.25; these demonstrated that with a decrease in n to 0.25 there should be an appreciable decrease in V_m (in comparison with n = 1.0 it can attain 16 m/sec). In the case n = 0.75

the computations with an accuracy to 1-2 m/sec coincide with the computations for $n = 1.0$. For checking on the basis of the entire series of initial data we examined the case $n = 0.5$ (as the most probable). Figure 4 shows the differential and integral position of the difference V_m computed with $n = 1.0$ and $n = 0.5$. It can be seen that the maximum frequency of recurrence $\Delta = V_{m\,1} - V_{m\,0.5}$ falls at 2-3 m/sec and with a probability of about 65% Δ does not exceed the limits 3 m/sec, that is, the Δ value does not exceed the accuracy in measuring wind velocity under storm conditions. Taking into account the uncertainty in selecting n, an examination of the case $n = 1.0$ in the first approximation can be considered justified. An analysis of the results of the computations shows that Δ is slightly dependent on the parameter $\omega_z r_0$ and is determined, for the most part, by $P_1 - P_0/\rho$ and k (Δ increases with an increase in the first and with a decrease in the second). Since Δ always has one and the same "minus" sign, it acquires the nature of a systematic error. Since the most probable Δ value is -2.5 m/sec, for practical purposes it is useful that the maximum wind velocity V_m obtained from (18) be decreased by 2.5 m/sec.

Thus, the proposed model makes possible a quite reliable determination of the maximum wind (near the upper boundary of the atmospheric boundary layer) in tropical cyclones. For checking it in the future it would be desirable to use measurements in the Atlantic Ocean and refine the value of the n coefficient. Although at the present time the accuracy in determining the parameters leaves much to be desired and therefore the model is only at the level of the best local empirical dependences, the use of universal dependences of the type (16)-(17) and (18)-(20) is without question more promising and raises the problem of the accuracy in determining the parameters characterizing a tropical cyclone.

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UDC 551.511.33

POSSIBLE MECHANISM OF TRANSFER OF DISTURBANCES FROM THE LOWER THERMOSPHERE INTO THE MESO-STRATOSPHERE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 42-49

[Article by Candidates of Physical and Mathematical Sciences V. I. Bekaryukov and V. V. Mikhnevich and V. M. Zadvernyuk, Institute of Applied Geophysics, submitted for publication 28 May 1979]

Abstract: The article gives a formulation of the nonlinear problem of the dynamic mechanism of transfer of disturbances downward from the thermosphere in the case of an impact on the strato-mesospheric circumpolar vortex. A system of 12 first-degree recurrent equations in partial derivatives is derived. Geopotential and temperature are found with $\theta \leqslant 20°$ for the case of linear temperature stratification.

[Text] In [1], on the basis of a precise solution of a one-dimensional system of equations in hydrodynamics, the authors demonstrated the fundamental possibility of propagation of disturbances of thermodynamic parameters from the upper atmosphere in a downward direction. Naturally, under real conditions the horizontal flows caused by the forming nonuniformity of the pressure field, to a greater or lesser degree should smooth this effect. The three-dimensional problem must be solved in order to determine the possibility and nature of propagation of disturbances of thermodynamic parameters downward from the upper atmosphere under real conditions.

Taking into account that the strato-mesosphere is characterized by the presence of a symmetric circumpolar anticyclone relative to the pole (in summer) and cyclone (during winter, during periods free of stratospheric restructurings), it is possible to solve the zonally symmetric problem if we stipulate the disturbance in the upper atmosphere at the center of the circumpolar vortex. Then at the center of the eddy, due to the absence of horizontal flows there, the solution obtained in [1] is correct and we can use it as a boundary condition.

We will write a system of hydrothermodynamic equations for the case of axially symmetric movement in p-coordinates, in a spherical coordinate system with its center at the pole:

$$1.\ \frac{\partial u}{\partial t}+\tau\frac{\partial u}{\partial p}+\frac{v}{a}\frac{\partial u}{\partial \theta}+\frac{uv}{a}\operatorname{ctg}\theta+2\omega\cos\theta\, v=0,$$

$$2.\ \frac{\partial v}{\partial t}+\tau\frac{\partial v}{\partial p}+\frac{v}{a}\frac{\partial v}{\partial \theta}+\frac{u^2\operatorname{ctg}\theta}{a}-2\omega\cos\theta\, u=-\frac{g}{a}\frac{\partial \Phi}{\partial \theta}, \qquad \text{(I)}$$

$$3.\ \frac{\partial T}{\partial t}+\tau\frac{\partial T}{\partial p}+\frac{v}{a}\frac{\partial T}{\partial \theta}-\frac{\gamma\tau RT}{gp}=\frac{1}{c_p}Q,$$

$$4.\ \frac{\partial \tau}{\partial p}+\frac{1}{a}\frac{\partial v}{\partial \theta}+\frac{v\operatorname{ctg}\theta}{a}=0,$$

$$5.\ T=-\frac{gp}{R}\frac{\partial \Phi}{\partial p},$$

$$\gamma=\frac{\varkappa-1}{\varkappa}\frac{g}{R};\quad \varkappa=\frac{c_p}{c_v}.$$

Here τ is the analog of vertical velocity, Φ is geopotential, p is pressure, u, v are zonal and meridional velocities respectively.

The system was written without taking into account the viscous terms, whose influence in the free atmosphere and in the considered time intervals can be neglected in the first approximation. This system of equations can be solved by relatively simple generally accepted methods.

Employing equation (4), we introduce the stream function ψ:

$$\sin\theta\frac{\partial \tau}{\partial p}+\frac{1}{a}\frac{\partial}{\partial \theta}(v\sin\theta)=0,$$

$$\frac{\partial \psi}{\partial \theta}=\tau\sin\theta,\ \frac{\partial \psi}{\partial p}=-\sin\theta\frac{v}{a};$$

thus, τ (an analogue of w) and meridional velocity v are expressed through the stream function.

Expanding into a series for θ and taking into account that when $\theta = 0$ $u = v = \partial\Phi/\partial\theta = \partial T/\partial\theta = 0$, and restricting ourselves to fourth-order terms, we obtain:

$$\psi=\psi_2\theta^2+\psi_3\theta^3+\psi_4\theta^4+\psi_5\theta^5+\ldots,$$

$$\Phi=\Phi_0+\Phi_2\theta^2+\Phi_3\theta^3+\Phi_4\theta^4+\Phi_5\theta^5+\ldots \qquad \text{(II)}$$

$$T=-\frac{gp}{R}\frac{\partial \Phi_0}{\partial p}-\frac{gp}{R}\frac{\partial \Phi_2}{\partial p}\theta^2-\frac{gp}{R}\frac{\partial \Phi_3}{\partial p}\theta^3-\frac{gp}{R}\frac{\partial \Phi_4}{\partial p}\theta^4-\ldots,$$

$$u=u_1\theta+u_2\theta^2+u_3\theta^3+u_4\theta^4+\ldots$$

$$\tau=2\psi_2+3\psi_3\theta+\left(\frac{1}{3}\psi_2+4\psi_4\right)\theta^2+\left(\frac{1}{2}\psi_3+5\psi_5\right)\theta^3+\ldots$$

$$v=-a\frac{\partial \psi_2}{\partial p}\theta-a\frac{\partial \psi_3}{\partial p}\theta^2-a\left(\frac{1}{6}\frac{\partial \psi_2}{\partial p}+\frac{\partial \psi_4}{\partial p}\right)\theta^3-\ldots$$

Substituting (II) into (I) and equating the terms with identical θ^n, we obtain a system of 12 recurrent equations in partial derivatives:

$$\Theta^0\left[\;1.\; p\frac{\partial^2\Phi_0}{\partial p\,\partial t}+2p\psi_2\frac{\partial^2\Phi_0}{\partial p^2}+\frac{2}{\varkappa}\psi_2\frac{\partial\Phi_0}{\partial p}=0,\right.$$

$$\Theta^1\left[\begin{array}{ll}2.\;\; \dfrac{\partial u_1}{\partial t}+2\psi_2\dfrac{\partial u_1}{\partial p}-2u_1\dfrac{\partial\psi_2}{\partial p}-2a\omega\dfrac{\partial\psi_2}{\partial p}=0, & \qquad\text{(III)}\\[2ex] 3.\;\; a\dfrac{\partial^2\psi_2}{\partial t\,\partial p}+2a\psi_2\dfrac{\partial^2\psi_2}{\partial p^2}-a\left(\dfrac{\partial\psi_2}{\partial p}\right)^2+\dfrac{u_1^2}{a}+2\omega u_1=\dfrac{2g}{a}\Phi_2, & \\[2ex] 1.\;\; \varkappa p\psi_3\dfrac{\partial^2\Phi_0}{\partial p^2}+\psi_3\dfrac{\partial\Phi_0}{\partial p}=0, & \end{array}\right.$$

$$\Theta^2\left[\begin{array}{ll}2.\;\; \dfrac{\partial u_2}{\partial t}+3\psi_3\dfrac{\partial u_1}{\partial p}+2\psi_2\dfrac{\partial u_2}{\partial p}-2u_1\dfrac{\partial\psi_3}{\partial p}-a\omega\dfrac{\partial\psi_3}{\partial p}=0, & \\[2ex] 3.\;\; a\dfrac{\partial^2\psi_3}{\partial t\,\partial p}+3a\psi_3\dfrac{\partial^2\psi_2}{\partial p^2}+2a\psi_2\dfrac{\partial^2\psi_3}{\partial p^2}-3a\dfrac{\partial\psi_2}{\partial p}\dfrac{\partial\psi_3}{\partial p}+ & \qquad\text{(IV)}\\[2ex] \qquad\qquad +\dfrac{2}{a}u_1u_2+2\omega u_2=\dfrac{3g}{a}\Phi_3, & \\[2ex] 1.\;\; p\dfrac{\partial^2\Phi_2}{\partial t\,\partial p}+2p\psi_2\dfrac{\partial^2\Phi_2}{\partial p^2}-2p\dfrac{\partial\psi_2}{\partial p}\dfrac{\partial\Phi_2}{\partial p}+\dfrac{2}{\varkappa}\psi_2\dfrac{\partial\Phi_2}{\partial p}+ & \\[2ex] +\dfrac{\psi_2}{3}p\dfrac{\partial^2\Phi_0}{\partial p^2}+4p\psi_4\dfrac{\partial^2\Phi_0}{\partial p^2}+\dfrac{\psi_2}{3\varkappa}\dfrac{\partial\Phi_0}{\partial p}+\dfrac{4}{\varkappa}\psi_4\dfrac{\partial\Phi_0}{\partial p}=0, & \end{array}\right.$$

$$\Theta^3\left[\begin{array}{ll}2.\;\; \dfrac{\partial u_3}{\partial t}+\left(\dfrac{\psi_2}{3}+4\psi_4\right)\dfrac{\partial u_1}{\partial p}+2\psi_2\dfrac{\partial u_3}{\partial p}-4u_3\dfrac{\partial\psi_2}{\partial p}- & \\[2ex] \qquad -2u_1\dfrac{\partial\psi_4}{\partial p}+2a\omega\left(\dfrac{1}{3}\dfrac{\partial\psi_2}{\partial p}-\dfrac{\partial\psi_4}{\partial p}\right)=0, & \qquad\text{(V)}\\[2ex] 3.\;\; \dfrac{a}{6}\dfrac{\partial^2\psi_2}{\partial t\,\partial p}+a\left(\dfrac{\psi_2}{3}+4\psi_4\right)\dfrac{\partial^2\psi_2}{\partial p^2}+\dfrac{a}{3}\psi_2\dfrac{\partial^2\psi_2}{\partial p^2}-\dfrac{2a}{3}\left(\dfrac{\partial\psi_2}{\partial p}\right)^2+ & \\[2ex] \qquad +a\dfrac{\partial^2\psi_4}{\partial t\,\partial p}-4a\dfrac{\partial\psi_2}{\partial p}\dfrac{\partial\psi_4}{\partial p}+2a\psi_2\dfrac{\partial^2\psi_4}{\partial p^2}-\dfrac{u_1^2}{3a}+ & \\[2ex] \qquad +\dfrac{1}{a}\left(u_2^2+2u_1u_3\right)-\omega\left(u_1-2u_3\right)=\dfrac{4g}{a}\Phi_4, & \\[2ex] 1.\;\; p\dfrac{\partial^2\Phi_3}{\partial t\,\partial p}+2p\psi_2\dfrac{\partial^2\Phi_3}{\partial p^2}+5p\psi_5\dfrac{\partial^2\Phi_0}{\partial p^2}-3p\dfrac{\partial\psi_2}{\partial p}\dfrac{\partial\Phi_3}{\partial p}+ & \\[2ex] \qquad +\dfrac{5}{\varkappa}\psi_5\dfrac{\partial\Phi_0}{\partial p}+\dfrac{2}{\varkappa}\psi_2\dfrac{\partial\Phi_3}{\partial p}=0, & \qquad\text{(VI)}\end{array}\right.$$

$$\left[\begin{array}{l}2.\;\; \dfrac{\partial u_4}{\partial t}-5u_4\dfrac{\partial\psi_2}{\partial p}+\dfrac{\partial u_1}{\partial p}\left(\dfrac{\psi_2}{2}+5\psi_5\right)+\dfrac{\partial u_2}{\partial p}\left(\dfrac{\psi_2}{3}+4\psi_4\right)+\\[2ex] +3\psi_3\dfrac{\partial u_3}{\partial p}+2\psi_2\dfrac{\partial u_4}{\partial p}-4u_3\dfrac{\partial\psi_3}{\partial p}-\dfrac{u_2}{6}\dfrac{\partial\psi_2}{\partial p}-2u_1\dfrac{\partial\psi_5}{\partial p}-\\[2ex] \qquad -3u_2\dfrac{\partial\psi_4}{\partial p}+2a\omega\left(\dfrac{1}{3}\dfrac{\partial\psi_3}{\partial p}-\dfrac{\partial\psi_5}{\partial p}\right)=0,\end{array}\right.$$

$$\Theta^4 \left| \begin{array}{l} 3. \quad -\frac{a}{6}\frac{\partial^2\psi_3}{\partial t\,\partial p} - a\frac{\partial^2\psi_2}{\partial p^2}\left(\frac{\psi_3}{2} + 5\,\psi_5\right) - a\frac{\partial^2\psi_3}{\partial p^2}\left(\frac{\psi_2}{3} + 4\,\psi_4\right) - \\ -\frac{a}{2}\,\psi_3\frac{\partial^2\psi_2}{\partial p^2} - \frac{a}{3}\,\psi_3\frac{\partial^2\psi_3}{\partial p^2} + \frac{5}{3}\frac{\partial\psi_2}{\partial p}\frac{\partial\psi_3}{\partial p} + 5\frac{\partial\psi_2}{\partial p}\frac{\partial\psi_5}{\partial p} + \\ + 5\frac{\partial\psi_3}{\partial p}\frac{\partial\psi_4}{\partial p} - a\frac{\partial^2\psi_5}{\partial t\,\partial p} - 2\,a\,\psi_2\frac{\partial^2\psi_5}{\partial p^2} + \frac{2}{3\,a}\,u_1u_2 - \frac{2}{a}\times \\ \times(u_1u_4 + u_2u_3) + \omega\,(u_2 - 2\,u_4) = -\frac{5\,g}{a}\,\Phi_6. \end{array} \right. \qquad \text{(VI)}$$

The boundary conditions are written in the form

$$u\,|_{t=0} = u_{10}\left(\ln\frac{P_0}{p} - d\right)\times\Theta; \quad T\,|_{t=0,\ \Theta=0} = \frac{g}{R}\,\Phi_{00},$$

with

$$p = p_1\ \Phi_0 = \Phi_{00}\ln\frac{P_0}{P_1} + \Delta\Phi(1 - \cos\omega_1 t),\ \psi_2 = f(p, t).$$

It was demonstrated in [1] that in a one-dimensional case the vertical velocity (disturbed) attenuates near 20-30 km. In application to our problem such conditions (absence of horizontal currents) can exist only at the center of a cyclone (anticyclone). Thus, w, obtained in [1], will correspond tc the vertical velocity at the center of the vortex, and it is possible to stipulate ψ_2 in the following way:

$$\psi_2 = \frac{b\,\gamma\omega_1\sin\omega_1 t}{[1 + \gamma\,(1 - \cos\omega_1 t)]}\ p\left(\ln\frac{p}{p_0} + d - 1\right). \qquad (1')$$

Here b, γ, d are the coefficients for selecting the value and direction of w, the values for the source and change in sign of zonal circulation near 15-20 km respectively, ω_1 is the frequency of the disturbance, P_0 = 1000 mb.

As can be seen from (1'), the vertical velocity increases with time and altitude and with b = 0.1 at the altitude $z \approx 80$ km $w \approx 3$-4 cm/sec, decreasing at $z \approx 30$ km to 0.

Thus, stipulating w from [1] at the center of the polar vortex and solving (III)-(VI), we determine the influence exerted on the parameters of the vortex (u, v, Φ, T) by the initial disturbance, that is, the development or destruction of the circumpolar vortex with different initial conditions and with different sources of disturbances.

It goes without saying that the solution of the system of equations (I) cannot be applied to the troposphere due to the absence of viscous terms in the initial system, the presence of which makes it possible to solve the boundary problem (an analytical solution of which is impossible), but we will solve the Cauchy problem.

In [2] the system (I) was solved for the case of an isothermic initial atmosphere, whose choice is attributable to the fact that in [1] the vertical velocity was obtained for this case. It is shown that in the region $\theta \leqslant 20°$ in the computations with a sufficient degree of accuracy it is possible to limit ourselves to the first three terms of the expansion. The influence of disturbances in the lower thermosphere on the parameters of the circumpolar vortex was determined:

1. Ascending vertical currents (+w), with different initial conditions, cause the destruction of the cyclone and deepening of the anticyclone (since at the center of the vortex there is a greater rising of the atmosphere than at the periphery — a domelike disturbance with a convex top); the meridional velocity is directed from the pole;

2. Descending currents (-w) cause destruction of the anticyclone and deepening of the cyclone (since at the center of the vortex the atmosphere descends more than on the periphery — a domelike disturbance with a concave top); the meridional velocity is directed poleward.

The possibility of a layer-by-layer effect with the propagation of disturbances in a downward direction has been demonstrated.

In order to clarify the role of the temperature gradients in the process of propagation of disturbances we obtain, using [1], the vertical velocity for the case of linear stratification $T = T_0 + \alpha z'$:

$$w = \frac{k \int_0^\infty \left(\frac{T_0 + \alpha z'}{T_0}\right)^{\frac{g}{R\alpha}} e^{-\frac{\left[z + \int_0^t A(t)\,dt - z'\right]^2}{4kt}} \left\{ \frac{\left[z + \int_0^t A(t)\,dt - z'\right]}{2kt} \times \right.}{\int_0^\infty \left(\frac{T_0 + \alpha z'}{T_0}\right)^{\frac{g}{R\alpha}} e^{-\frac{\left[z + \int_0^t A(t)\,dt - z'\right]^2}{4kt}} \times} \rightarrow \quad (2)$$

$$\rightarrow \frac{\left. \times \left[z - z' - 2t(a_0 - b_0)\sin\omega_1 t + \int_0^t A(t)\,dt\right] - 1 \right\} dz'}{\times \left[z + \int_0^t A(t)\,dt - z'\right] dz'}.$$

Integrating (2) numerically for different initial conditions and sources, we obtain weak variations ($(2-3)\cdot 10^{-4}$ m/sec) w with altitude for different temperature gradients (α). This makes it possible, leaving (1') unchanged, to obtain geopotential and temperature with $\Theta = 0$ (at the center of the eddy) for the case of a linear change in temperature with altitude $T = T_{0.1} + a_{1,2} \ln p/P_{1,2}$:

$$p \frac{\partial^2 \Phi_0}{\partial t\, \partial p} + 2p\psi_2 \frac{\partial^2 \Phi_0}{\partial p^2} + \frac{2}{\varkappa} \psi_2 \frac{\partial \Phi_0}{\partial p} = 0, \quad \frac{\partial \Phi_0}{\partial p} = H',$$

with
$$t=0 \quad H' = -\frac{R}{gp}\left(T_{0,1} + a_{1,2} \ln \frac{p}{P_{1,2}}\right);$$

(here $T_{0,1}$ and $P_{1,2}$ are temperature and pressure at the beginning of each linear segment: T_0, P_1 -- at the level $z \approx 80$ km, T_1, P_2 -- at the level $z \approx 50$ km).

$$p\frac{\partial H'}{\partial t} + 2p\psi_2 \frac{\partial H'}{\partial p} + \frac{2}{\varkappa}\psi_2 H' = 0,$$

$$\frac{dt}{p} = \frac{dp}{2p\psi_2} = -\frac{\varkappa}{2\psi_2}\frac{dH'}{H'},$$

$$\int \frac{2b\gamma\omega_1 \sin \omega_1 t}{1+\gamma(1-\cos\omega_1 t)}\, dt = \int \frac{dp}{p\left(\ln \frac{p}{P_0} + d - 1\right)} \Longrightarrow$$

$$\Longrightarrow [1+\gamma(1-\cos\omega_1 t)]^{2b} = C_1\left(\ln \frac{p}{P_0} + d - 1\right),$$

$$P_{00} = P_0 \left(\frac{p}{P_0}\right)^{\frac{1}{y}} e^{(d-1)\left(\frac{1}{y}-1\right)},$$

$$H' = \frac{\partial \Phi_0}{\partial p} = -\frac{R}{g}\left(T_{0,1} + a_{1,2} \ln \frac{P_{00}}{P_{1,2}}\right) P_{00}^{\frac{1-\varkappa}{\varkappa}} p^{-\frac{1}{\varkappa}} =$$
$$= -\frac{R}{g}\left\{T_{0,1} + a_{1,2}\left[\ln \frac{P_0}{P_{1,2}} + \frac{1}{y}\ln\frac{p}{P_0} + (d-1)\left(\frac{1}{y}-1\right)\right]\right\} \times$$
$$\times e^{(d-1)\frac{1-\varkappa}{\varkappa}\left(\frac{1}{y}-1\right)} P_0^{\frac{1-\varkappa}{\varkappa}\left(1-\frac{1}{y}\right)} p^{\frac{1}{\varkappa}\left(\frac{1-\varkappa}{y}-1\right)}.$$

Here $y = [1+\gamma(1-\cos\omega_1 t)]^{2b}$.

Assume that when $p = P_1$ $\quad \Phi_0 = \Phi_{00} \ln \frac{P_0}{P_1} + \Delta\Phi(1-\cos\omega_1 t),$

then for the two layers 80-50 km and 50-30 km we obtain $\tilde{\Phi}_0$ and T:

$$\Phi_0 = \Delta\Phi_{0,1} - \frac{R\varkappa y}{g(\varkappa-1)(y-1)} e^{\frac{\varkappa-1}{\varkappa}(d-1)\left(1-\frac{1}{y}\right)} \left\{\left(\frac{p}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)} \times\right.$$
$$\times \left[T_{0,1} + a_{1,2}\left(\ln \frac{P_0}{P_{1,2}} + (d-1)\left(\frac{1}{y}-1\right) - \frac{\varkappa}{(\varkappa-1)(y-1)} + \right.\right.$$

$$+\frac{1}{y}\ln\frac{p}{P_0}\Big)\Big]-\left(\frac{P_1}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\Big[T_{0,1}+a_{1,2}\Big(\ln\frac{P_0}{P_{1,2}}+(d-1)\Big(\frac{1}{y}-1\Big)-$$

$$-\frac{\varkappa}{(\varkappa-1)(y-1)}+\frac{1}{y}\ln\frac{P_1}{P_0}\Big)\Big]\Big\}.$$

we obtain $\Delta\Phi_1$ with the joining of solutions at the level P_2:

$$\Delta\Phi_1=\Delta\Phi_0+\frac{R\varkappa y}{g(\varkappa-1)(y-1)}e^{(d-1)\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\Big\{\Big[\left(\frac{P_2}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\times$$

$$\times\Big((d-1)\Big(\frac{1}{y}-1\Big)-\frac{\varkappa}{(\varkappa-1)(y-1)}+\frac{1}{y}\ln\frac{P_2}{P_0}\Big)-\left(\frac{P_1}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\times$$

$$\times\Big((d-1)\Big(\frac{1}{y}-1\Big)-\frac{\varkappa}{(\varkappa-1)(y-1)}+\frac{1}{y}\ln\frac{P_1}{P_0}\Big)\Big](a_2-a_1)+$$

$$+\Big(T_1-T_0+a_2\ln\frac{P_0}{P_2}-a_1\ln\frac{P_0}{P_1}\Big)\Big[\left(\frac{P_2}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}-\left(\frac{P_1}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\Big]\Big\}.$$

$$T=\Big\{T_{0,1}+a_{1,2}\Big[\ln\frac{P_0}{P_{1,2}}+\frac{1}{y}\ln\frac{p}{P_0}+(d-1)\Big(\frac{1}{y}-1\Big)\Big]\Big\}\times$$

$$\times e^{(d-1)\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)}\left(\frac{p}{P_0}\right)^{\frac{\varkappa-1}{\varkappa}\left(1-\frac{1}{y}\right)},$$

$$T_1=T_0+a_1\ln\frac{P_0}{P_1}-a_2\ln\frac{P_0}{P_2}+(a_1-a_2)\Big[\frac{1}{y}\ln\frac{P_2}{P_0}+(d-1)\Big(\frac{1}{y}-1\Big)\Big].$$

We obtain the change in altitude z = f(p) for evaluating the disturbances Φ_0 and T as follows:

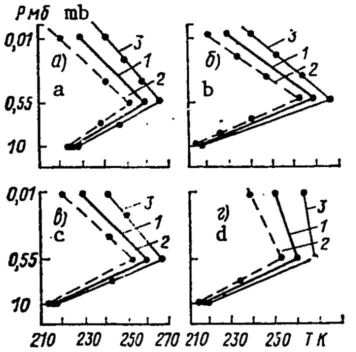
$$p=P_0e^{-\frac{g}{R}\int\limits_0^z\frac{dz}{T_{0,1}+a_{1,2}z}},$$

$$z=z_{0,1}+\frac{T_{0,1}}{a_{1,2}}\Big[\left(\frac{p}{P_{1,2}}\right)^{\frac{a_{1,2}R}{g}}-1\Big],$$

$$z_0=0,\quad z_1=\frac{T_0}{a_1}\Big[\left(\frac{P_2}{P_1}\right)^{\frac{a_1R}{g}}-1\Big].$$

Computations show that the relative changes in pressure in the mesosphere and upper stratosphere remain approximately constant, which, as indicated above, is attributable to the fact that we are solving the Cauchy problem. The changes in temperature in p-coordinates in the presence of ascending and descending currents (3-5 cm/sec) are given in Fig. 1; it can be seen that:

1) considerable changes in the temperature of the mesopause (20 K) (c, d) cause a weak temperature change -- 1.5°K at z∼75 km and about 0.6°K at other levels; the geopotential changes insignificantly (0.1-0.4 km);
2) a temperature increase at the stratopause by 10°K (b,c) causes a temperature change in the entire layer by approximately 0.5°K and virtually does not change the geopotential;
3) a temperature increase of the lower stratosphere by 10 K (a, c) does not change geopotential and weakly disturbs stratospheric temperature (0.3-0.4 K).



same notations in Fig. 2

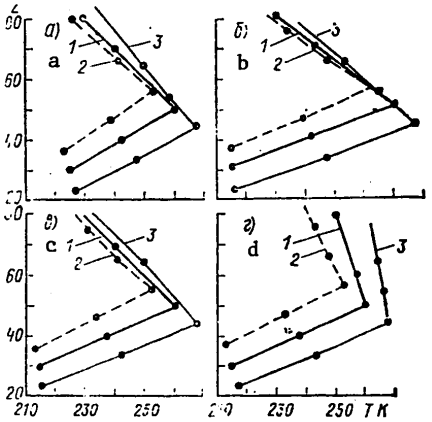


Fig. 1. Temperature stratification of the atmosphere in p-coordinates with different initial conditions. 1) initial, 2) disturbed by ascending currents, 3) disturbed by descending currents. Fig. 2. Temperature stratification of the atmosphere in z-coordinates with different initial conditions.

Thus, the maximum variations of temperature and geopotential, caused by vertical currents, are observed in the case of a very warm mesosphere (d), but they are quite small and it can be asserted that the role of the temperature gradients in the process of downward propagation of disturbances is also small.

From (III) (2, 3):

$$u_1 = C_5 y e^{\frac{1}{C_2}(y-1)} - a\omega,$$

$$\Phi_2 = \frac{1}{2g}\left\{ e^{\frac{2}{C_2}(y-1)} y^2 C_5^2 - (a\omega)^2 \right\}.$$

Here

$$C_2 = \frac{y}{\ln \frac{p}{P_0} + d - 1}, \quad C_6 = a\omega - u_{10}\left(1 + \frac{1}{C_2}\right).$$

It was demonstrated in [2] that the solution of system (III)-(VI) has the following peculiarity: all the even terms in the expansion $u(u_2, u_4, \ldots)$ and odd terms $\psi(\psi_1, \psi_3, \ldots)$ and $\Phi(\Phi_1, \Phi_3, \ldots)$ become equal to zero. Therefore from (IV) (2, 3) $u_2 = \Phi_3 = 0$.

In the case of a linear stratification it is impossible to obtain an analytical solution for u_3 and Φ_4, but estimates show that the temperature gradients do not change the behavior of u_3, obtained in [2] ($|u_3| < |u_1|$ and of the same sign), but decrease $|u_3|$ by 20-50% with different initial conditions, and this means that Φ_4 changes insignificantly. Since the contribution of the terms $\theta^3 u_3$ and $\theta^4 \Phi_4$ is small (less than 15%) and they can only intensify the effect, it can be assumed that the vortex for the most part is determined by the terms u_1, Φ_0 and Φ_2. Thus, the transformation of the circumpolar vortex described in [2] is correct also for a real temperature stratification.

Now we will cite variations of the temperature profile computed in z-coordinates (Fig. 2). It can be seen that in this case the role of the temperature gradients is quite large. For example, at $z \approx 70$ km the variations $\Delta T \approx 2.5$ K -- b (1, 2) and $\Delta T \simeq 8$ K -- d (1, 2); at $z \simeq 40$ km -- $\Delta T \simeq 15$ K -- a (1, 2) and $\Delta T \simeq 20$ K -- b (1, 2). Moreover, from the figure (b, d) it can be seen that an increase in the temperature gradient in the mesosphere causes a decrease in ΔT in it, and as indicated by computations, with great gradients ($a \geqslant 2$ K/km) the ascending currents cause a cooling of the mesosphere and heating of the stratosphere, which agrees well with experimental data [3, 4].

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CHARACTERISTIC DIURNAL VARIATIONS OF WINDS IN THE UPPER MESOPAUSE REGION OVER CENTRAL EUROPE AND EASTERN SIBERIA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 50-54

[Article by Doctor R. Schminder, Doctor of Physical and Mathematical Sciences E. S. Kazimirovskiy, Doctor D. Kurschner and Candidate of Physical and Mathematical Sciences V. D. Kokourov and V. F. Petrukhin, Kollm Geophysical Observatory, Leipzig University, and Siberian Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, submitted for publication 26 February 1979]

Abstract: On the basis of an analysis of simultaneous wind observations in the upper mesopause region over Central Europe and Eastern Siberia in the winter of 1977/1978 and in the spring of 1978 it is demonstrated that together with the coinciding nature of the diurnal variation there are differences indicating the existence of major regional structures in circulation and in the systems of tidal winds. A synoptic analysis requires an adequately dense network of observation stations.

[Text] During the winter of 1974/1975 joint work was undertaken by the Kollm Geophysical Observatory at Leipzig University imeni K. Marks and the Badary Observatory of the Siberian Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation Siberian Department USSR Academy of Sciences in the upper mesosphere region by the radiophysical method by measuring ionospheric drift with the spaced reception of signals of long-wave radio transmitters (D_1 method). Continuing this program [1, 2, 4], it was possible to obtain results of simultaneous measurements for the periods 4-5 - 16-17 December 1977 and 1-2 - 19-20 March 1978 (the measurement method was such that the observations were made during the nighttime hours local longitude time between sunset and sunrise). In addition to the results of measurements of long-wave drifts, the analysis was supplemented by wind measurement data for this same region obtained by the radiometeor method (D_2) by specialists of the Kuhlungsborn Observatory of the Central Institute of Solar-Terrestrial Physics Academy of Sciences German Democratic Republic (Heinrich Hertz

Institute). The characteristics of the measurement paths are given in Table 1.

Table 1

Wind Measurement Paths in the Upper Mesopause Region at the Observatories in Kollm and Kuhlungsborn (German Democratic Republic) and Badary (Soviet Union)

Измерительная трасса 1	Расстояние, *км* 2	Метод 3	Частота 4	Обозначение 5	Координаты точки отражения 6
7 Целлендорф—Коллм	170	D_1	185 *кгц* 12	К 185	52° с. ш. 13° в. д.
8 Иркутск—Бадары	150	D_1	200	Б 200	52 13 103 14
9 Варшава—Коллм	460	D_1	227	К 227	52 17
10 Кулунгсборн—Коллм	500	D_1	245	К 245	53 12
11 Радиометеорные измерения ветра	150	D_2	32,5 *мгц* 15	К—РАМ	54 15 56 12

KEY:

1. Measurement path
2. Distance, km
3. Method
4. Frequency
5. Notation
6. Coordinates of reflection point
7. Zellendorf-Kollm
8. Irkutsk-Badary
9. Warsaw-Kollm
10. Kuhlungsborn-Kollm
11. Radiometeor wind measurements
12. KHz
13. N
14. E
15. MHz

K = Kuhlungsborn
Б = Badary
PAM = Radiometeor observations

The selected interval of synchronous measurements did not make it possible to investigate disruptions of circulation associated with stratospheric heating, which according to measurements at Kollm reached the upper mesopause region over Central Europe only on 1-2 January 1978. And here the March measurement period coincided with the onset of the spring restructuring of circulation, which despite the considerable distance between Kollm and Badary (about 5,000 km) began virtually simultaneously on 2-3 March 1978 and was manifested as a weakening of the westerly wind, a frequent change in the directions of zonal movement and an intensification of the easterly wind. With respect to the semidiurnal tide there was a decrease in amplitude, a strong phase instability, and at the beginning of the third 10-day period in March a rapid change in phase characteristic for the transition from a winter to a summer type of circulation [5].

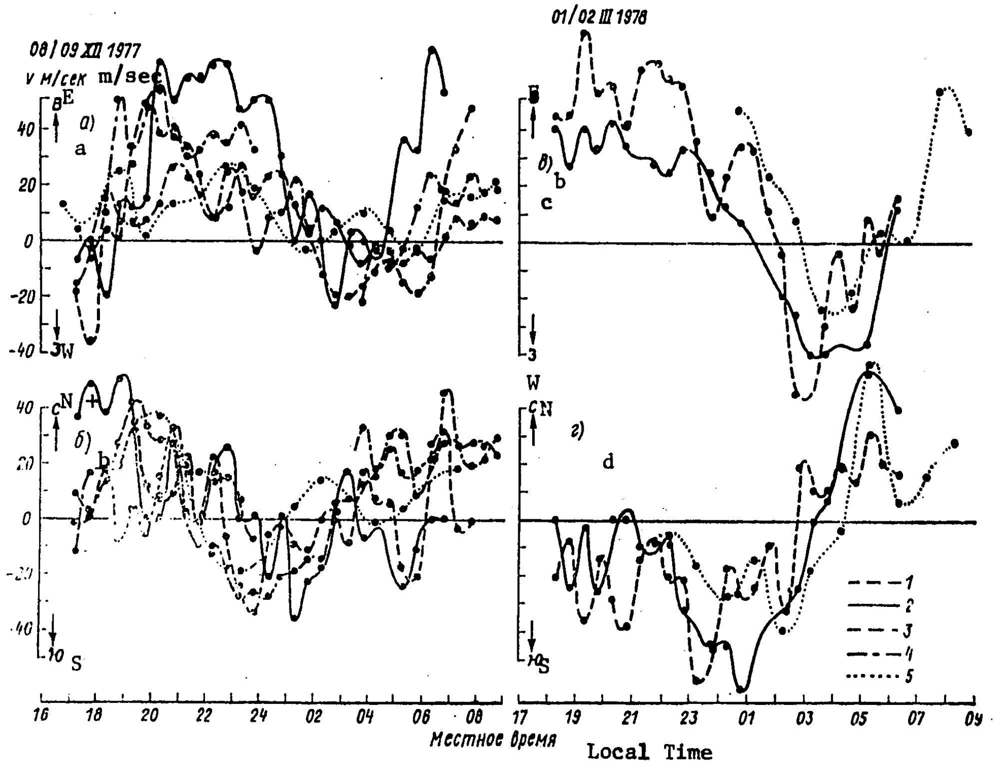

Fig. 1. Diurnal variations of wind velocity vector in upper mesopause region over Central Europe and Eastern Siberia at middle (a, b) and at end (c, d) of winter. a, b) zonal component, b, d) meridional component. 1) K 185; 2) B 200; 3) K 227; 4) K 245; 5) K-PAM [K = Kollm; Б = Badary; PAM = radiometeor wind measurements]

An analysis of wind measurement data on all paths in December 1977 and in March 1978 indicated a coincidence of the nature of the diurnal variations for all stations having an approximately identical geographical latitude, regardless of longitude. However, in details it is possible to see an excellent correlation and very great difference in both the prevailing and in the tidal winds. With respect to the short-period variations, which are interpreted as the effects of internal gravitational waves, here it is impossible to detect any correlation, since the coherence scale for these variations is less than 200 km [6].

Figure 1 presents data from simultaneous measurements for one night in December and one night in March, when the agreement of the results was rather good. The values are given in local longitude time. It must be remembered that the difference in time between Central Europe and Eastern Siberia is 7 hours. Figure 1a,b, which shows the wind values for all five measurement paths (including measurements by the D_2 method at Kuhlungsborn), gives some idea concerning the real differences in the results between the paths with reflection points situated very close together. For all the European paths they are all in a small volume with dimensions in longitude and latitude of the order of several degrees and with respect to altitude not more than 10 km. It can be seen that the measured values occupy some interval and in general it would be very useful in many respects on the basis of measurements in Central Europe to ascertain the center of this "zone of values" and provide users not only the mean wind value, but also the width of this interval. Twelve years of experience with measurements at Kollm, where at first the measurements were made only on one path, enables us to note that in the interpretation of such measurements it is necessary to approach very carefully the evaluation of the accuracy in the measurements themselves and the representativeness of the results for one reflection point relative to the mean characteristic of the wind regime on a regional scale.

Figure 1,c,d shows the diurnal variations on the last day of stable winter circulation for the paths K 185, Б 200 and K-PAM.

The data from radiometeor measurements were furnished through the courtesy of the Kuhlungsborn ionospheric observatory (see Table 1).

Figure 1c,d clearly shows the excellent agreement of the results of measurements by the D_1 and D_2 methods for Europe. The agreement is not always so good, but already available observational data, making it possible to carry out their comparison, indicated that a high correlation exists with adherence to the following conditions. First, when the measurement conditions ensure statistical reliability of the result; second, when a stable circulation ensures a spatial uniformity of the wind regime; third, when there are sufficiently great amplitudes of the tidal winds, which facilitates the relative analysis. If at least one of these conditions is violated, the correlation rapidly decreases. This means that if we observe differences in the measurement results by both methods, they can be attributed either to a certain uncertainty in the method itself (for example, due to the lack of data on the precise reflection altitude) or to some still not finally clarified peculiarities of these methods.

Table 2 gives a sample of results for other days. It also gives some idea concerning both the coincidences and discrepancies in measurements at two points. After comparing the results, we must conclude that in addition to the coinciding nature of the diurnal variation for both the prevailing and the tidal wind in the upper mesopause region over Central Europe and Eastern Siberia, there are differences indicating the presence of regional structures in circulation and in the systems of tidal winds. This means

Table 2

Results of Analysis of Wind Measurements in Upper Mesopause Region at the Observatories Kollm (GDR) and Badary (USSR) on Paths With Close Frequencies (185 and 200 KHz) and Approximately Equal Distances from Transmitters

Ночь 1	Обозначение 2	Зональный компонент 3			Меридиональный компонент 4		
		V_0	V_2	T_2	V_0	V_2	T_2
5 05/06 декабря 1977 г.	7 К 185	—05	38	20.45	—03	17	18.00
	8 Б 200	+18	11	20.00	+09	33	15.45
08/09	К 185	+09	29	21.45	±00	12	19.15
	Б 200	+28	31	21.30	+04	17	19.15
12/13	К 185	+28	33	21.15	+06	35	17.45
	Б 200	+32	12	17.30	—17	07	14.45
14/15	К 185	+24	32	20.00	+01	23	18.15
	Б 200	+17	20	17.00	—18	21	13.15
6 01/02 марта 1978 г.	К 185	+21	42	21.15	—11	23	16.30
	Б 200	+07	35	21.15	—13	27	18.00
06/07	К 185	+03	30	20.30	—04	18	15.45
	Б 200	—17	24	22.15	—15	34	17.15

KEY:

1. Night
2. Notation
3. Zonal component
4. Meridional component
5. December
6. March
7. Kolmm
8. Badary

Note: V_0 — prevailing wind, positive to the north or to the east, V_2 -- amplitude of the semidiurnal tidal wind, T_2 (local time) -- phase of semidiurnal tidal wind, moment of maximum wind, directed to the north or east.

the detailed coincidence of the curves of temporal wind variations can be either random (Fig. 1a,b) or associated with a marked seasonal change in the wind fields (Fig. 1c,d). A study of changes in the prevailing wind from day to day could afford a possibility for investigating planetary waves, but this would require intermediate measurement points [2]. In the future, evidently, it is necessary to make a detailed study of the discovered regional large-scale structures separately in each region and only then, in the second stage, combine the results for constructing a general model of circulation. Real synoptic investigations require the organization of additional measurement points; the density of the network which exists at the present time for these purposes is inadequate.

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EVALUATION OF ERRORS IN COMPUTING EFFECTIVE RADIATION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 55-61

[Article by Doctor of Geographical Sciences A. I. Budagovskiy and L. Ya. Dzhogan, Institute of Water Problems, submitted for publication 20 March 1979]

Abstract: The paper describes a method for the indirect evaluation of errors in computing effective radiation. It is based on a comparison of the differences between the temperature of the soil surface and the air, determined by three independent methods. The method is applied to observational data from Takiatash actinometric station. The authors give a brief analysis of the results.

[Text] Regular observations of the radiation regime have been made in the relatively dense network of actinometric stations in the Soviet Union since the mid-1950's. The accumulated data are necessary for the use of modern methods for climatological and hydrological computations, in particular, for computations of evaporation and irrigation norms. However, the use of the mentioned materials involves considerable difficulties. They are caused, in particular, by the fact that the measured values of the radiation balance to a considerable degree are dependent on the albedo and temperature of the underlying surface at the measurement site. The difficulties mentioned above are usually overcome by the use of the total radiation values measured at actinometric stations and accumulated data on the characteristics of albedo for different underlying surfaces; in this case effective radiation is determined by computations.

It is evident that errors in such computations are in need of evaluation. It is desirable that this be done on the basis of quite extensive material so as to form some idea concerning the statistical stability of the results. This problem can be solved indirectly. It involves essentially the following.

On the basis of data from observations made at actinometric stations it is possible to determine the effective radiation value. It is equal to the difference between the measured values of absorbed short-wave radiation and the radiation balance. The latter is dependent, in particular, on the temperature of the underlying surface in the measurement sector beneath the balancemeter. The effective radiation value obtained in this way will henceforth be called the "measured" radiation and in case of necessity it can be assumed conditionally that it does not contain errors.

It is convenient to represent the effective radiation value found in this way in the form of the sum of two terms. The first of these is equal to the effective radiation for a case when the temperature of the underlying surface beneath the balancemeter T_u is equal to the air temperature measured in the meteorological booth. The second term takes into account the influence exerted on effective radiation by the difference between the mentioned temperature values.

$$I_{\text{п}} = I^* + 4\sigma S (273 + T_2)^3 (T_{\text{п}} - T_2). \tag{1}$$

[п = u]

Here I_u is the effective radiation found by the method indicated above on the basis of the measurement results, I^* is the effective radiation when $T_u = T_2$.

We will denote the computed effective radiation by I_{comp} and assuming that $I^* \approx I_{comp}$, on the basis of (1) we write

$$\Delta I_{\text{р}} = I_{\text{п}} - I_{\text{р}} = 4\sigma S (273 + T_2)^3 (T_{\text{п}} - T_2). \tag{2}$$

[р = comp; п = u]

Since the computed values of effective radiation in the most general case can contain both random and systematic errors, they will automatically enter into ΔI_{comp}. These errors can be evaluated by computing the ΔI values by some other two independent methods.

The first of these methods involves the use of measurements of soil surface temperature. At meteorological stations they are carried out on bare sectors of the soil. Therefore, their use for the purposes mentioned above in principle is possible only when the measurements of the radiation balance are carried out over a sector with bare soil. On the basis of these measurements the ΔI_u value can be computed using the expression

$$\Delta I_{\text{п}} = 4\sigma S (273 + T_2)^3 (T_{\text{п}} - T_2). \tag{3}$$

The second possible method for indirect but independent determination of the difference $T_u - T_2$ involves use of the formula

$$P = \alpha \rho c_p D (T_{\text{п}} - T_2), \tag{4}$$

in which P is turbulent heat exchange, α is a conversion factor, ρ is air density, c_p is the specific heat capacity of air at constant pressure, D is a coefficient having the dimensionality of velocity. It characterizes the turbulent conductivity of the air layer between the soil surface and any fixed altitude (in this case 2 m). Henceforth we will call it the exchange coefficient.

The turbulent heat exchange value enters into the heat balance equation

$$R = P + B + LE, \tag{5}$$

in which R is the radiation balance, B is heat exchange in the soil, L is the latent heat of evaporation, E is the turbulent flux of moisture or evaporation.

The day-to-day changes in heat exchange in the soil are usually small and rarely exceed 10% of the radiation balance. Therefore, in an approximate estimate of turbulent heat exchange this heat balance component can be omitted or estimated approximately using data from the literature [3, 5].

Under extremely dry conditions, especially in the arid zone during the summer months, evaporation from the surface of the bare soil can be assumed equal to the precipitation (H). Accordingly, assuming $E \approx H$ and limiting ourselves to the above-mentioned approximate estimate of heat exchange in the soil, it is possible to obtain turbulent exchange values which are employable for practical purposes. In their subsequent use for computing the differences $T_u - T_2$, and then ΔI it is necessary to know the values of the exchange coefficient. The literature gives estimates of this coefficient used in climatological computations. However, a high percentage of these coefficients were obtained on the basis of observations over the plant cover. Therefore, we used additional observational data given in [4]. They include information on all the components of the heat balance and meteorological elements, including on the temperature of the soil surface, measured using scattered temperature sensors [6], giving the spatially averaged temperature and having a small radiation error. The observations were made in the Fergana valley in cotton fields in 1956 beginning on 7 May. In the study observational data were used from early in May through the first 10-day period of June inclusive, when the cotton plants are extremely small and do not exert a significant influence on formation of soil surface temperature.

Computations of the exchange coefficient D were made using expression (4) and on their basis it was possible to construct the dependence D = f(U), where U is wind velocity at a height of 2 m (see Fig. 1). We note in passing that an attempt to construct a curve of the dependence of the exchange coefficient on wind velocity, taking into account the influence of temperature stratification, did not give significant advantages.

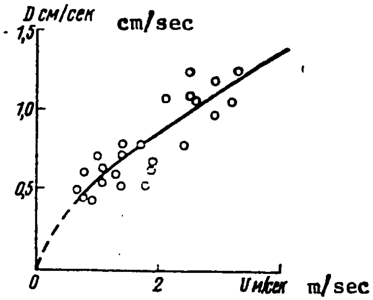

Fig. 1. Curve of dependence of exchange coefficient on wind velocity. Along y-axis: D cm/sec; along x-axis: U m/sec

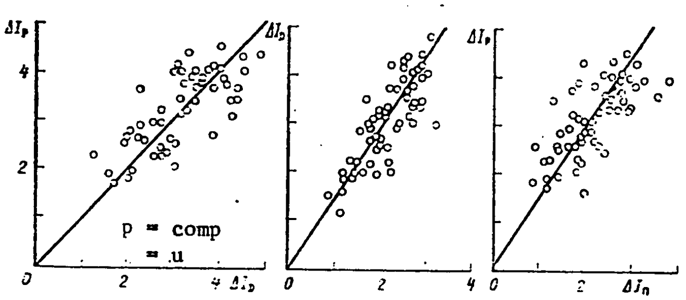

Fig. 2. Curves of correlation between ΔI_i values computed by different methods.

In order to estimate the error in the dependence D = f(U) on the basis of data on the diurnal sums of turbulent heat exchange, by means of inverse computations we computed the temperature difference $T_u - T_2$ and compared this with the corresponding measured values. Then after scaling the computed and measured $T_u - T_2$ values into radiation units we determined the standard deviation σ_Δ characterizing the error in determining ΔI, associated with the use of the mentioned dependence. According to computation data, $\sigma_\Delta = 0.46$ Cal/(cm^2·month).

Taking into account what has been said above, on the basis of (4) and (5) we can write

$$\Delta I_D = 4\sigma S(273 + T_2)^3 \frac{R - B - LH}{a\rho c_p D}. \quad (6)$$

Since the errors in computing effective radiation, according to the comment made above, are completely included in ΔI_{comp}, their evaluation involves the paired comparison of the determined ΔI_i values.

It is possible to obtain some idea concerning the systematic differences of the ΔI_i values computed by the three above-mentioned methods by using the expressions

$$\begin{gathered}\Delta I_{\text{р}} = a_1 \Delta I_D, \\ \Delta I_{\text{р}} = a_2 \Delta I_{\text{п}}, \\ \Delta I_D = a_3 \Delta I_{\text{п}}, \\ a_1 = \frac{\Sigma \Delta I_{\text{р}}}{\Sigma \Delta I_D},\ a_2 = \frac{\Sigma \Delta I_{\text{р}}}{\Sigma \Delta I_{\text{п}}},\ a_3 = \frac{\Sigma \Delta I_D}{\Sigma \Delta I_{\text{п}}}.\end{gathered} \qquad (7)$$

[p = comp; π = u]

Graphs of the dependence (7) are shown in Fig. 2.

It is evident that the measure of the relative value of the systematic differences between the ΔI_i values, determined by the two independent methods, is the deviation of the corresponding a_i values from 1.

The random deviations between the paired comparable ΔI values, computed by different methods, can be characterized by the values of the corresponding dispersions

$$\begin{gathered}\sigma_1^2 = \overline{(\Delta I_{\text{р}} - a_1 \Delta I_D)^2}, \\ \sigma_2^2 = \overline{(\Delta I_{\text{р}} - a_2 \Delta I_{\text{п}})^2}, \\ \sigma_3^2 = \overline{(\Delta I_D - a_3 \Delta I_{\text{п}})^2}.\end{gathered} \qquad (8)$$

Here the horizontal line is the averaging symbol.

Since the ΔI_{comp}, ΔI_D and ΔI_u values were computed by independent methods, the errors in these computations are also independent. In actuality, the random errors in computing ΔI_{comp} are related primarily to the deviation of the real vertical distribution of air temperature and humidity, the deviation of clouds from their "typical" values adopted in validation of the parameters in the computation formulas, and also their approximate character. The error in computing ΔI_D is determined by the corresponding error in the dependence D = f(U), incomplete adherence to the hydrodynamic conditions for its use, and also the conditions necessary for adequately reliable determination of the monthly sums of turbulent heat exchange. Finally, the random error in computing ΔI_u is related to the corresponding errors in measuring the soil surface temperature. Accordingly, the values of the dispersions of each of the two paired comparable values must be the sum of the two corresponding dispersions, to wit

Table 1

Число членов ряда Number of terms in series	a_1	a_2	a_3	σ_1^2	σ_2^2	σ_3^2	σ_p	σ_D	$\sigma_п$
29	1,07	1,60	1,49	1,10	1,26	0,94	0,84	0,63	0,74
29	0,98	1,45	1,48	1,03	1,33	0,88	0,86	0,54	0,77
58	1,02	1,52	1,49	1,06	1,30	0,91	0,85	0,58	0,76

p = comp π = u

$$\sigma_1^2 = \sigma_p^2 + \sigma_D^2,$$
$$\sigma_2^2 = \sigma_p^2 + \sigma_п^2, \qquad (9)$$
$$\sigma_3^2 = \sigma_D^2 + \sigma_п^2.$$

[π = u; p = rad] Here σ^2_{rad} is used to denote the dispersion ΔI_p, σ^2_D denotes the dispersion ΔI_D and σ^2_u denotes the dispersion ΔI_u.

The three equations of the very simple system (9) contain three unknown parameters σ^2_{rad}, σ^2_D and σ^2_u, which can be determined using the already computed values σ^2_1, σ^2_2 and σ^2_3.

In order to apply the described method to an evaluation of the errors in computing effective radiation we used observational data for the actinometric station Takhiatash (lower course of the Amudar'ya River), in whose description, given in [1] and in handbooks on climate, there is a clear indication that the observations were made in a sector with a bare soil surface, that is, there was satisfaction of the requirements necessary for computing the ΔI_D and ΔI_u values. In addition, this region of Central Asia is characterized by very little precipitation (the annual precipitation norm is 98 mm). Therefore, here, more frequently than in other regions, for monthly time intervals there is satisfaction of the condition $E \approx H$ necessary for computing ΔI_D.

In the computations we used the Brent formula, the values of whose coefficients were refined by M. Ye. Berlyand [2] on the basis of theoretical computations. A linear dependence was used in taking into account the influence of cloud cover. The value of the parameter c entering into it was also taken from M. Ye. Berlyand.

The values ΔI_{comp}, ΔI_u and ΔI_D were determined using expressions (2), (3) and (6). In the computations we used observational data obtained during the warm half-year (April-September) during 1955-1959 and 1961-1968, given in [2], in actinometric handbooks and in handbooks on USSR climate. Additional data on temperature of the soil surface, temperature and air humidity, wind velocity, total cloud cover and precipitation were taken from handbooks on climate and archival data. In computations we excluded cases when satisfaction of the condition $E \approx H$ caused well-founded doubt or when there were gaps in the observations of one of the elements. The results of observations for a total of 58 months were used in the computations. In order to form some idea concerning the statistical stability of the computed characteristics the series was broken down into two equal parts.

The results of paired comparison of the computed values are given in Fig. 2. The computed a_i and σ_i values (in Cal/(cm^2·month)) are given in Table 1.

We must note that the differences between the a_i and σ^2_i values obtained for the first and second halves of the investigated period and also for the period as a whole do not exceed the limits of the admissible error in estimating the sample values of the corresponding parameters, that is, the obtained a_i and σ_i^2 values have an adequate statistical stability. The second important conclusion following from an examination of the computed values is that the values of the coefficient a_1 (the systematic discrepancies between the compared ΔI_{comp} and ΔI_D values) do not differ significantly from unity not only for the investigated period as a whole, but also for its parts, that is, the two values virtually coincide. On the other hand, the values of the coefficients a_2 and a_3 differ substantially from unity, evidence of considerable systematic differences between the computed ΔI_{comp} and ΔI_D values, on the one hand, and ΔI_u on the other. The reason for this, as is clearly noted, is the systematic error in measuring temperature of the soil surface, data for which are considerably too low. The latter for the conditions in Central Asia during the summer months is entirely natural since the surface of even dry soil has a considerably lesser reflectivity in comparison with the reflectivity of the thermometer reservoir. As a result the mean value of the characteristic temperature of the latter is considerably below the temperature of the dry soil surface. Thus, the results, even with the most cautious approach, give basis for drawing the conclusion that there are no significant systematic differences between the effective radiation parameters obtained by computations and their measured values (under the condition $T_u = T_2$).

In evaluating the determined values characterizing the random error ΔI in computations attention must be given to the fact that for all three computation methods they differ little from one another and in general are not great. A more complete idea concerning the magnitude of the computation error ΔI_{comp} can be obtained by comparing it with the computed values of effective radiation and the radiation balance.

The mean value of the computed values of the effective radiation for April-September during the above-mentioned time interval (1955-1959, 1961-1968) is 3.2 Cal/(cm^2·month). Accordingly, the relative probable error in such computations is 18%, and the error with an 80% guaranteed probability -- 34%.

The mean value of the radiation balance, obtained on the basis of the results of measurements of absorbed short-wave radiation and the computed values of effective radiation, is 10.8 Cal/(cm^2·month). In such a case the probable error and the error with 80% guaranteed probability, related to the use of the computed values of effective radiation for the warm half-year, on the average will be 5.3 and 10.1% respectively, which does not exceed the errors in measuring the monthly sums of the radiation balance, which, in accordance with [7], are estimated at 10%.

Next we note that the σ_Δ value, cited above in the text, and σ_D, cited in Table 1, determining the error in computing ΔI_D, differ relatively little from one another. However, insignificant differences between them are entirely to be expected because σ_Δ was obtained on the basis of use of heat balance observations and σ_D on the basis of mass materials. It is more important that σ_D is appreciably less than σ_{comp} and σ_u. This conclusion is important for evaluating the error associated with the introduction of a correction to the radiation balance in computations of evaporation from the surface of the moistened soil.

Finally, it should be noted that despite the well-known incorrectness of standard observations of temperature of the soil surface carried out in the network of meteorological stations the σ_u value, dependent in the last analysis on the random errors of these observations, is relatively small. It is even somewhat less than the random error in computations of effective radiation characterized by the σ_{comp} value.

The described method for estimating the errors in computations of effective radiation can also be used for other points if there is satisfaction of the above-mentioned conditions necessary for computing the ΔI_u and ΔI_D values.

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OPTICAL CHARACTERISTICS OF THE ATMOSPHERE IN THE TROPICAL ZONE OF THE ATLANTIC OCEAN

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 62-69

[Article by V. N. Adnashkin, L. K. Veselova and Candidates of Physical and Mathematical Sciences O. D. Barteneva, A. G. Laktionov and N. I. Nikitinskaya, Main Geophysical Observatory, Leningrad State University and Institute of Applied Geophysics, submitted for publication 22 May 1979]

Abstract: This paper presents the results of investigations of the spatial-temporal variability of the aerosol-optical characteristics of the near-water layer and atmospheric layer of the tropical zone in the Atlantic Ocean according to data from TROPEKS-72 and GATE-74. Also considered is the latitude variation of integral and spectral values in the region 0.35-1.00 μm of atmospheric transparency, the selectivity index of aerosol attenuation of solar radiation and moisture content of the atmospheric layer, and also a number of characteristics of the near-water layer: meteorological range of visibility, concentrations of large ($d \geqslant 0.63\ \mu$m) and giant ($d > 10\ \mu$m) aerosol particles. It is shown that the principal factor responsible for the inconstancy of optical weather in the tropical region of the North Atlantic is the transport of dust from the deserts of the African continent.

[Text] Experimental investigations of the parameters of microstructure and optical characteristics of aerosol in the near-water layer and atmospheric layer in the tropical latitudes of the Atlantic Ocean indicate their considerable temporal variability and spatial nonuniformity [1, 3, 4, 6, 7, 12-14, 16]. It is shown in this study that the principal factor responsible for the inconstancy of optical weather in the tropical region of the North Atlantic is the transport of great quantities of dust into the ocean from the deserts of the African continent.

During the period of GATE-74, from 27 June through 10 September, on the basis of data from the geostationary satellite GMS-1, "dust cyclones" nine times crossed the Atlantic Ocean from east to west in the latitude zone from 10 to 20°N [2]. The eastern part of this region of the Atlantic Ocean, the so-called "sea of gloom," in which the transport of dust from the African continent by the NE Trades is systematically observed [10], can also be seen clearly in the averaged latitude variation of optical and aerosol characteristics of the atmosphere from 50°N to the equator, represented in Fig. 1 on the basis of data from TROPEKS-72 [1, 6]. Specifically in this region of the ocean all the aerosol-optical characteristics considered below attain their extremal values. For example, in the "sea of gloom" the following are noted: the lowest integral transparency P_2 [9] and the highest value of the aerosol component of the optical layer of the atmosphere τ^*_λ for $\lambda = 1.00 \mu m$; the maximum N concentrations of large ($d \geqslant 0.63 \mu m$) and giant ($d > 10 \mu m$) particles and the minimum values of the meteorological range of visibility S in the near-water layer of the atmosphere. The n parameter, characterizing the degree of selectivity of aerosol attenuation of solar radiation in the well-known Angstrom formula $\tau^*_\lambda = \beta\lambda^{-n}$ has a value on the order of 0.2, that is, the spectral variation of the aerosol component of optical thickness of the atmosphere in the spectral range 0.35-1.00μm is extremely close to neutral.

Figure 1 shows that the air masses in the temperate latitudes are characterized by appreciably higher values of the transparency characteristics and the selectivity of aerosol attenuation, and also a relatively small moisture content W of the atmospheric layer, which with the degree of advance into the tropics increases and attains maximum values in the ICZ -- intertropical convergence zone [8].

The equatorial region from 10°N to the equator, within which the ICZ is situated, is also subject to the influence of the transport of continental dust from the central and southwestern regions of Africa. However, the effect of the "cloud filter" in the ICZ region and the arrival of pure oceanic air masses in the lower layers of the atmosphere with southerly and Anti-Trades westerly winds favor this picture: with movement from 10°N toward the equator there is a tendency to an increase in transparency of the entire layer of the atmosphere and especially its near-water layer [6]. Thus, Fig. 1 shows how nonuniform this region of the Atlantic Ocean is with respect to its optical properties.

In Fig. 2, where the days of observations have been plotted along the x-axis, we show the temporal variability of the parameters of microstructure and optical characteristics of aerosol considered above for the period of the three phases of GATE-74 from 28 June through 19 September during which the "Passat" scientific research weather ship was situated at a point on the equator 10°W at a distance of about 500 km from Africa.

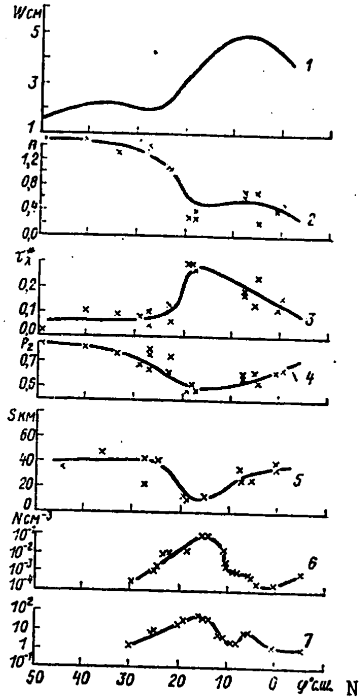

Fig. 1. Latitude variation of aerosol-optical characteristics of atmospheric layer and near-water layer over the Atlantic Ocean (Northern Hemisphere).

Figure 2 shows that the amplitude of variation of aerosol-optical characteristics of the atmosphere during this period is extremely significant. The integral coefficient of atmospheric transparency P_2 varied from 0.59 to 0.75. The concentration of large ($d \geqslant 0.63 \mu m$) aerosol particles in the near-water layer varied from 2 to 30 cm^{-3} and the concentration of particles $d > 2 \mu m$ was from 0.1 to 1.3 cm^{-3}. The meteorological range of visibility S varied in the range 10-100 km.

The values of the aerosol component of the optical layer of the atmosphere τ_λ^* for $\lambda = 1.0 \mu m$ were in the range 0.10-0.40. A fact of importance is that the nature of the spectral variation of aerosol attenuation varied from close to neutral n = 0.1 to extremely selective n = 1.3. The water vapor content in the atmospheric layer was 2.5-4.5 cm. The concentration of giant particles with $d > 10 \mu m$ during the entire period was very low and did not exceed 10^{-3} cm^{-3}.

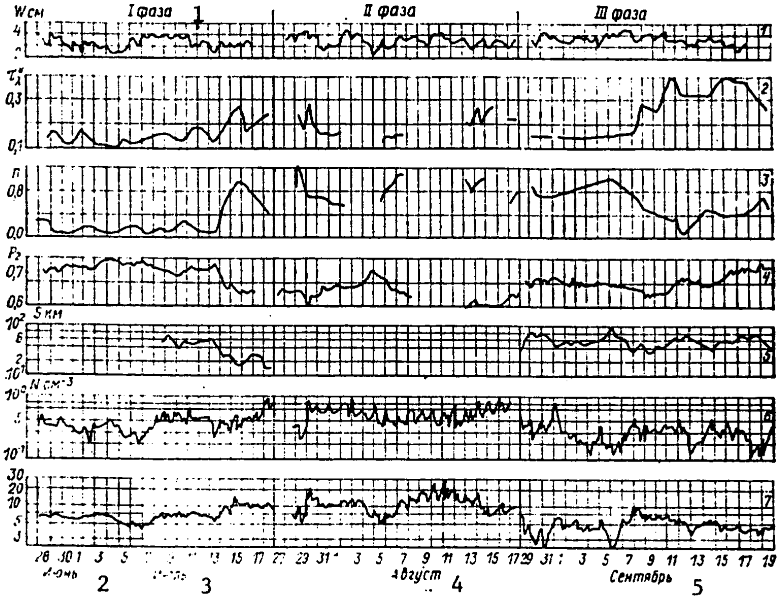

Fig. 2. Temporal variation of aerosol-optical characteristics of atmosphere during GATE-74 period ("Passat" scientific research weather ship, 0° latitude, 10°W). 1) moisture content of atmospheric layer; 2) aerosol component of atmospheric layer for $\lambda = 1.0 \mu m$; 3) index of selectivity of aerosol attenuation of solar radiation; 4) integral coefficient of atmospheric attenuation; 5) meteorological range of visibility in near-water layer; 6) concentration of giant particles ($d > 2 \mu m$); 7) concentration of large particles ($d \geqslant 0.63 \mu m$).

KEY:

1. Phase
2. June
3. July
4. August
5. September

We should note the presence of a high correlation between the values characterizing atmospheric turbidity P_2 and τ_{λ}^{*}, and also between the concentration of large ($d \geqslant 0.63 \mu m$) particles and the meteorological range of visibility; in the latter case the correlation coefficient was 0.94. In the considered region of the ocean the concentration of large particles in the near-water layer is essentially dependent on the direction of the flows in the free atmosphere. The increase in the concentration of aerosol particles is associated, in particular, with advection of northeasterly flows in the layer 2-3 km, which carry dust-laden air from Africa, whereas its decrease is associated with an intensification of monsoonal circulation in the layer 1-1.5 km [7]. These results agree with the data obtained in TROPEKS-72, on the basis of which the conclusion was drawn that the basic mass of large aerosol particles is of continental origin [6].

Table 1

Aerosol-Optical Characteristics of Atmosphere During Dust Intrusion Periods

Место измерения 1	Дата 2	P_2	S км	$\tau^*_\lambda = \beta\lambda^{-n}$: n	$\tau^*_\lambda = \beta\lambda^{-n}$: $\beta = \tau^*_{\lambda=1,0\,мкм}$ 3	Концентрация больших частиц, $см^{-3}$ 4	Концентрация гигантских частиц $см^{-3}$ 5
6 НИСП «Пассат», 7 0° ш., 10° з. д.,	15 июля 1974 г. 11	0.61	17	0,9	0,29	16	0,5
	Среднее за I фазу 12	0,71	45	0,2	0,14	8,1	0,5
	29 июля 1974 г. 11	0,59	15	1,3	0,24	9	0.4
	30 »	0,58	16	0,7	0,30	23	1,3
	11 августа 1974 г. 13	0,50	8	—	—	30	0,7
	13 »	6,59	—	1,0	0,23	16	0,6
	14 »	6,59	—	0,9	0,26	14	0,8
	Среднее за II фазу 14	0,68	40	0,5	0,16	8,5	0,6
8 НИС «Академик Курчатов», 9 18,8° с. ш., 16,5° з. д. 10	1 августа 1972 г. 13	0,58	12	0,2	0,34		

KEY:

1. Place of measurement
2. Date
3. μm
4. Concentration of large particles
5. Concentration of giant particles
6. "Passat" scientific research weather ship
7. 0° latitude, 10°W
8. "Akademik Kurchatov" scientific research ship
11. ...July
12. Mean for phase I
13. ..August
14. Mean for phase II

A comparison of curves 2-7 in Fig. 2 shows that the greatest variations in aerosol-optical characteristics of the atmosphere occurred on 14-15 and 29-30 July and 9-14 August, when dust-laden air masses arrived in this region of the Atlantic, some of which, moving from the arid zones of North and Southwest Africa in a southwesterly direction, under definite synoptic conditions reached the equator. A joint analysis of TV and IR images for this region of the earth from the American meteorological satellite GMS-1 indicated, for example, that on 30 July 1974 the centers of the dust storms were situated in regions with the coordinates $\varphi = 18°$ N, $\lambda = 8°$W and $\varphi = 31°$N, $\lambda = 0°$W at a distance of about 2000 km or more from the measurement site [15].

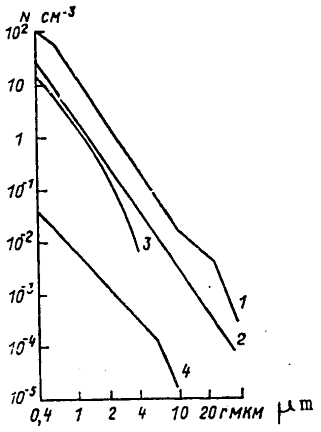

Fig. 3. Spectra of size of aerosol particles in near-water layer obtained in different regions of tropical zone of Atlantic Ocean. 1) "sea of gloom," (14°N, 19°W); 2) "sea of gloom" (18.8°N, 16.5°W), 1 August 1972; 3) Equatorial Atlantic (0° latitude, 10°W), 30 July 1974; 4) low-dust region in ocean (14°S, 19°W).

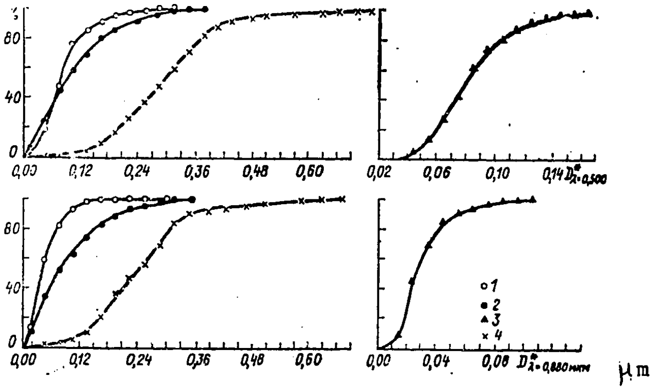

Fig. 4. Integral probability distribution curves for distribution of aerosol optical thickness of atmosphere $\tau^*_\lambda = 2.3\ D^*_\lambda$ for $\lambda = 0.500$ and 0.880 μm according to data in [14]. 1) Miami, 2) Barbados, 3) Bermuda, 4) Sal Island.

Table 1 gives some aerosol-optical characteristics of the days on which there were dust intrusions during the GATE-74 and TROPEKS-72 periods. As a comparison, the table also gives their mean values for phases I and II with the transport of dust. The most powerful transport of dust, lasting several days, was observed in August. For example, on 11 August 1974 the integral transparency coefficient P_2 for the atmospheric layer decreased to 0.50, whereas the concentration of large particles with $d \geqslant 0.63 \mu m$ in the near-water layer attained a maximum value 30 cm^{-3}. The influence of dust aerosol on variability of the parameters of microstructure of the near-water layer to a considerable degree is caused by the peculiarities of the circulation regime in the atmosphere in the eastern part of the Atlantic Ocean, the distance of the observation point from the centers of development of dust storms, and also the intensity and duration of the transport. Precisely for these reasons the intrusion of dust storms into the region of bunkering of ships during TROPEKS-72, situated in the immediate neighborhood of the continent and at the focus of dust storms, was accompanied, as indicated by Table 1, by a considerable increase in the concentration of all fractions of aerosol particles, including giant particles (with $d > 2 \mu m$), whereas at the equator, according to data from GATE-74, an increase in the concentration of large particles was observed with an almost constant and very small concentration of giant particles.

The variability of the characteristics of aerosol microstructure in the near-water layer is manifested most clearly in a comparison of the particle size spectra obtained in different regions of the tropical zone of the Atlantic Ocean and illustrated in Fig. 3. Curve 1 corresponds to the maximum concentrations registered in the "sea of gloom" which exceed the concentrations in the region of the ocean with little dust by more than three orders of magnitude -- curve 4. In the latter distribution there are virtually no aerosol particles with $d > 10 \mu m$. The particle size spectra observed during the powerful dust intrusions of 1 August 1972 and 30 July 1974 in the eastern part of the Atlantic Ocean are shown by curves 2 and 3 respectively. We should note the significant discrepancies in the nature of these distributions for the coarsely disperse fraction of aerosol particles with $d > 2 \mu m$, which can be caused by the influence of sedimentation.

A comparison of the results of measurements of the concentration and microstructure of aerosol in the surface layer at Sal Island (16.8°N, 23°W, Barbados (13.2°N, 59.4°W) and Miami (25.8°N, 80.2°W), carried out in [14, 16], indicated that in general the mass concentrations of mineral dust decrease with increasing distance from the continent. The maximum of the mass concentration curve, situated at a particle diameter of about $6 \mu m$ (Sal Island), is displaced into the interval of diameters $2-3 \mu m$ (Barbados). However, cases are noted when the mass concentration is maximum at Barbados.

During the period of GATE-74, at the stations enumerated above, and also at Bermuda (32°N, 65°W), measurements of atmospheric transparency were made at wavelengths 0.500 and $0.880 \mu m$ using a Volz photometer [14]. Figure 4 shows integral curves for the distribution probability of the aerosol optical thickness of the atmosphere τ^*_λ in accordance with the data in [14]. Essentially, these results give some idea concerning the spatial variability of the aerosol component of the optical thickness in a latitudinal direction, from which it follows that with increasing distance from the African continent atmospheric transparency increases, and the limits of its oscillation about the mean value decrease.

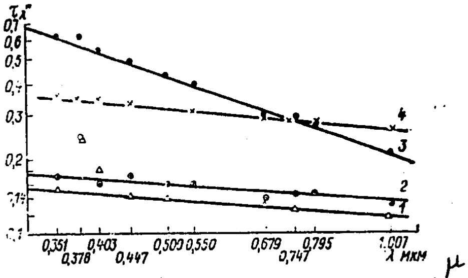

Fig. 5. Spectral dependence of aerosol attenuation in region of wavelengths 0.35–1.0μm. 1) 27 June 1972 (0.9°S, 28°W), P_2 = 0.70, n = 0.2; 2) 5 July 1974 (0°latitude, 10°W), P_2 = 0.72, n = 0.2; 3) 13 August 1974 (0° latitude, 10°W), P_2 = 0.59, n = 1.0; 4) 1 August 1972 (16.8°N, 16.5° W), P_2 = 0.60, n = 0.2.

The propagation of a Sahara dust cloud from east to west occurs, for the most part, in the latitude zone from 10 to 20°N, within whose limits Barbados is situated. Therefore, here, in contrast to the remaining stations, also situated in the western part of the Atlantic Ocean, the coarsely disperse fraction of aerosol particles of continental origin evidently is of very great importance and exerts a substantial influence both on the aerosol characteristics of the near-water layer [14] and on the optical properties of the aerosol component of the atmospheric layer. In actuality, as indicated by Figure 4, the mean values τ^*_λ for λ = 0.500 μm for the entire group of stations situated in the western part of the Atlantic are completely comparable, whereas the mean τ^*_λ value in the region λ = 0.880μm for Barbados is appreciably greater. The presence of a considerable number of large particles evidently determines the nearly neutral nature of aerosol attenuation of solar radiation in the Sal Island and Barbados regions.

The circumstance that the τ^*_λ value for 0.500μm on Sal Island relatively rarely was less than 0.420 (see Fig. 4) is evidence that North Africa during the GATE-74 period was a quite constant source of optically active aerosol particles [14]. However, for different regions of the Atlantic Ocean the tendencies to variability of both the τ^*_λ value itself, and especially the type of spectral dependence of the aerosol component of the optical layer of the atmosphere, caused by the influence of continental aerosol, can be substantially different.

Some examples of the spectral variation of aerosol attenuation of solar radiation in the spectral region 0.35-1.00μm are illustrated in Fig. 5. The nature of aerosol attenuation, extremely close to neutral, was observed in the case of low atmospheric transparencies in the "sea of gloom" (straight line 4) and in the case of high transparencies -- at the equator (straight lines 1, 2). We note that the advection of dust into the equatorial region led to a considerable increase in the selectivity of aerosol attenuation. The n parameter was equal to 1.0 or more (straight line 3). At Miami, according to the data in [14], there was an inverse phenomenon -- a decrease in selectivity of the aerosol attenuation in those cases when the drifts of dust reached this region. The ambiguous nature of variability of the spectral curve $\tau^*_\lambda = f(\lambda)$, caused by the influence of continental aerosol, was evidently associated with the peculiarities of atmospheric circulation in the tropical zone of the Atlantic Ocean, which determine the differences in the processes of transport and transformation of this aerosol in the atmosphere over the ocean. The observed deviations τ^*_λ from the linear dependence $\tau^* = f(\lambda)$ at a wavelength 0.38μm (straight lines 1, 2) are similar to those noted earlier in the Karakum Desert, which were attributed to aerosol absorption [11, 15].

Thus, the experimental data which have now been obtained make it possible to form a general idea concerning the nature of aerosol attenuation of solar radiation and also make it possible to judge the prevailing role of aerosol particles of continental origin in the variability of the aerosol-optical characteristics of the tropical atmosphere in the North Atlantic.

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UDC 551.463.6

PRESENT STATUS OF RESEARCH ON SEA SURFACE TEMPERATURE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 70-77

[Article by Candidates of Geographical Sciences F. S. Terziyev, G. V. Girdyuk and V. V. Vinogradov and Professor G. M. Tauber, State Oceanographic Institute, submitted for publication 17 April 1979]

Abstract: The paper presents the results of generalization of experimental investigations of different methods for measuring the surface temperature and temperature of the surface layer of the sea using contact and noncontact methods on ships, aircraft and artificial earth satellites. Data are given on the interrelationship between surface temperature and temperature of the surface layer of the seas and oceans.

[Text] At the present time in the practice of measurement of the temperature of the surface waters of the seas and oceans use is made of different methods from the traditional standard methods of direct measurements in a sample of water taken from over the ship's side to modern noncontact methods based on remote measurements of the IR radiation of the sea surface using radiation thermometers on ships, aircraft and artificial earth satellites.

The measurement data obtained by these methods have not been identical with respect to their physical significance and differ in value. The methods used in direct measurements, included in the group of contact methods, characterize the temperature of the mixed water layer of some thickness (up to 1 m), averaged for 1-2 minutes, arbitrarily applied to the immediate area of the sea or ocean.

With respect to noncontact methods, they characterize the instantaneous temperature of a very thin surface film of the sea with a thickness of about 10-20 μm.

The physical processes determining the formation of the temperature regime of the surface film and the surface layer of water are different. The temperature of the surface film is formed under the influence of the principal forms of heat exchange between the water surface and the atmosphere -- turbulent, radiant and heat exchange associated with phase changes of fluid, primarily during evaporation. These processes cause a cooling of the surface film and the appearance of negative gradients in the uppermost layer of the sea and heating during condensation.

The temperature of the surface layer of the sea is formed under the influence of absorption of solar radiation penetrating under the surface and the vertical propagation of heat as a result of convective and turbulent mixing.

It can therefore be seen that the term SWT (surface water temperature), firmly established in the practice of sea observations and investigations, in actuality relates only to the thin surface film of water characterized by the readings of a radiation thermometer. This term is not admissible with respect to the results of direct measurements by standard shipboard instruments, since these instruments measure the temperature of the surface water layer at any depth beneath the surface. The term SWLT (surface water layer temperature) is correct applicable to such measurement results. The use of the terms SWT and SWLT is justified by the fact that they give a clear idea concerning the physical importance of data on water temperature obtained by different methods. In the USSR a State Standard has already been established for the mentioned terms and definitions [6]. A draft of a recommendation on the introduction of this terminology into international practice has been prepared for the next Eighth Session of the Commission on Marine Meteorology WMO. This matter is now acquiring great timeliness in connection with expansion of use of the IR radiometry method.

The problem of standardization of the depth of measurement by contact methods is of considerable importance. Until recently this problem has not been solved in the Commission on Marine Meteorology WMO and therefore in the international practice of shipboard observations measurements of the temperature of the water surface layer are made at different horizons -- from the surface to a depth of 5-10 m, depending on the type and size of vessel and on the methods and technical apparatus employed. This applies to the greatest degree to the remote sensors attached to the body of the ship and in the cooling system of its engines, since in such cases the depth of measurements is dependent on changes in the vessel's draught.

As a result, the water temperature data arriving from the network of shipboard stations are not adequate, especially in those cases when under definite conditions the temperature stratifications at the surface and at different depths in the surface layer can substantially differ. The influence of this factor on measurement errors is indicated to some extent by the results of investigations carried out in the USSR. N. T. Filatov [14] and later G. V. Girdyuk, on the basis of a great number of comparative observations of the temperature of the surface layer and at depths of 5 and 10 m in the Barents Sea, Sea of Japan and the Black Sea, indicated that the temperature difference between the surface layer and a depth of 5-10 m for the most part is dependent on the geographic position of the sea and on the season. In summer this value in the Black Sea can attain 10°C, in the Sea of Japan 5°C and in the Barents Sea 3-4°C. In the cold season it does not exceed 1°C. As an average for all the three seas the temperature at a depth of 5 m differs from the surface layer temperature (0.5-1.0 m) by 0.5°C. Thus, the measurement errors arising only as a result of deviations of the measurement depth from the standard zero horizon of oceanographic observations (up to 1 m) considerably exceed the necessary accuracy in measurements of temperature in the surface layer of the sea (±0.1°C), particularly in the warm season of the year.

Theoretical and experimental investigations of the vertical distribution of the exchange coefficient and the influence of absorbed radiation on formation of the temperature regime in the sea surface layer [1, 8-10] make it possible to consider a depth up to 1.0 m as the layer characteristic for measurement of temperature in the sea surface layer (SWLT).

Accordingly, for the purpose of obtaining comparable data there is basis for recommending that the Commission on Marine Meteorology WMO adopt a layer up to 1 m as the standard level in which all ships should carry out observations of temperature in the sea surface layer (SWLT). In our country this depth for measuring the SWLT has been approved in a USSR State Standard and has been included in the Manual on Making Hydrological Observations in Seas [11].

A number of technical apparatuses are now employed for contact measurements on shipboard to determine surface water layer temperature. These make it possible to carry out direct measurements at drift and while the ship is under way. On the basis of operating principles these means can be classified into two main groups. The first includes instruments in which the sensor is a mercury thermometer measuring the temperature of a water sample taken from the surface layer by means of a Shpindler apparatus, pail and its modifications of the Crawford bucket type. With the present-day great speeds of ships the application of this method is difficult or impossible.

The second group includes remote instruments in which the sensor used is the electric resistance thermometer. [The most reliable is the platinum resistance thermometer, having a good reproducibility of the temperature characteristics, a good linearity and a high stability of graduation.] These sensors are attached to the ship's hull or are towed behind. Their use with a remote scale, placed conveniently on shipboard, considerably simplifies the work on measuring water temperature and increases the accuracy of shipboard observations. Taking these advantages into account, the Seventh Session of the Commission on Marine Meteorology adopted a recommendation approving the development of such apparatus and their broadest possible use in shipboard hydrometeorological stations.

In the USSR A. D. Zhokhov and B. A. Maksimov [7] proposed and tested on expeditionary ships a new remote apparatus making it possible to carry out measurements of the surface water layer temperature at a stipulated depth in the range 0-1 m at drift and while the ship was on course without restrictions on velocity with compensation of the influence of the variable draught of the vessel. In this apparatus there is protection of the sensor against interference and distortions with variable deepening of the position of the sensor during waves and rolling. It was established during sea tests in comparison with a standard instrument that in 84% of the cases the deviations do not exceed ±0.1°C. The extensive use of this apparatus can favor an increase in the quality of information on the surface water layer temperature arriving from the network of shipboard stations.

It should be noted that on many ships the water temperature sensor is placed in the cooling system of the engines. An analysis of the great number of comparative observations with such sensors and standard shipboard thermometers in a mounting indicated that data on water temperature received from the engine compartment are characterized by great errors. For example, according to [13] errors greater than 0.5°C have a frequency of recurrence up to 98%; in 83% of the cases the magnitude of the errors was from 1.2 to 2.3°C. The distribution of the error values does not have any well-expressed pattern and to a considerable degree is dependent on the operating regime of the cooling system in the engine compartment. At drift when the engines are stopped the entry of water into the cooling system lessens or completely stops, which leads to an intensification of the thermal effect of the ship and a marked increase in the errors (to 8-10°C). For this reason, and also in connection with the great diversity of types and qualities of sensors, the places of their installation in the cooling system, in connection with measurements at different levels from the sea surface (0.5-5.0 m or more) in dependence on the type and size of ship and changes in its draught, the results of measurements of surface layer water temperature are not adequate. All this makes it possible to draw the conclusion that measurements of temperature of water from ~~outside~~ the ship in the engine compartment are unreliable and that it is undesirable to use this method in the practice of shipboard hydrometeorological observations.

During recent years there has been a broadening of use of the radiation method for measuring the temperature of sea surface waters. The principal advantage of this method is the possibility of using shipboard, aviation and space carriers of IR radiometers, which is making it possible to obtain a greater volume of information during a short time interval. Among the shortcomings is the need for taking into account the systematic measurement errors caused by the influence of the atmosphere, which, despite the use of special filters in the IR radiometers, remain significant for aviation and space measurements. The influence of clouds, fog and precipitation is also great, introducing major errors. In addition, a factor of considerable importance for the accuracy of IR measurements is the difference between the emissivity of water and the emissivity of an ideally black body.

The measurement errors caused by nonblackness of the surface are dependent on the spectral interval, surface emissivity, its temperature, atmospheric emission and sighting angle. In the case of normal sighting in the spectral range 8-13μm in the case of continuous cloud cover the values of the errors do not exceed 0.1°C. In the case of a clear sky the values of the errors can vary from 0.4 to 0.6°C for a clean water surface and up to 1.0-1.6°C for a surface covered by petroleum contaminations. Similar results for a clean water surface were obtained in [18]. With a change in the sighting angle from 0 to 30° the errors virtually do not change and after 40° their sharp increase begins. With a sighting angle of about 50° the values of the errors are doubled.

Theoretical estimates and data from shipboard observations show that SWT, measured with a radiometer, as a rule is lower than the surface layer water temperature. According to available data, among all the observations in the North Atlantic during the summer-autumn period in 83% of the cases the temperature difference between the water surface and the water surface layer was negative, in 8% of the cases -- positive and in 9% of the cases -- close to zero (±0.1°C). Similar results were obtained on the basis of measurements in the Barents Sea and in the Norwegian Sea on board the scientific research weather ship "Vsevolod Berezkin" during the autumn-winter period. Here positive values were observed in 4% of the cases, whereas the number of negative values was 86%.

The frequency of recurrence of the temperature differences between the water surface and the surface water layer is essentially dependent on the hydrometeorological conditions in the measurement region. In the tropical latitudes of the Atlantic, according to the data in [2], these values varied from 0 to -2.0°C with a maximum frequency of recurrence of values -0.1-0.3°C. In the North Atlantic the maximum frequency of recurrence falls in the gradation -0.3 - -0.5°C. For the northern seas during the autumn-winter period, according to observational data obtained aboard the scientific research weather ship "Vsevolod Berezkin," the considered values varied from 0.5°C to -2.2°C with a maximum frequency of recurrence of the gradation -0.4 - -0.6°C. It should be noted that the negative values of the temperature difference between the surface water and surface layer water still persist when the wind velocities are about 15-16 m/sec, when there is intensive mixing in the surface layer water.

In the case of aerial measurements the comparative data show that the temperature differences between the water surface and the water surface layer, measured with a radiometer and by standard methods, increase to 3-4°C

[5, 15, 20]. The increase in these values is caused by the influence of the atmosphere on the results of radiation measurements. The errors in measuring SWT from an aircraft, caused by atmospheric influence, are determined by the working spectral range of the IR radiometer, the thickness and physical characteristics of the intermediate layer of the atmosphere. The use of narrow spectral ranges for the filters of IR radiometers makes possible a considerable decrease in the measurement error [20], but does not make possible its complete elimination.

Most existing methods for taking into account the influence of the atmosphere are based on a determination of the atmospheric transmission function for IR radiation in dependence on the parameters of its state [19]. The value of the correction for the range 8-13 μm was obtained in dependence on the parameters of its state [19]. The value of the correction for the range 8-13 μm was obtained in dependence on the thickness of the atmospheric layer and its moisture content, the difference between water and air temperatures, the air temperature gradient in the intermediate layer of the atmosphere. The computations show that for the layer 100-200 m the errors introduced by the atmosphere for all practical purposes do not exceed the instrumental error of the instrument and almost are not dependent on the air temperature gradient. For the atmospheric layer 300 m or more the corrections increase considerably; in this case it is essential to make allowance for air temperature stratification and a number of other factors.

Table 1

Errors in Measuring SWT (°C) from Ship, Aircraft and Artificial Earth Satellite in Long-Wave (8-13 μm) Atmospheric Transparency "Window"

Interfering factors	Shipboard IR radiometer	Aircraft IR Radiometer	Satellite IR Radiometer
Atmospheric absorption	0	0.1-2.0	2-13
Fluctuations of background radiation	up to 1.2	up to 1.2	*up to 1.2
Surface contaminations	up to 1-2	up to 1-2	*up to 1-2
Aerosol absorption	0	up to 0.5	up to 3
Sun reflections	up to 1	up to 1	up to 1
Other factors (waves, foam, instrumental errors)	0.3-1	0.4-1	over 0.3

*Cases of entry of cloud cover into the radiometer field of view are not taken into account.

In Table 1 we give comparative data on the errors arising when measuring water surface temperature by an IR radiometer when it is used on a ship, aircraft and artificial earth satellite.

At the present time a problem of considerable interest is that of checking the accuracy of satellite data on the temperature of the ocean surface. In most cases as the standard for satellite measurements use is made of data obtained for this same region by contact methods from ships. Several methods are known for comparison of satellite and shipboard data. The simplest and most commonly employed of these methods is that of computing the mean and standard deviations of the compared data. For example, in the United States during 1974-1975 there was checking of the reliability of temperature maps of the world ocean; these were obtained from NOAA artificial earth satellites within the framework of the GOSTCOMP program. The checking was accomplished by means of a comparison of more than 1.5 million values of surface temperatures taken from maps compiled using shipboard measurements for this same region. A comparison of shipboard and satellite data was carried out every time when the measurement from an AES and shipboard readings fell in one and the same zone with an area of 100 x 100 km. As a result, it was found that the mean deviation of satellite data from shipboard data was from -0.9 to +0.39°C, and the standard deviation was from 1.67 to 2.23°C [17].

Under the GATE-74 program the Leningrad Division of the State Oceanographic Institute, using the scientific research ship "Akademik Korolev," obtained experimental records of satellite telemetric information on the radiation temperature of the ocean. In the investigated water area there were about 40 scientific research ships, and also a number of flying aircraft laboratories. The collected synchronous materials of both Soviet and American meteorological satellites, as well as data from aircraft and shipboard measurements, made it possible to evaluate the reliability of the radiation maps of ocean surface temperature. We also constructed maps on the basis of shipboard data for this purpose.

Some difference between these maps can be attributed to the fact that in actuality the very choice of shipboard measurements as a standard for the checking of satellite data cannot be deemed entirely correct for a number of reasons.

First, for a comparison of satellite and shipboard data it is necessary to employ several ships simultaneously, whereas for a temperature survey of the ocean it is sufficient to have one artificial earth satellite with an IR radiometer. Simultaneous measurements of water temperature by several ships can give different results for one and the same spatial point due to the use of different types of thermometers on the latter for measuring the surface temperature at different depths and in different places on the ship, not to mention the influence of the thermal effect of the ship on these measurements. As a rule there is no comparative calibration of the shipboard measurement instruments participating in an experiment for checking correspondence between satellite data and really observed data. For example, source [17] gives the results of comparison of measurements of water temperature carried out using different ships in one and the same zone (within the limits of 100 km^2) in different geographic regions. A comparison indicated that in 78% of the cases shipboard measurements differ from one another by not more than 1.5°C; in 22% of these they differ by a value of more than 1.5°C. Even on a single ship the observations carried out in different parts of the ship give a difference up to 1.2°C [3].

It is clear that for standard measurements such a discrepancy of shipboard data cannot be regarded as entirely acceptable. In addition, the use of several ships for investigations of one and the same water area still does not make it possible to detect all the small-scale changes in the heat fields of the ocean because the ships are at a distance as much as 100 miles apart, at the same time that satellite maps ensure a discreteness between individual measurements of 8-20 km or less, that is, make it possible to detect small-scale variability of the temperature field.

Second, a comparison of satellite and shipboard measurements is inadequate because the ship gives a discrete temperature value characteristic for a local point on the ocean surface and the comparison is made with a temperature obtained by an artificial earth satellite for some spatial region measuring not less than 1 x 1 km, that is, in essence here we are dealing with a spatially averaged temperature. Naturally, mean temperature is a more stable concept than the temperature of a point, since in reality it is possible to observe its local random changes caused by different factors.

Third, noncontact and contact methods for measuring water temperature in principle measure different temperatures: noncontact methods measure the radiation temperature and contact methods measure the thermodynamic temperature. The radiation temperature of water by its very nature is more variable than the thermodynamic temperature because the conditions in the uppermost layer of the ocean are determined to a high degree by the state of the ocean-atmosphere discontinuity, that is, by such parameters as wind, humidity, air temperature, etc., in actuality forming some temperature gradient in the upper film layer of the ocean. It is clear that this reason for the inadequacy of satellite and shipboard measurements is easily eliminated by proceeding to a comparison of data from satellite and shipboard IR radiometers, but for this it is necessary to have a subsatellite network of scientific research ships outfitted with shipboard IR radiometers.

In addition, certain complexities arise due to the difficulty in carrying out a precise geographical tie-in between satellite data and tie-in to a standard moment of measurement time.

Finally, at the present time an important reason for the discrepancy in satellite and shipboard data is an inadequately rigorous allowance for the atmospheric absorption of radiation picked up by a satellite radiometer and the influence of cloud cover. At the present time different empirical formulas are used for introducing corrections into satellite measurements for the absorption of radiation by water vapor, ozone, carbon dioxide and aerosols. For the time being they cannot ensure the necessary accuracy in the correction of satellite measurements.

In general, the numerous results of comparison of satellite and shipboard measurements of water surface temperature lead to a standard deviation of about 1°C. Henceforth it seems possible, by means of introducing a more precise correction of satellite data, to reduce these deviations to 0.5°C or less.

The computation of temperature of the water surface layer on the basis of data from radiation measurements of water surface temperature is of great practical interest. In these computations, in addition to the error caused by the absorption of radiation in the atmosphere, it is necessary to take into account the errors associated with the presence of negative temperature gradients in the film layer of the sea. As already mentioned, the physical reasons for their formation are the processes of heat and moisture exchange between the sea surface and the atmosphere. The temperature difference between the surface and the surface layer (0.5-1.0 m), caused by these processes, is dependent for the most part on the water-air temperature difference, wind velocity and total cloud cover. It has been established that the temperature difference between the surface and the surface layer increases with an increase in the water-air temperature difference, decreases with an intensification of the wind and an increase in the cloud cover. The indicated regularities served as a basis for the method for computing the temperature of the water surface layer on the basis of data from radiometric measurements of sea surface temperature [4].

Computations are made using the formula

$$t_{water} = t_{rad} + \Delta t_a + \Delta t_{water},$$

where t_{water} is the temperature of the water surface layer, t_{rad} is the surface temperature determined by radiometer, Δt_a is a correction for atmospheric absorption, Δt_{water} is the correction for the deviation of water surface temperature from temperature of the water surface layer.

When determining the temperature of the water surface layer on the basis of water surface temperature with mean computation errors close to the value of the instrumental error in measurements with the IR radiometer, but in computations using data from specific measurements, considerable errors can arise. Therefore, it is necessary to carry out work for refining methods for computing the temperature of the surface layer using data from measurements with IR radiometers in different climatic zones.

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MAXIMUM POSSIBLE HEIGHTS OF WIND WAVES IN THE OCEANS AND SEAS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 78-81

[Article by Candidate of Physical and Mathematical Sciences G. V. Matushevskiy, State Oceanographic Institute, submitted for publication 12 March 1979]

Abstract: The article describes a method for determining the maximum possible heights of waves, based on statistical considerations. The initial data for their determination is the regime function of individual wave heights, truncated at some limiting value obtained for quasistationary samples. On this basis it was found that the regime guaranteed probability of the maximum possible height is $3 \cdot 10^{-9}$. Hence, with different forms of regime distribution functions it is possible to find the desired height. The author gives examples of computations for the Black Sea, North Atlantic and Antarctica.

[Text] In the designing and operation of ships and hydraulic structures it is necessary to know the extremal parameters of the wind waves acting on them. This information is taken from regime manuals on wind waves which cover all the oceans and seas. On the basis of the data cited in these manuals it is possible to find the maximum height of waves possible once during a stipulated number of years. The maximum height h_m in deep water was was earlier assumed to be three times greater than the mean height of the waves possible during a stipulated number of years. The latter is found from the distribution function $F(\bar{h})$, which determines the probability of exceeding the mean heights of waves of some fixed $\bar{h}$ value. As demonstrated in [3], this method for finding the h_m parameter is incorrect, and the author there examined a new method for determining the height h_m. Specifically, it is proposed that use be made of the distribution function $\Phi(h)$, determining the probability that individual wave heights in a particular prolonged nonstationary series will exceed some fixed h value [2, 7].

The following problem remains unsolved: what are the maximum wave heights h_{lim} which under any conditions cannot be exceeded and in this connection what is the limiting number of years n_{lim} for which the height h_{lim} should be determined? For the time being the n_{lim} number is selected somewhat speculatively. The order of magnitude n_{lim} is assumed to be different in an analysis of different hydrometeorological elements. For example, in determining the water discharge in rivers at the time of high waters specialists operate with periods of thousands and tens of thousands of years and in determining the maximum heights of waves -- with periods from 30-50 to 100 years.

Here we will limit ourselves to an examination of wave heights and we will explain the idea which served as a basis for this investigation: for any ocean, sea or reservoir there must be such a limiting height of waves which by virtue of physical and statistical limitations cannot be exceeded during even the most prolonged series of observations. The question therefore arises: how to find this limiting possible height and accordingly the number of years n_{lim}?

There can be three ways to solve this problem. The first is a determination of such a combination of wave-forming factors in which the maximum possible waves appear. It is known that with an increase in wind velocity the extent of the water area affected by a storm and the duration of wind effects decrease. In addition, at the same time there is an increase in movement of a cyclone (typhoon), which also limits the possibilities of wave growth. Such an idea was used for obtaining data on extremal wave heights in the Pacific Ocean [9]. On the basis of a model of an extremal cyclone it was established that for this particular cyclone the maximum heights of the wind waves can attain 34.2 m, and simultaneously existing (but in another sector of the cyclone) swell waves -- 12.2 m. However, it was stated at the same time that there could be a still more severe storm and accordingly the wave heights could be still greater. This means that although the concept itself is true, due to the great diversity of hydrometeorological conditions it is extremely difficult to find the mentioned combination.

The second means checked by the author is as follows. We make use of the distribution functions for individual wave heights and the square of individual wave periods $\Phi(h)$ and $\Phi(\tau^2)$ [2] and by means of extrapolation of these functions we will find such an n_{lim} value (of the number of waves N_{lim}) for which the ratio $\delta = h/\tau^2$ will attain the limiting value δ_{lim}. In the case of irregular waves the δ_{lim} parameter was obtained with a great scatter. But regardless of its adopted value the n_{lim} number, and accordingly, the height h_{lim} are found to be improbably high. This means that it is not wave steepness, but some other factor, which limits the growth of wave height.

Therefore, the author seeks a solution by the statistical method. His idea is based on the fact that the ratio of the maximum wave height to the mean height in quasistationary samples, which make up the long-term nonstationary series of wave heights, cannot exceed some limiting value. This concept is satisfied well in actual practice. It has been established that in a large set of quasistationary samples the maximum heights on the average are close to their mathematical expectation (with a small scatter) [8].

Now we describe this method in greater detail. Earlier for describing the wave regime it was proposed that one determine the generalized distribution function for wave heights $\Phi(h)$ characterizing the statistical structure of wind waves in a long nonstationary series [2, 7]. The $\Phi(h)$ function is related to the ordinary regime distribution function $F(\bar{h})$ of mean wave heights $\bar{h}$ by the expression

$$\Phi(h)=\int_0^\infty G(h;\ \bar{h})\, f(\bar{h})\, d\bar{h}, \tag{1}$$

where the regime distribution density is $f(\bar{h})=\frac{dF(\bar{h})}{d\bar{h}}$,

and $G(h;\ \bar{h}) = G(h/\bar{h})$ is the distribution function for wave heights in a quasistationary sample.

On the basis of the above-mentioned concept, in place of (1) it is necessary to write an expression which includes the distribution, truncated from above, $G(h/\bar{h}) = \hat{G}(h/\bar{h})$:

$$\hat{\Phi}(h)=\int_0^\infty \hat{G}(h/\bar{h})\, f(\bar{h})\, d\bar{h}. \tag{2}$$

The upward-truncated distribution has the form [1]

$$\hat{G}(h/\bar{h})=\frac{G(h/\bar{h})-G(h_0/\bar{h})}{1-G(h_0/\bar{h})}, \tag{3}$$

where h_0 is the maximum possible height in the quasistationary interval.

Now we will assume that

$$h_0=m\bar{h}, \tag{4}$$

where m is a still unknown constant several times greater than unity.

Then $G(h_0/\bar{h})=G(m)\ll 1$ and

$$\hat{\Phi}(h)=[1-G(m)]^{-1}[\Phi(h)-G(m)]\approx \Phi(h)-G(m)\geqslant 0. \tag{5}$$

Therefore, it can be seen that the maximum possible height h_{lim} is observed under the condition that

$$\Phi(h_{lim})=G(m). \tag{6}$$

It is only necessary to find the parameter m and accordingly G(m), and using the Φ (h) distribution function it will be possible to determine the quantile h_{lim}.

We find the m parameter on the basis of the following considerations. It is known on the basis of observational data that $m \geqslant 4$. Since reference is to determination of the limiting heights, that is, an upward estimate, this value must be increased. Therefore, we will use the reasonable estimate $m = M = 5$, confirmable by some theoretical considerations.

It is known that in deep water the $G(h/\overline{h})$ function is approximated well by a Rayleigh distribution

$$G(h/\overline{h}) = G_R(h/\overline{h}) = \exp[-A(h/\overline{h})^k], \tag{7}$$

where $A = \pi/4$, $k = 2$.

Therefore

$$\Phi(h_{lim}) = G_R(M) = 3\cdot 10^{-9}. \tag{8}$$

If the Φ (h) function is approximated by any analytical expression, the h_{lim} parameter can be found in explicit form. Thus, with approximation of Φ (h) by a Weibull distribution [2]

$$\Phi(h) = \Phi_W(h) = \exp[-\alpha(h/h_{0,5})^{\beta}], \tag{9}$$

where $h_{0.5}$ is the median height, $\alpha = \ln 2$, we have

$$\Phi_W(h_{lim}) = G_R(M). \tag{10}$$

Hence

$$h_{lim} = h_{0,5}\left[-\frac{1}{\alpha}\ln G_R(M)\right]^{\frac{1}{\beta}} = h_{0,5}(28{,}3)^{\frac{1}{\beta}}. \tag{11}$$

The number of years n_{lim} which corresponds to the maximum possible height h_{lim}, by analogy with the maximum heights h_m, is determined in the form [3]

$$n_{lim} = \frac{0{,}562 <\tau>}{K\Phi(h_0)\,G(M)}, \tag{12}$$

where $<\tau>$ is the mean period of waves in the regime, $K = 3.15\cdot 10^7$ is the number of seconds in a year, h_0 is the height which when not exceeded can be considered a calm sea surface.

Now we will cite examples of computation of the maximum possible waves.

Example 1. We will make computations of the height h_{lim} for the northeasterly region of the Black Sea (winter season) -- its stormiest part. Earlier [3] the values of the maximum heights possible once in a season $h_m = 11.4$ m and once in 30 seasons $h_m = 14.4$ m were obtained for this region. In order to find h_{lim} we will find an analytical expression for the upper segment of the distribution function curve given in [2, 3]. It appears that this segment is approximated by the function (9) with the parameters $h_{0.5} = 0.3$ m and $\beta = 0.86$. As follows from formula (11), $h_{lim} = 15$ m, which is the maximum possible height of waves for the entire Black Sea. Accordingly, $n_{lim} = 110$ years.

Example 2. According to data published by Battjes [7], the distribution function for wave heights in the region of the weather ship "Julliett" is approximated by the Weibull formula with the parameters $h_{0.5} = 1.32$ m, $\beta = 0.99$. Using these data we find $h_{lim} = 38$ m. With a mean wave period 9.3 sec the number $h_{lim} \approx 55$.

Example 3. Now we will find the maximum possible height for the entire world ocean. The most stormy region for which there are at least wind data available is assumed to be the neighborhood of Kerguelen Island in the Indian Ocean sector of the Antarctic region [4, 5]. For this region the authors of [3, 4] used data on synoptic charts for three years (1956-1958) in ascertaining the regime distribution functions for wave parameters. Formula (9), where $h_{0.5} = 2.2$ m, $\beta = 1.14$ is correct for Φ(h). The maximum height possible once a year $h_m = 34.2$ m; once in 30 years -- $h_m = 40.0$ m. Computations using formula (11) give $h_{lim} = 42$ m, which corresponds to $h_{lim} = 58$ years. We note that the maximum wave heights measured up to the present time are 37 m [6].

This type of computations can be carried out for all the oceans and seas. They are particularly important for the shelf zones, where petroleum- and gas-producing platforms are installed, for which determination of the elevation of the upper decking of the structures is of the utmost importance. The reliability of the computations is determined completely by the reliability of the initial regime distribution function Φ(h). The accuracy in determining the β parameter is of the greatest importance.

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EVALUATION OF ACCURACY IN DETERMINING WATER DISCHARGE IN STREAMS

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[Article by Professor G. V. Zheleznyakov and Candidate of Technical Sciences B. B. Danilevich, Moscow Institute of Transportation Engineers and Moscow Civil Engineering Institute, submitted for publication 24 May 1979]

Abstract: The authors give the derivation of a formula for computing the mean square error in water discharge when it is measured by the "velocity-area" method. An analysis of some publications on this problem is given.

[Text] We will approximate the water discharge formula

$$Q = \int_0^B q\,db, \tag{1}$$

where q is the water discharge at the velocity vertical; b is the width of the flow, varying from 0 to B, in the form (see Fig. 1)

$$Q = kq_1b_1 + \frac{q_1 + q_2}{2}b_2 + \dots + \frac{q_{n-1} + q_n}{2}b_n + kq_nb_{n+1} \tag{2}$$

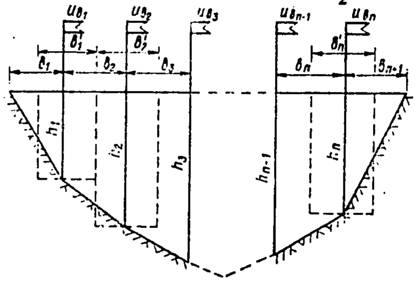

Fig. 1

Expressing the discharges $q_1, q_2, \dots, q_n$ through the products of the measured depths $h_1, h_2, \dots, h_n$ and the corresponding mean velocities at the verticals $u_{B\,1}, u_{B\,2}, \dots, u_{B\,n}$ we will have:

$$Q = kh_1 u_{B,1} b_1 + \frac{1}{2} h_1 u_{B,1} b_2 + \ldots + \frac{1}{2} h_{n-1} u_{B,n-1} b_n + kh_n u_{B,n} b_{n+1}. \tag{3}$$

The differentiation of formula (3) for all the variables with subsequent replacement of the differentials by the absolute values of the errors Δu_B, Δh and Δb makes it possible to find the maximum absolute error in discharge ΔQ using a formula from [3]

$$\Delta Q = \omega \Delta u_B + \omega_{u_B} \Delta h + \Delta b \sum_{i=1}^{i=n} q_i. \tag{4}$$

In a special case, assuming in formula (3)

$$b_1 = b_2 = \ldots = b_{n+1} = b \tag{5}$$

and assuming $k \approx 0.5$ for the purpose of simplifying the structure of the formula, by the same method we obtain the following expression for the relative error:

$$\frac{\Delta Q}{Q} = \frac{b}{Q} \sum_{i=1}^{i=n} q_i \left(\frac{\Delta u_B}{u_B} + \frac{\Delta h}{h} + \frac{\Delta b}{b} \right). \tag{6}$$

Applying to formula (3) the rule for finding the mean square error of a function of the type [1], under the condition (5) we will have:

$$\sigma_Q = \left[b^2 \left(\sigma^2_{u_B} \sum_{i=1}^{i=n} h_i^2 + \sigma^2_h \sum_{i=1}^{i=n} u^2_{B,i} \right) + \left(\sum_{i=1}^{i=n} q_i \right)^2 \sigma^2_b \right]^{1/2}, \tag{7}$$

where σ_Q, σ_{u_B}, σ_h and σ_b are the absolute values of the mean square errors of the discharge and the measured values for velocity, depth and distance between the velocity verticals.

If we multiply and divide the corresponding partial derivatives of the function by $u_{B,i}$, h_i, then, converting to the relative mean square errors $\tilde{\sigma}_Q$, $\tilde{\sigma}_{u_B}$, $\tilde{\sigma}_k$ and $\tilde{\sigma}_b$, with this same condition (5) we obtain

$$\tilde{\sigma}_Q = \frac{b}{Q} \left[\sum_{i=1}^{i=n} q_i^2 (\tilde{\sigma}^2_{u_B} + \tilde{\sigma}^2_h) + \left(\sum_{i=1}^{i=n} q_i \right)^2 \tilde{\sigma}^2_b \right]^{1/2}. \tag{8}$$

As is well known, the two cited methods for evaluating the accuracy of the function are used extensively.

We will compare the derived formulas (6)-(8) with the R. Herschy computation dependence [8, 9], obtained from the approximation (1) in the form

$$Q = \sum_{i=1}^{i=n} q'_i = \sum_{i=1}^{i=n} u_{B,i} h_i b'_i, \tag{9}$$

where, in contrast to (2), the distance b'_i is measured in both directions from the velocity verticals (Fig. 1), q'_i is the partial discharge (discharge through a fragment of the area).

On the basis of (9) R. Herschy obtained

$$\tilde{\sigma}_Q=\left[\tilde{\sigma}_n^2+\frac{\sum\limits_{i=1}^{i=n} q_i^2\,(\tilde{\sigma}^2_{u_i}+\tilde{\sigma}^2_{h_i}+\tilde{\sigma}^2_{b_i})}{Q^2}\right]^{1/2}, \qquad (10)$$

where $\tilde{\sigma}_n$ is the additional error determined experimentally and taken into account in the case of a small number n of verticals [9].

It can be seen from equations (2) and (9) that in formula (10), similar in structure to (6), there is not complete allowance for the partial discharges along the shore segments, which in the case of small n, evidently is partially compensated by the term $\tilde{\sigma}_n$. With an increase in n the difference between the results, computed using formulas (8) and (10), is decreased. Formula (7) is similar to the more general formula derived in [2].

In [5, 6] I. F. Karasev proposed the formula

$$\tilde{\sigma}_Q=\left[\frac{\beta}{n}\,(\tilde{\sigma}^2_{\omega_s}+\tilde{\sigma}^2_{u_s})\right]^{1/2}, \qquad (11)$$

where $\tilde{\sigma}_{\omega_s}$ and $\tilde{\sigma}_{u_s}$ are the relative mean square errors in measuring the areas of the segments between the velocity verticals and the mean velocities of the flow in these segments respectively; n is the number of segments; β is a parameter computed using the formula

$$\beta=\frac{n\sum\limits_{s=1}^{s=n} q_s^2}{Q^2} \qquad (12)$$

or [5]

$$\tilde{\sigma}_Q=\left[\frac{\sum\limits_{s=1}^{s=n} q_s^2}{Q^2}\,(\tilde{\sigma}^2_{\omega_s}+\tilde{\sigma}^2_{u_s})\right]^{1/2}. \qquad (13)$$

In contrast to the computation dependences considered above, formula (11) cannot be used for practical purposes since it is incorrect in its mathematical basis. The reason for this is a number of fundamental errors allowed in its derivation. The most important of these is the assumption of a mutual nondependence of the partial discharges $(\omega_{s2}\, u_{s2})$, (ω_{s3}, u_{s3}), ..., $(\omega_{sn-1}\, u_{sn-1})$.

In actuality, these terms are closely correlated since they contain measured values of velocities u_B and depths h common for adjacent verticals of the segments.

As a result of this rough error the radicands in (13) were less than the actual values by

$$\frac{1}{Q^2}\left[\sum_{s=2}^{s=n-1} 2\, r_{u_{s_i}\, u_{s_{i+1}}} \left(\frac{\partial q_{s_i}}{\partial u_{s_i}}\right)\left(\frac{\partial q_{s_{i+1}}}{\partial u_{s_{i+1}}}\right) \sigma_{u_{s_i}}\, \sigma_{u_{s_{i+1}}} + \right. \tag{14}$$

$$\left. + \sum_{s=2}^{s=n-1} 2\, r_{\omega_{s_i}\, \omega_{s_{i+1}}} \left(\frac{\partial q_{s_i}}{\partial \omega_{s_i}}\right)\left(\frac{\partial q_{s_{i+1}}}{\partial \omega_{s_{i+1}}}\right) \sigma_{\omega_{s_i}}\, \sigma_{\omega_{s_{i+1}}}\right],$$

where $r_{u_{si} u_{si+1}}$ and $r_{\omega_{si}\, \omega_{si+1}}$ are the correlation coefficients.

Accordingly, the substitution of β from (12) into (11) is inadmissible. Another fundamental error of formula (11) is the equality of the relative errors $\tilde{\sigma}_{\omega_s}$ and $\tilde{\sigma}_{u_s}$ adopted by its authors for all segments. It is easy to see that such an equality is correct only when all the mean velocities at the verticals are equal to one another and also the depths are equal to one another. This means that the stream channel has a rectangular configuration with an infinite width. The unrealness of such a schematic representation of the river channel cross section is evident.

In addition, we did not take into account the discharges along the shore segments (the Q function is differentiated only with respect to ω_s and u_s). Since the subsequent computation dependences, recommended by I. F. Karasev (formulas (12)-(14) in [6]) were written on the basis of formula (11)), they also are fundamentally incorrect, as in the case of (11). Accordingly, the analysis of these formulas cited in [5, 6] is not of interest from either the theoretical or practical points of view. Naturally, all the conclusions and recommendations based on these formulas are erroneous. Equally obvious is the uselessness of attempts to confirm the correctness of the I. F. Karasev formula in [7]; they only put in doubt the reliability of the results of the computations made in [7].

The inconsistency of the method for estimating the accuracy of the discharges in [5, 6] also can be noted earlier in [4], as was mentioned in [2].

In essence, in formula (11) there was a repetition of all the errors allowed in [4]. It is a pity that articles containing formulas known to be incorrect were published.

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STATUS AND PROSPECTS FOR THE DEVELOPMENT OF AGROCLIMATIC INVESTIGATIONS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 86-93

[Article by Candidate of Biological Sciences I. G. Gringof and Doctor of Geographical Sciences Yu. I. Chirkov, All-Union Scientific Research Institute of Agricultural Meteorology and Moscow Agricultural Academy imeni Timiryazev, submitted for publication 22 May 1979]

Abstract: This paper presents the principal attainments in Soviet agroclimatology during the last 10-15 years and discusses the next problems to be solved in its further development.

[Text] The program for the intensification of agriculture in our country during the Tenth Five-Year Plan, adopted by the 25th Congress CPSU, provides for the further development of melioration work, increased use of chemical fertilizers, mechanization, and also a further improvement in the distribution of agricultural production on the basis of more effective use of natural economic conditions.

The resolutions of the July (1978) Plenary Session of the Central Committee CPSU provide for an increase in the effectiveness of scientific research as one of the decisive factors in the acceleration of scientific and technical progress in agricultural production.

Along these lines Soviet agroclimatology has proceeded along a long and glorious path in its development, making a serious contribution to the establishment and transformation of socialist agriculture in our country. Under conditions of great diversity in soil and climatic conditions the planned development of agricultural production has required from agroclimatologists first and foremost the development of the scientific principles for the optimum distribution over the territory of our country of different agricultural crops in dependence on climatic conditions.

During recent decades the areas of distribution of a number of agricultural crops over the territory of the USSR have substantially changed and at the present time to a great extent correspond to climatic conditions, moreso than during the pre-Revolutionary period.

There has been a considerable expansion of the areas of cultivation of winter and spring wheat and a northward advance of the boundaries of areas for the cultivation of rice, cotton, corn (for grain, and in particular, for silage), sunflowers, sugar beets, soy beans, a number of fruit crops and grapes. The principal productive expanses of grain and a number of industrial crops during recent years have attained the limits of climatic assurance of heat and moisture resources required for their cultivation. However, the distribution of new, more promising varieties of crops will always require investigations for more precise determination of where they can be grown.

The methods for agricultural evaluation of climate were developed by Soviet climatologists and agroclimatologists: beginning with A. I. Voyeykov, this task has been worked through by G. T. Selyaninov, F. F. Davitaya, P. I. Koloskov, S. A. Sapozhnikova, D. I. Shashko, L. N. Babushkin, Yu. I. Fedoseyev, L. S. Kel'chevskaya, and others. On the basis of these methods it has been possible to carry out a general agroclimatic regionalization of the USSR and its individual regions, presented on maps. Special regionalizations have been carried out for the principal agricultural crops.

I would like to mention some of the major studies carried out by Soviet agroclimatologists during the last 10-15 years: AGROKLIMATICHESKOYE RAYONIROVANIYE SSSR (Agroclimatic Regionalization of the USSR), D. I. Shashko, 1964; AGROKLIMATICHESKOYE RAYONIROVANIYE SREDNEY AZII (Agroclimatic Regionalization of Central Asia) and AGROKLIMATICHESKOYE OPISANIYE SREDNEY AZII (Agroclimatic Description of Central Asia), L. N. Babushkin, 1964; AGROKLIMATICHESKIY ATLAS MIRA (Agroclimatic Atlas of the World), edited by I. A. Gol'tsberg, 1972; the map AGROKLIMATICHESKIYE RESURSY SSSR (Agroclimatic Resources of the USSR), compiled by S. A. Sapozhnikova and D. I. Shashko and edited by F. F. Davitaya, 1973. In collaboration with the agroclimatologists of the Socialist countries, under the direction of the Soviet agroclimatologists I. A. Gol'tsberg, F. F. Davitaya, Yu. I. Chirkova, S. A. Sapozhnikova, and others, a major investigation was carried out under the theme AGROKLIMATICHESKIYE RESURSY SOTSIALISTICHESKIKH STRAN YEVROPY (Agroclimatic Resources of the Socialist Countries of Europe), 1974. The map AGROKLIMATICHESKIYE RESURSY NECHERNOZEM'YA (Agroclimatic Resources of the Nonchernozem Zone), compiled by L. S. Kel'chevskaya and A. R. Konstantinov, was published in 1977. During these same years, under the methodological direction of L. S. Kel'chevskaya, about 130 volumes of the handbooks AGROKLIMATICHESKIYE RESURSY OBLASTI, KRAYA, RESPUBLIKI (Agroclimatic Resources of the Oblast, Kray, Republic) for the entire territory of the USSR were written and published. These have come into broad use in the practical work of agricultural agencies and subdivisions of the hydrometeorological service of the country.

This major and important study was preceded by a stage of serious agroclimatic investigations for determining the agroclimatic indices of growth, development and formation of the productivity of the principal agricultural crops cultivated in our country.

As is well known, in the late 1960's many Soviet and foreign agronomists expressed the opinion that the increase in technical outfitting of agriculture had attained such a perfection that it was making it possible to eliminate the dependence of agriculture on the variability of weather. However, a number of years which were extremal with respect to weather conditions, occurring during the growing seasons in a number of regions of the world and in the USSR, makes clear that it is necessary to carry out still more thorough agroclimatic investigations for the purpose of scientific validation of the distribution of traditional types of crops in the existing and new regions of crop cultivation, and also the introduction of new promising crops and varieties.

In this connection it is necessary to note the serious contribution of agroclimatology to the mastery of the virgin and idle lands of Kazakhstan, the 25th anniversary of which is being widely noted in the entire country. We have in mind the monograph entitled AGROKLIMATICHESKIYE I VODNYYE RESURSY RAYONOV OSVOYENIYA TSELINNYKH I ZALEZHNYKH ZEMEL' (Agroclimatic and Water Resources in the Regions of Mastery of the Virgin and Idle Lands) (1955), edited by F. F. Davitaya, the studies of A. P. Fedoseyev and others.

An evaluation of weather conditions for the fate of virgin land grain is given in a book by L. I. Brezhnev, entitled TSELINA (Virgin Lands): "For example, let's say that no rain has fallen on the virgin lands up to 15 June. Then I know that it is necessary to subtract several centners from the yield. If there is no rain to the end of the month -- subtract still more" (p 4).

As is well known, dangerous and especially dangerous meteorological phenomena inflict an appreciable loss on agricultural production. A number of Soviet scientists have carried out investigations of the agroclimatic characteristics of such phenomena as droughts and hot, drying winds (Ye. A. Tsuberbiller, K. A. Karetnikova, M. S. Kulik, and others), dust storms (Yu. I. Chirkov, N. N. Romanov, and others), the wintering of winter crops (V. A. Moiseychik, V. M. Lichikaki, A. M. Shul'gin), etc.

Investigations in this direction must be continued for the purpose of using their results for improving modern methods for creating agricultural systems best corresponding to the climatic conditions of a specific territory. As an example of such a system we can mention the system developed by Academician A. I. Barayev for Northern Kazakhstan, etc.

The present-day tasks in further advancing agriculture oblige agroclimatologists to broaden considerably the information on the behavior of the "climate-yield" system. In addition to the classical criteria of heat and moisture supply for agricultural crops there is a need for precise data on the reaction of the crop or phyto-agrocoenosis as a whole to extremal conditions. There must be a detailed evaluation of the comparative productivity of crops under specific climatic conditions as one of the most important components in the complex determining the structure and specialization of agricultural production.

Long-range planning of the development of agriculture involves a careful allowance for and inventorying of agroclimatic resources, as well as determination of the climatic resources for the productivity of agricultural crops.

The agricultural "quality" of climate is usually established on the basis of total indices for the growing season as a whole or for the year. This leads to the smoothing of the characteristics of the degree of favorability of climatic conditions. It is well known that even a brief exposure to unfavorable combinations of heat and moisture in individual stages of organogenesis of plants can sharply reduce their productivity.

One of the modern problems in agroclimatic investigations is a determination of the influence of climate on the productivity of plants in individual stages in their development (F. M. Kuperman, Yu. I. Chirkov, 1970) with allowance for the frequency of recurrence of combinations of the principal factors in critical periods of yield formation.

A multisided evaluation of the degree of support of the yield with climatic resources can be given on the basis of the frequency of recurrence of 10-day periods with different combinations of heat and moisture -- the principal and most dynamic factors in the life of plants.

In our opinion, such a detailed approach to an analysis of the influence of the principal climatic factors on the formation of plant productivity (on the basis of the frequency of recurrence of combinations of temperature and moisture, taking into account the stages in plant development) will make it possible to carry out both a substantial refinement of both the general, and in particular, the special agroclimatic regionalization of agricultural crops. For such an approach it is necessary to use a modern technical base: electronic computers and archives of climatic data.

In order to ascertain the area of distribution for any agricultural crop it is necessary to make a detailed allowance for the entire complex of natural conditions, including soil, relief, microclimatic peculiarities p of specific fields, depth and degree of salinization of ground water, etc. Therefore, classical methods for evaluating agroclimatic resources and special regionalization can be regarded as the first and a necessary stage in complex regionalization. Incidentally, in Uzbekistan (and also in other republics in Central Asia) the followers of the agroclimatic direction developed by Prof. L. N. Babushkin are proceeding along the path of devising complex agroclimatic characteristics applicable to the most important agricultural crops.

The proper distribution of agricultural production is a complex socioeconomic problem whose solution also requires allowance for the material-technical and population resources present in the region, oblast or rayon. For this it is necessary to create complex creative teams of agroclimatologists, economists, soil scientists and other specialists. In such a case the evaluation of the agroclimatic resources must in quantitative respects carry the maximum of information in order that it can be readily incorporated into economic schemes.

The broad use of economic-mathematical methods and mathematical modeling methods will make it possible to use the results of agroclimatic computations for making economic decisions.

Proceeding on the basis of these considerations, specialists at the All-Union Scientific Research Institute of Agricultural Meteorology at present are developing a method for stochastic evaluation of losses of the yield of agricultural crops due to anomalous weather conditions. The climatic resources applicable to agricultural production in this case will be expressed in units of possible losses of the gross yield in climatic terms, obtained with different distribution strategies, comprehensible for practical workers in agriculture.

It is necessary to say a few words about the importance of development of microclimatic investigations and the climate of soils for agroclimatology.

In the course of a number of years specialists in the Hydrometeorological Service system have carried out investigations of microclimate and the climate of soils (MIKROKLIMAT SSSR -- USSR Microclimate -- I. A. Gol'tsberg, KLIMAT POCHV I YEGO REGULIROVANIYE -- Climate of Soils and its Regulation -- A. M. Shul'gin, the studies of Z. A. Mishchenko and others). It is difficult to overestimate the importance of these investigations for the agroclimatic evaluation of a territory and the distribution of agricultural crops.

For example, it is known that under the conditions prevailing in the Nonchernozem zone the considerable diversity of agrophysical properties of the soil causes marked differences in the microclimate of the plowed layer. In comparison with heavy soils, on sandy and sandy loam soils the duration of the period with a mean diurnal temperature above 10°C is 3-4 weeks longer. During this period on light soils the temperature sum exceeds by 300-600°C the temperature sum for heavy soils. The heating of heavy soils to +5°C occurs 10-15 days later than the passage of air temperature through +5°C, and in the case of light soils -- 7-10 days earlier.

Thus, variability of the soil temperature regime over an area is considerably greater than the air temperature. Suffice it to mention that the differences in air temperature sums during the period of the active growing season in Vologodskaya Oblast (over the area) are about 100°C, whereas the differences in the sums of soil temperature at a depth of 10 cm during the June-September period are greater than 500°C; in Pskovskaya Oblast, however, according to data from expeditionary investigations of the Main Geophysical Observatory, the differences in the temperature sums for soils different in their agrophysical properties attain even 800°C. It is evident that the differences in soil temperature must be taken into account in the distribution of fields of agricultural crops and in the improvement of the methods for their cultivation. In this respect further investigations of the microclimatic peculiarities of agricultural fields with accompanying agroclimatic mapping using an electronic computer, in our opinion, corresponds to the present-day practical requirements of agriculture. This direction has been developed at the Estonian Agrometeorological Laboratory of the All-Union Scientific Research Institute of Agricultural Meteorology (P. Kh. Karing, and others).

In the investigations of Soviet climatologists and agroclimatologists considerable attention is being devoted to study of the peculiarities of microclimate of different relief elements (I. A. Gol'tsberg, B. A. Ayzenshtat, Ye. N. Romanova, L. N. Babushkin, and others). From the point of view of agricultural production, allowance for the redistribution of precipitation, soil moisture content, extremal temperatures and other elements is of fundamental importance. The results of investigations of the microclimate of agricultural fields and soil climate should find extensive application in validating many agroengineering and meliorative measures.

Already in the 1930's the well-known agrometeorologist Academician R. E. David of the All-Union Academy of Agricultural Sciences formulated the principles for differential use of agroengineering techniques, taking into account the existing and anticipated weather conditions. These ideas were further developed in studies made at the Southeast Scientific Research Agricultural Institute (P. G. Kabanov) and the All-Union Scientific Research Institute of Agricultural Meteorology (A. P. Fedosyev, M. S. Kulik, and others).

The agroclimatic validation of such technological procedures as the choice of a system for the basic processing of the soil, selective use of occupied and clean fallow, times, quantities and methods for the application of fertilizers, times and norms for seeding and the organization of the optimum structure of a sown area, measures for the care of sown areas, choice of methods for crop harvesting, etc. is of great importance for agricultural production practice.

Until recently recommendations on the differential use of agroengineering methods were based on data from point observations in the meteorological network. The above-mentioned diversity of soil microclimatic conditions could not be taken into account. At the same time, recent attainments in remote methods for determining the state of the underlying surface make it possible to proceed to an areal characterization.

In the future the development of agroengineering methods for differential use must make more complete use of information from remote apparatus on the spatial distribution of the principal elements of microclimate. Investigations should be developed in this same direction on the optimization of the microclimate of agricultural plantings.

At the present time in the field of seed selection, which is acquiring an ever-increasing specialized direction, the need is increasing for using data from agroclimatology in order to evaluate the correspondence between the requirements of the variety and the agroclimatic resources of the territory. A useful initiative along these lines has been manifested by the Agrometeorology Division of the All-Union Research Institute of Plant Cultivation (A. I. Korovin), who has developed a "Model of Agrometeorological Certification of a Variety of an Agricultural Crop," which more precisely should be called a "Model of Agroclimatic Certification."

The "model" of certification of a variety includes the indices necessary for a quantitative evaluation of a variety: winter hardiness, tolerance to cold, resistance to drought, overmoistening, critical temperatures, need of water per unit dry mass, etc. The importance of such a certification is very great for agriculture because it is the basis for the most desirable distribution of new promising varieties and hybrids over the enormous territory of our country.

However, I would like to note the need for some improvements in the content and construction of the model (1977):
-- it is necessary to discriminate the principal agroclimatic characteristics of the variety: temperature sums (active or effective required for the growing season as a whole), critical temperatures for resistance to frost and freezing (for perennial and winter crops), indices of moisture requirements;
-- it is necessary to describe the method for obtaining the agroclimatic characteristics included in the model of the certification, for example, the indices of resistance to heat, the indices of resistance to drought or the indices of reaction of the plants to diurnal variations of temperatures since the model is a methodological instruction;
-- finally, we feel that it is desirable to give preference in the model to those agroclimatic indices which are easily comparable with the materials and indices cited in agroclimatic handbooks and on agroclimatic maps.

The work in this direction should receive extensive support and dissemination.

At the present time the problem of programming yield has become an integral part of agricultural production. In the programming of yields it is necessary to ascertain to what degree the yield formation in a particular year will be ensured with heat and moisture. This is one of the most complex problems in the program due to the lack of reliable weather forecasts for the growing season. Accordingly, it is necessary to develop a method for employing a system of stochastic characteristics for computing the anticipated quantity of precipitation, temperature sums, times of ending of frosts and other factors making it possible to ascertain the limits of yield variation under the conditions prevailing in a specific year.

We must also note those directions in agroclimatology which have not yet been adequately developed but which are promising.

It is known from data published by the FAO that pests and diseases of agricultural crops each year destroy up to 25-30% of all the agricultural production produced on the earth. The cyclogenesis of development of pests and diseases is closely associated with the meteorological (especially with microclimatic) conditions and climatic zonality.

The agroclimatic aspect of the struggle with pests and diseases of agricultural crops is obvious. Unfortunately, this direction has still not been broadly developed in agrometeorology. Up to the present time there have been only individual interesting studies carried out for predicting the spreading of pests and diseases and the validation of measures for contending with them (V. V. Vol'vach, L. A. Makarova, T. S. Druzhelyubova and others). The efforts of agroclimatologists in solution of this problem must be multiplied, especially in the regional hydrometeorological institutes of the State Committee on Hydrometeorology in close contact with the institute (by plant protection stations).

The agroclimatic aspects of livestock raising and its fodder base are still not being adequately developed. These problems have been most developed in Kazakhstan, in the republics of Central Asia and in the Kalmytskaya ASSR in connection with evaluation of the resources of pasture vegetation (A. P. Fedoseyev, I. G. Gringof, S. A. Bedarev, G. G. Beloborodova and others) and evaluation of the influence of climate on farm animals (A. P. Fedoseyev, A. I. Fedoseyev, A. I. Chekeres, and others). Investigations have begun for evaluating the agroclimatic resources of regions of reindeer grazing in the North.

However, the enormous territories of the European and Asiatic parts of the RSFSR, Ukraine, Caucasus and Baltic Republics still do not have an agroclimatic evaluation of the conditions for fodder production. This problem is acquiring particular importance in the light of the resolutions of the July (1978) Plenary Session of the Central Committee CPSU and in connection with the expansion of the system of cultivated pastures, which at the present time occupy more than 2.5 million hectares in the country. An allowance for agroclimatic conditions is necessary in solving the problems relating to the distribution of cultivated pastures, determination of the times of their use and selection of the components of grass mixtures.

During recent years there has been ever-increased development of plant cultivation under glass for supplying major cities and industrial centers, as well as the Far North, and in the immediate future also the zones along the Baykal-Amur Railroad, with vegetables and fruits.

Agroclimatic investigations in this direction can favor a more rational choice of ground to be glassed over (glasshouses, greenhouses with natural or artificial heating with different types of coverings, etc.), taking into account the specific climatic conditions in the area. In addition, these investigations can be directed to the forming of the optimum microclimate of greenhouses corresponding to the requirements of crop cultivation. Such investigations have been carried out quite extensively abroad. In particular, within the framework of the World Meteorological Organization a special working group has been established for generalizing the experience of these investigations in the form of a WMO note "Climate Under Glass."

In our country there is regular implementation of a program of major meliorative measures directed to the optimization of the water, heat and salt balances of agricultural fields. The agroclimatic validation of major meliorative measures, such as irrigation and drainage, the territorial redistribution of the water resources of northern and Siberian rivers is an urgent problem in agroclimatology during the coming years. The evaluation of soil and climatic resources applicable to the agricultural production of melioration regions, evaluation of the moisture supply of sown areas under conditions of regulation of the water and heat balance of agricultural fields, evaluation of local changes in the ecological medium and the socioeconomic consequences of such measures must be carried out within the framework of multisided investigations with the involvement of a broad range of specialists: hydrologists, soil scientists, agronomists, ecologists, economists and others.

Major measures for the phyto- and silvimelioration of steppe, semidesert, desert and mountainous territories, directed to increasing the yield and stability of natural and sown pastures and hay fields, also require serious agroclimatic validation. For the time being only individual investigations have been made in this direction (A. P. Fedoseyev, M. Nurberdiyev, I. G. Gringof, O. N. Reyzvikh, K. Artykov, and others).

The agroclimatic aspects of the problem of advance of the desert, contending with soil erosion and with the negative influence of anthropogenic factors should attract the attention of the agroclimatologists of our country.

The World Climatic Conference which was held in February of this year in Geneva noted the importance of development of agroclimatic investigations in connection with climatic variations exerting an influence on food production in countries of the world, water resources, electric power, etc.

In this connection it is sufficient to mention the five-year drought in the Sahel zone and its tragic consequences for eight countries in Africa, the severe droughts of 1972 and 1975 in the USSR, as a result of which there were definite losses of yield, the unusually severe winters in North America, the floods in India and Bangladesh, etc.

During the last five years in the republics of Central Asia for four years in a row (1974-1977) there was low water in the rivers; in two of these years there were catastrophic low waters. For the time being the agroclimatic interpretation of climatic variations on a regional scale has not been properly developed.

However, allowance for possible climatic changes under the influence of both natural and anthropogenic factors is exceedingly important for planning the development of agricultural production and here we have still another prospect for the application of agroclimatology.

Among the most important problems in agroclimatology is ensuring the information necessary for Party, soviet, planning and agricultural agencies for the purpose of optimum organization of agricultural production in our country.

We have already noted the principal results of agroclimatic investigations published during the last 10-15 years. In the next year or two handbooks and atlases will be published on soil moisture content in different regions of the country applicable to grain crops. But this is inadequate. It is necessary to work constantly on improvement in the system for hydrometeorological support of agricultural production. A determination of the ways to improve this system, in particular, by agroclimatic information, must become one of the principal tasks of the agroclimatologists of the State Committee on Hydrometeorology and other departments. In order to solve the numerous and important problems of development of agroclimatology it is completely necessary to combine the efforts of all agroclimatologists working in different ministries and departments in the main directions of research, within the framework of the operating Section on Agrometeorology of the All-Union Agricultural Academy, combining these investigations with the work of scientists in other branches of science and specialists in agriculture -- production workers in the broad framework of activity of agricultural scientific and technical societies. One way to bring about such a combining of efforts would also be restoration of the activity of the Interdepartmental Council on Climatology and Agroclimatology.

The recently established All-Union Scientific Research Institute of Agricultural Meteorology, in businesslike cooperation with the agroclimatologists of the entire country, should make an appreciable contribution to the development of the main directions in Soviet agroclimatology.

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DEGREE OF ACTIVITY OF GROWING OF WINTER WHEAT DURING WINTER THAWS

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[Article by Candidate of Geographical Sciences I. V. Svisyuk, Northern Caucasus Administration of the Hydrometeorological Service, submitted for publication 3 April 1979]

Abstract: On the basis of an analysis of data from special field observations made using the author's method at 15 meteorological stations in different zones of the Northern Caucasus, Lower Volga and Rostovskaya Oblast during the winter seasons 1975/1976 - 1977/1978, a method is proposed for evaluating the intensity of the growing of winter wheat during the period of winter thaws.

[Text] With cessation of active growing of winter wheat in the autumn (after the air temperature passes through +3°C) observations of winter wheat virtually cease until the renewal of active growing of this crop in the spring. However, in winter in the southern regions of our country each year there are prolonged, in some cases rather intensive thaws during which winter crops renew their growing [1-5], which at times is so active that they pass through one or two initial interphase periods or form several lateral shoots. But these changes in the growth and development of plants during the period of winter thaws are noted only in spring, after the onset of appreciable indications of plant growth. Naturally, with such a situation in observations of winter wheat great difficulties are created in evaluating its wintering conditions. In order to make up for this shortcoming in winter observations we undertook an attempt to find such criteria by which it is easy to discover the presence of the growing of plants, especially since in most cases during the time of winter thaws the growing of winter crops transpires so weakly that it is simply impossible to detect it using the criteria proposed in the Instructions for Hydrometeorological Stations and Posts, Issue 11.

Accordingly, at 15 meteorological stations situated in different zones of the Northern Caucasus, Lower Volga region and in Rostovskaya Oblast, during the winter seasons 1975/1976 - 1977/1978 we organized special observations of fields of winter wheat during the winter period.

Taking into account the capacity of growing plants for accelerated restoration of damaged or lost leaves and stems, we carried out the clipping of winter wheat plants each 10-day period during the course of the entire winter period. Each time new plants were clipped in two repetitions (20 plants). We clipped all the above-ground part of the plant at a height of two centimeters from the soil surface. In late December the plants were measured with an accuracy to a millimeter and the mean linear added growth was determined. At the same time, we carried out observations of air temperature (mean daily, maximum, minimum), snow cover, freezing, thawing of the soil and its state at a depth of 10 cm.

The observations were usually made using two different (with respect to winter resistance) varieties of regionalized thickening-out winter wheat having 2-4 shoots per plant.

The special observations indicated that plants with an identical degree of development, with the same state of the soil, with one and the same sum of positive temperatures accumulating during a 10-day period of thawing, increase the linear added growth of the clipped plants by approximately one and the same value.

The intensity of aftergrowing is influenced not only by temperature conditions, but also by the state of moistening of the upper soil layers, the depth of its freezing at the beginning of the 10-day period and the degree of thawing during the subsequent days of the thaw. This correlation is easily traced in the cited examples (Table 1).

It is easy to note that during the time of the thaws the linear added growth of the trimmed plants transpires more rapidly in well-moistened soil than in poorly moistened and especially dry soil. The same pattern is also traced with respect to another criterion -- the thickness of the freezing soil layer above at the beginning of the thawed 10-day period. The greater is the depth of soil freezing, the less is the aftergrowing of the clipped plants. Taking these criteria into account, we discriminated five possible types of linear added growth (y) of the clipped winter wheat plants in dependence on the sum of positive temperatures accumulating during the thawed 10-day period (x). Each of these types can be described by the following equations:

first type -- well-moistened, thawed soil

$$y = e^{0.34} x^{0.79}. \tag{1}$$

second type -- well-moistened soil; at the beginning of the decade and on its individual days freezes not more than 10 cm or with deep freezing during the first one or two days thaws to a depth greater than 15-20 cm,

$$y = e_{-3.87} x^{1.67}. \qquad (2)$$

third type -- well-moistened soil, at the beginning of the 10-day period freezing deeper than 10 cm or on individual days freezing deeper than 10 cm,

$$y = e^{-5.26} x^{1.81}. \qquad (3)$$

fourth type -- slightly moistened soil, thawed or freezes on individual days of the 10-day period not more than 10 cm,

$$y = e^{-2,87} x^{1,21}. \qquad (4)$$

fifth type -- dry soil, melted or on individual days of the 10-day period freezes not more than 10 cm,

$$y = e^{-12.87} x^{3.30}. \qquad (5)$$

The correlation coefficients for the cited equations fall in the range 0.71-0.89. The error in the equations is $S_y = \pm 2-4$ mm. A graphic representation of equations (1)-(5) is given in Fig. 1.

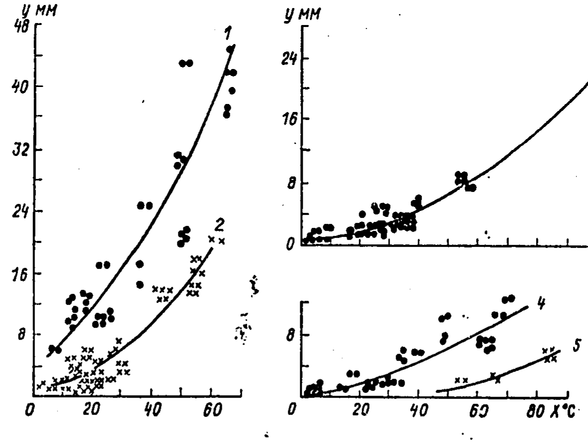

Fig. 1.

An analysis of the cited dependences shows that the growing of the winter crops in virtually all cases begins with the passage of air temperatures through 0°C to positive values, when during the 10-day period the sum of positive mean daily temperatures is only 3-5°C and simultaneously with the onset of the thaw there is thawing of the soil not covered by the snow.

Table 1

Linear Growth of Clipped Thickening-Out Winter Wheat Plants During Thawed Decade (mm) in Dependence on the Sum of Accumulated Positive Temperatures and State of Soils

Наименование метеорологической станции 1	Декада 2	Месяц 3	Год 4	Состояние почвы 5			Сумма положительных температур, (°С) 9	Линейный прирост подстриженных растений, мм 10
				увлажнение 6	промерзание в начале декады, см 7	оттаивание, см 8		
11 Усть-Лабинск	2	I	1976	хорошее 23	талая 27	—	6	6 - 6
12 Казанская	3	XI	1977	то же 24	то же	—	36	14 - 17
13 Гигант	2	III	1978	»	»	—	49	30—31
14 Краснослободск	1	XII	1975	»	ночью 28 <10	днем 29 полное 30	12	2—2
15 Михайловка	2	X	1977	»	то же	то же 24	33	12—12
15 Михайловка	2	XI	1977	»	»	»	55	16—16
16 Цимлянск	2	III	1978	»	>30	>10	37	2—2
17 Ново-Александровск	2	II	1978	»	>10	>10	52	9—9
18 Михайловка	3	III	1978	»	>30	>10	109	26—27
19 Чертково	2	X	1977	слабое 25	<10	днем 29 полное 30	28	2—2
20 Изобильное	3	X	1976	то же 24	талая 27	—	57	7—7
21 Красногвардейское	2	XI	1978	»	то же	—	67	12—13
22 Изобильное	2	XI	1975	сухая 26	<10	днем 29 полное 30	51	2—2
22 Изобильное	3	XI	1975	то же 24	талая 27	—	64	3 - 3
19 Чертково	1	X	1977	»	то же 24	—	83	5—6

KEY:

1. Name of meteorological station
2. Ten-day period
3. Month
4. Year
5. State of soil
6. Moistening
7. Freezing at onset of 10-day period, cm
8. Thawing, cm
9. Sum of positive temperatures (°C)
10. Linear increase in clipped plants, mm
11. Ust'-Labinsk
12. Kazanskaya
13. Gigant
14. Krasnoslobodsk
15. Mikhaylovka
16. Tsimlyansk
17. Novo-Aleksandrovsk
18. Mikhaylovka
19. Chertkovo
20. Izobil'noye
21. Krasnogvardeyskoye
22. Isobil'noye
23. Good
24. Same
25. Slight
26. Dry
27. Thawed
28. Night
29. Day
30. Complete

Analysis of the cited expressions shows that the growing of winter crops in virtually all cases begins with the transition of air temperatures through 0°C to positive values when during the 1-day period the sum of positive mean daily temperatures is only 3-5°C and simultaneously with the onset of the thaw there is thawing of the soil not covered by snow.

Whereas with all types of thaws and positive air temperatures (somewhat above 0°C) there are only indications of growing, when the soil is thawed the clipped plants of winter crops aftergrow on the average by 3-4 mm, that is, the growing is more conspicuous. With an increase in the intensity of the the thaw there is an increase in the activity of aftergrowing. When there is thawed soil and a temperature increase this process is accelerated, but as the depth of freezing increases and the degree of soil moistening decreases at the beginning of the thaw it transpires considerably more slowly.

Since during thaws the growing of winter crops does not transpire uniformly, we feel that as a criterion of the intensity of growing of winter crops during the period of winter thaws it is correct to use the linear increase of the clipped plants under the condition of their growing on thawed soil and with its good moisture supply. If this type of aftergrowing against a background of thaws transpiring when there is thawed and well-moistened soil is used as a standard, then on the basis of the aftergrowing of clipped plants it is possible to judge the activity of growing during the thawed 10-day period not only for the first type, but, using the sum of positive temperatures, also for the remaining types of aftergrowing (see Table 2).

Table 2

Scale for Taking into Account the Activity of Aftergrowing of Clipped Plants of Winter Wheat During Period of Winter Thaws

Интенсивность отрастания 1	Отрастание, *мм* 2	3 Сумма положительной температуры за декаду при разных типах отрастания, (°C)				
		1-й тип 4	2-й тип	3-й тип	4-й тип	5-й тип
5 Интенсивное	⩾ 28	49	—	—	—	—
6 Активное	17—28	31—49	>55	>86	—	—
7 Слабое	8—16	12—30	35—55	56—86	>56	—
8 Очень слабое	<8	<12	<35	>56	<56	>92

KEY:

1. Intensity of aftergrowing
2. Aftergrowing, mm
3. Sum of positive temperatures for 10-day period for different types of aftergrowing (°C)
4. 1st type, etc.
5. Intensive
6. Active
7. Weak
8. Very weak

Thus, if in the reference network of meteorological stations in the southern part of the country we organize simple observations of the aftergrowing of clipped plants of winter crops it is possible to fill the gap in information on the actual state of the sown crops in any winter 10-day period and soundly evaluate the course of wintering of winter crops. In our opinion such observations must be provided for in new instructions for agrometeorological observations.

The derived expressions put into the hands of the working agrometeorologist an additional possibility for a sounder evaluation of the conditions for the growing of winter crops during the period of winter thaws.

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SCIENTIFIC CENTER OF SOVIET HYDROLOGY (SIXTIETH ANNIVERSARY OF THE STATE HYDROLOGICAL INSTITUTE)

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[Article by Candidate of Geographical Sciences V. I. Korzun, USSR State Committee on Hydrometeorology and Environmental Monitoring, submitted for publication 14 September 1979]

Abstract: This paper gives the history of development of the State Hydrological Institute and gives a review of the scientific research activity of the institute over a period of 60 years.

[Text] Water resources are of enormous importance in the development of the national economy of the Soviet Union, in the solution of social problems and enhancing the well-being of the Soviet people. A study of water resources and their rational use and conservation is an important national problem. The successful solution of this problem is impossible without the development of scientific investigations of natural waters, clarification of the patterns of their formation, determination of the quantitative and qualitative changes under the influence of natural factors and human activity without reliable inventorying and evaluation of water resources, without creating a scientific and technical system making it possible to carry out prediction of different hydrological phenomena and processes and ensure engineering computations of hydrological parameters for construction planning and operation of different water management projects and structures.

Exceptional foresightedness was manifested by the outstanding Russian hydrologist Professor Viktor Grigor'yevich Glushkov, who in 1918, in the first year of establishment of Soviet rule, under conditions of economic turmoil and Civil War advanced and validated the idea that in Russia there was a need for organizing a scientific center on hydrology -- the Russian Hydrological Institute. This idea and the proposals prepared by V. G. Glushkov received the support of many well-known scientists -- V. N. Lebedev, S. A. Sovetov, N. M. Knipovich, Yu. M. Shokal'skiy, K. M. Deryugin, L. S. Berg,

G. Yu. Vereshchagin, V. Ye. Lyakhnitskiy and a number of others.

The board of the People's Commissariat of Education RSFSR, on 19 June 1919, adopted a resolution on the organization of a Russian Hydrological Institute, and on 7 October 1919 approved the proposal for an institute and the makeup of a permanent organizational committee for the institute.

The following were defined as the principal tasks of the Hydrological Institute: thorough study of all types of natural waters; development of theoretical problems in hydrology, programs and methods for hydrological investigations; collection, systematization and generalization of data on water features and their hydrological regime for support of the national economy of the republic with these data.

In 1926 the institute was transformed into an all-union center of scientific hydrology -- the State Hydrological Institute (SHI).

From the first years of organization the formation of the structure and directions of research in the institute proceeded along two lines: with respect to investigated features (rivers, ground water, lakes, seas) and with respect to scientific disciplines or practical purposes (hydrochemistry, hydrobiology, hydrophysics, hydraulics, hydroengineering, hydrometry).

Such an approach, in combination with the invitation of major scientists to head divisions of the institute (rivers -- V. M. Rodevich; seas -- N. M. Knipovich, K. M. Deryugin; lakes -- L. S. Berg, G. Yu. Vereshchagin; hydroengineering -- N. P. Puzyrevskiy, and others), made it possible to form a scientific team capable of solving a wide range of hydrological research problems and in a short period of time the institute could occupy a leading place in the development of both Soviet and world hydrological science and solve major problems in the national economy in connection with the formulation and implementation of the first five-year plans for the industrialization of the country and the restructuring of its agriculture on the basis of collectivization.

Three principal periods can be defined in the organization and development of activity of the State Hydrological Institute: from the moment of founding to the Great Fatherland War, the war years and the post-war period.

The first period was characterized by the following:
-- formation of the principal scientific and practical directions in hydrological research and the establishment of hydrology as a science devoted to the study of natural waters;
-- formulation of the principles of the theory of river runoff, channel, hydrophysical and hydrochemical processes, and also hydrological forecasts and computations;
-- formulation of scientific principles and engineering-technical procedures for planning and implementing individual kinds of experimental hydrological investigations under field and laboratory conditions;

-- formulation of the scientific and methodological principles for study of water resources (creation of the state control network), preparation of technical instructions on carrying out hydrological observations, development and assistance in industrial production of hydrological instruments and equipment;
-- introduction, on a national scale, of a system for the collection, analysis, generalization and publication of information on the water resources of the country ("USSR Water Inventory") which is unified in scientific-technical and systematic respects;
-- assistance in the organization and development of hydrological education in the USSR, the training of professional hydrologists with higher and intermediate skills and scientific cadres.

This period is characterized by the joining of efforts and incorporation in a single scientific body of three generations of hydrologists: older, who had devoted their lives to solution of the water problem already in the pre-Revolutionary period and actively striving to make their contribution to the development and strengthening of the USSR economy; intermediate, forming in the course of establishment of the Soviet state, and young, for the most part consisting of graduates of the Moscow Hydrometeorological Institute, Leningrad State University and a number of other higher educational institutions. This generation was part of the new scientific-technical intelligentsia, growing up under Soviet conditions.

A decree of the Central Executive Committee and the USSR Council of People's Commissars, dated 7 August 1929, on organization of a Unified USSR Hydrometeorological Service, with the Hydrological Institute included in it, was of substantial importance for the activity of the SHI and the entire matter of studying the water resources of the country.

The joining of the hydrological and meteorological networks, scientific institutes devoted to the fields of meteorology and hydrology, in a single scientific and technical system favored orderliness and an increase in the level of study of the weather, climatic and hydrological phenomena and processes, in many ways interrelated to one another, and the organization of a service for hydrometeorological forecasts and supply of the national economy with systematic data and reference materials on the hydrometeorological regime.

During the first period two hydrological congresses were organized and held. The importance of these congresses, as well as the subsequent third (1957) and fourth (1973) congresses for the development of hydrology in the USSR and in general for the development of world hydrological science was enormous.

The Hydrological Institute was the initiator and organizer of the hydrological congresses and their scientific leader.

The First All-Russian Hydrological Congress was held in Leningrad during the period 7-14 May 1924. Academician A. P. Karpinskiy, President of the USSR Academy of Sciences, was honorary chairman of the congress. The actual work of the congress was headed by V. G. Glushkov. The organizing committee for the congress included well-known scientists -- Ye. V. Oppokov, Ye. V. Bliznyak, K. M. Deryugin, L. S. Berg, V. M. Rodevich, M. A. Velikanov, V. Ye. Timonov, G. Yu. Vereshchagin and others.

At the congress emphasis was on the development of investigations of river runoff, the creation and improvement of the hydrological network, the implementation of collection, analysis and generalization of observational data in the network and expeditionary work for evaluating water resources.

The Second All-Union Hydrological Congress was also held in Leningrad, during the period 20-27 April 1928, and also transpired under the chairmanship of V. G. Glushkov with the active participation of the scientists who were members of the organizing committee for the first congress.

This congress was of particular importance because it transpired on the eve of the adoption and implementation of grandiose plans for the restructuring of our country (first five-year plans), in which the solution of the water problem in the interests of development of electric power, transportation, industrial and household water supply and development of agriculture occupied an important place.

The congress examined the status and reviewed the plans for development of investigations of rivers, lakes and ground water. Reports devoted to the problem of computing runoff were of great importance. Among these were the fundamental reports of D. I. Kocherin on the runoff norm and M. A. Velikanov on the method for the approximate computation of runoff when observational data are lacking.

The congress discussed the problem of creating a water inventory of the USSR and its basic content. This facilitated the organization and implementation, during 1936-1940, of an enormous amount of work on drawing up such an inventory.

The activity of the State Hydrological Institute during the period of the Great Fatherland War 1941-1945 was radically restructured and was subordinate to the problems involved in many-sided hydrological support of combat operations of the Red Army for the defeat of Fascist Germany.

This activity was carried out in several directions and particularly with respect to the compilation of different types of manuals (handbooks, maps, etc.) containing data on the hydrography and hydrological conditions of the theater of military operations, the carrying out of experimental investigations of the passability of terrain by different types of military vehicles, improvement in methods for computing hydrological characteristics applicable to solution of problems in military engineering, participation in the development and improvement of methods for hydrological forecasts and in a number of other directions. The institute carried out work on a large scale and of exceptional importance for the restoration of the hydrological network in the territory liberated from the occupying forces and for the improvement of methods and instruments for hydrological observations.

It is particularly important to note that under the conditions of the difficult war years the State Hydrological Institute carried out a series of measures and investigations having the purpose of creating, after the war's end, of major scientific experimental bases of the institute at Zelenogorsk (near Leningrad) and at Valday.

The third period (from 1946) was most saturated and effective with respect to the results of scientific investigations and the practical contribution of hydrological science to the planning of the distribution of productive forces, particularly in the development of general and basin schemes for the rational use and preservation of water resources; in the development of projects, construction and operation of hydroelectric complexes on the Volga, Kama, Dnepr, Don, Ob', Angara and other rivers; in mastery of the virgin and idle lands of Kazakhstan; in the development of melioration, construction and operation of irrigation and drainage systems and structures; in the mastery of petroleum- and gas-bearing deposits in Western Siberia; in solving the problem of partial shifting of river runoff from the northern to the southern slopes of the territory of the USSR; in creating major industrial complexes (Kursk Magnetic Anomaly and others); in the construction of the Baykal-Amur Railroad and in solving many other problems having the national importance of economic and scientific-technical undertakings.

During the post-war period the Hydrological Institute has been creating a major experimental base for investigating channel and hydrophysical processes and processes of water exchange in soils at Zelenogorsk (Main Experimental Base of the State Hydrological Institute) and the experimental base at Valday, not having any equal in the world.

The creation of these bases, the formulation and implementation of different types of investigations at them, including the formulation of an active experiment, simultaneously with the organization of specialized water balance (runoff) stations in the territory of the USSR under different physiographic conditions, signified the formation of a new direction in hydrological science -- experimental hydrology.

Exceptional services in the development of hydrology and in the direction of the State Hydrological Institute during the period of the Great Fatherland War and during the post-war period were rendered by Valerian Andreyevich Uryvayev, who continuously directed the State Hydrological Institute over a period of 26 years (1942-1968).

V. A. Uryvayev was an outstanding scientist and engineer, a talented organizer and a man exclusively dedicated to hydrology. Without exaggeration it can be said that V. A. Uryvayev and the personnel at the State Hydrological Institute which he directed determined an entire and the brightest epoch in the development of Soviet and world hydrological science. For its achievements in study of water resources and for its services in the hydrological support of the national economy and in the development of Soviet science, in 1944, by a decree of the USSR Supreme Soviet, the Hydrological Institute was awarded the Order of the Red Banner of Labor. V. A. Uryvayev was a holder of the Order of Lenin, the Red Banner of Labor, the Red Star and the "Emblem of Honor."

In 1971 the V. G. Glushkov-V. A. Uryvayev Prize was established, to be awarded once each three years for the best work in the field of hydrology of the land and experimental hydrological research. The same as in the pre-war period, during the post-war years the State Hydrological Institute was the organizer of the Third and Fourth All-Union Hydrological Congresses. In contrast to the preceding congresses, the Third All-Union Hydrological Congress (Leningrad, 7-17 October 1957) was devoted only to the problems of hydrology of waters of the land and there was no consideration of the problems of hydrology of the seas and oceans.

At the same time, at the congress the problems relating to the waters of the land were subjected to detailed examination in nine sections: computations and predictions of runoff (section leaders D. L. Sokolovskiy, A. I. Chebotarev), lakes and reservoirs (Ye. V. Bliznyak), general hydrology (L. K. Davydov, A. A. Sokolov), hydrodynamics and channel processes (M. A. Velikanov), hydrophysics (B. P. Orlov), water management (M. F. Menkel', S. N. Kritskiy), ground water and underground feeding (B. I. Kudelin), hydrochemistry (O. A. Alekin), hydrometry and methods for hydrological research (A. K. Proskuryakov).

V. A. Uryvayev exerted direct leadership in preparations for the congress and its conduct.

The Fourth All-Union Hydrological Congress was held during the period 9-13 October 1973 and its basic task was a summarization of the results of hydrological research carried out after the third congress, determination of the directions for further development of study of water resources and hydrological science in the light of the resolutions of the Party and government on the rational use and preservation of water resources. The congress heard and at the plenary sessions discussed 11 general reports and more than 300 scientific reports in nine sections of the congress. The general reports covered the most important problems in hydrology and its practical use including the status and prospects for the development of hydrology in the USSR (V. I. Korzun, A. A. Sokolov); the influence of man on water resources and hydrological processes (K. P. Voskresenskiy, S. I. Kharchenko, I. A. Shiklomanov); status and prospects for the development of hydrological computations and their application in construction planning (A. I.

Chebotarev, F. V. Zalesskiy); status and prospects for the development of hydrological forecasts (Ye. G. Popov, V. D. Komarov); water quality and its change under the influence of economic activity (A. A. Zelon, V. R. Lozanskiy); modern problems in the hydrology of lakes and reservoirs (A. V. Shnitnikov, A. B. Avakyan, S. L. Vendrov, V. A. Znamenskiy); theory and methods for computing channel processes (N. Ye. Kondrat'yev, I. V. Popov, B. F. Snishchenko); scientific and organizational principles for a unified state system for the inventorying of water, its use and the implementation of a USSR Water Inventory (S. K. Cherkavskiy, A. A. Konoplyantsev); water exchange in nature (O. A. Drozdov, G. P. Kalinin, M. I. L'vovich); patterns of long-term river runoff as a basis of the theory of its regulation and use (S. N. Kritskiy, M. F. Menkel', D. Ya. Ratkovich).

The main work on preparations for and holding of the Fourth All-Union Hydrological Congress was carried out by the leading scientists of the State Hydrological Institute under the direction and with the direct participation of the institute director Aleksey Aleksandrovich Sokolov.

During the post-war period the State Hydrological Institute made a considerable contribution to the organization and development of international cooperation in the field of hydrology on a global, regional and bilateral basis. A particularly great personal contribution to this cooperation was made by the directors of the State Hydrological Institute V. A. Uryvayev and A. A. Sokolov, and also the deputy directors of the institute V. V. Kupriyanov and I. A. Shiklomanov. Many scientific specialists at the institute have taken and are taking an active part in different international measures, in working groups for implementing the programs of the International Hydrological Decade and the International Hydrological Program, in scientific conferences, symposia and seminars, in the preparation of international scientific and technical publications on the main problems in hydrology.

The attainments in Soviet hydrological science received broad international recognition. As the most significant results of the activity of the State Hydrological Institute during the 60 years of its existence we should note the following.

Study of water resources. There were several directions in this field of activity. In particular, this included the creation of a national reference and specialized network of hydrological stations and posts as the basis for a study and evaluation of water resources and the regime of waters of the land. The State Hydrological Institute played a fundamental role in having developed scientific principles of organization and distribution of the hydrological network, as well as principles applicable to practical needs, in the development and standardization of the programs and methods for hydrological observations, their analysis and generalization, in the creation and standardization of hydrological instruments and equipment, and also in the organization of a system for monitoring their operation, in the preparation and systematic revision of technical rules and manuals for the making of hydrological observations and studies, and participated actively in the training of hydrological workers.

This activity of Soviet hydrology in the 1930's-1950's to a great extent outpaced the level of many countries which were leaders in scientific and technical respects.

The second direction in the study of water resources, which had and still has enormous importance, is the development of expeditionary investigations. Even in the pre-Revolutionary period Russian hydrologists accumulated great experience in carrying out expeditionary hydrological, or to be more precise, hydrographic, navigational and descriptive studies. During the Soviet period the method of expeditionary investigations experienced substantial changes, considerably enhancing its effectiveness. The State Hydrological Institute, systematically improving the direction and content of expeditionary studies, concentrated its main attention not on a descriptive nature of this type of work (which retains its definite value), but in obtaining, as a result of expeditionary studies (in combination with the organization of a temporary hydrological network and the carrying out of a broad complex of hydrometeorological observations and studies) the characteristics of the hydrological regime, their variability and other parameters necessary for the planning and implementation of different water management measures. Along these lines, especially worthy of note is the complex of expeditionary studies carried out over a period of 10 years for study of water resources and the hydrological regime of the enormous territory of exploitation of the virgin and idle lands in Kazakhstan, finalized by the publication of a multivolume series of special monographs.

Along similar lines the State Hydrological Institute carried out and is carrying out different expeditionary hydrological investigations in Western and Eastern Siberia, in the region of the Kursk Magnetic Anomaly, in the zone of construction of the Baykal-Amur Railroad and in a number of other unstudied or inadequately studied (in hydrological respects) regions having great economic importance.

A major contribution to the development of the fundamental problems involved in the organization of the hydrological network and expeditionary investigations and in the creation of methods and instruments for hydrological observations was made by V. A. Uryvayev, V. V. Kuznetsov, K. Ye. Zhestovskiy, V. V. Ukhanov, O. N. Borsuk, I. F. Karasev, A. M. Dimaksyan, K. D. Zav'yalov, P. N. Burtsev and many other scientists and engineers of the State Hydrological Institute.

In the complex of hydrological investigations and in the evaluation of water resources a considerable place is occupied by work on the collection, analysis, generalization and publication of materials from hydrological observations and the results of expeditionary work. This type of activity makes it possible to ensure planning, designing, production and scientific organizations and institutions with the hydrological data which they require.

The generalization and representation of hydrological materials for use was and is accomplished in three types of publications: in hydrological yearbooks, in the USSR WATER INVENTORY and in the form of specialized monographs.

Hydrological yearbooks are the most widely distributed and permanent form of generalization and publication of hydrological data. The Hydrological Institute not only has developed and systematically improved the content and form of the yearbooks and the methods for analysis and evaluation of the reliability of the statistical data presented in the yearbooks, but also a long time was responsible for their acceptance, scientific approval and editing.

The multivolume publications USSR WATER INVENTORY constitute fundamental generalizations of information on the water resources of the USSR and the hydrological regime. The first edition of the USSR WATER INVENTORY (1931-1940) covered all types of waters and water bodies and included generalized materials from long-term observations and expeditionary studies on rivers, lakes, seas and ground water, and also data on precipitation and evaporation. The total volume of the INVENTORY was about 10,000 author's pages. Its materials have found extensive use in the national economy, in the development of the five-year plans for development of the national economy, in solution of different problems in electric power, transportation and water management. At the same time, the INVENTORY materials facilitated a substantial development of hydrological science. On the basis of these materials specialists at the State Hydrological Institute carried out fundamental investigations. D. L. Sokolovskiy, B. D. Zaykov, V. K. Davydov and a number of other outstanding scientists investigated annual and maximum runoff, precipitation, evaporation and other elements of the hydrological regime.

The compilation of the first USSR WATER INVENTORY was an extremely complex and time-consuming task, aggravated both by the scattered nature of the sources and the fragmentary character of the hydrological materials in different departments and organizations and the need for creating scientific-methodological principles for their analysis and systematic organization, and also needs for preparation and training of the necessary scientific, engineering and technical workers. The Hydrological Institute successfully dealt with these tasks. In the first stage the scientific direction of work on the INVENTORY was carried out by L. K. Davydov, and later by A. A. Sokolov (for surface waters) and Ye. M. Selyuk (for the seas).

During the period 1959-1974, under the direction of and with the direct participation of the State Hydrological Institute a new USSR WATER INVENTORY was prepared and published. It consisted of 139 volumes in three series: 1. EXTENT OF HYDROLOGICAL STUDIES; 2. PRINCIPAL HYDROLOGICAL

CHARACTERISTICS; 3. Regional monographs USSR SURFACE WATER RESOURCES.

During the period of compilation of the INVENTORY specialists made a complete inventory of rivers, lakes and reservoirs, substantially broadening the information available concerning the number and principal characteristics of water features in the territory of the USSR.

The main direction of work on the INVENTORY at the State Hydrological Institute was under A. P. Domanitskiy, and since 1963 -- V. V. Kupriyanov.

Specialized monographs, constituting the third type of generalization of data on water resources and the hydrological regime, together with issues of the TRANSACTIONS OF THE STATE HYDROLOGICAL INSTITUTE, are of exceptional scientific and practical interest. These types of monographs include major generalizations of data on river runoff and its principal parameters carried out by B. D. Zaykov and S. Yu. Belinkov SREDNIY MNOGOLETNIY STOK REK SSSR (Mean Long-Term Runoff of USSR Rivers) (1937) and K. P. Voskresenskiy NORMA I IZMENICHIVOST' GODOVOGO STOKA SOVETSKOGO SOYUZA (Norm and Variability of Annual Runoff in the Soviet Union) (1962). We have already told of the series of monographs on the virgin and idle lands of Kazakhstan. Another type of monograph is the publication VODNYYE RESURSY I VODNYY BALANS TERRITORII SSSR (Water Resources and Water Balance of USSR Territory) (1967), in which there is a substantial refinement of the information on the principal elements of the water balance and water resources and this information is cited for the territories of all krays (oblasts), autonomous and union republics, for 20 natural-economic regions and for the entire territory of the USSR, and also for the basins of the 800 largest rivers, for 10 lakes and 12 reservoirs. The information published in the monograph was widely used and is being used in the development of general, regional and basin schemes for the rational use and preservation of water resources and for other scientific and practical purposes.

The State Hydrological Institute is preparing and publishing specialized monographs applicable to the interests of supporting major national-economic measures. An example of this type of monograph is the publication VODNYYE RESURSY REK ZONY "BAM" (Water Resources of Rivers in the "BAM" Zone). In the monograph there is not only a generalization of data on water resources and the hydrological regime of rivers, which is complex due to natural conditions and the inadequately studied region in which the Baykal-Amur Railroad is being constructed, but what is especially important, it also gives recommendations on computation of the most important hydrological characteristics (norm of annual runoff and its intra-annual distribution, maximum spring and rain-fed water discharges, minimum runoff).

A fundamental investigation, winning broad international recognition, was the compilation and publication (1974) of the monograph entitled MIROVOY VODNYY BALANS I VODNYYE RESURSY ZEMLI (World Water Balance and the Earth's Water Resources). The main role in implementing this study was played by the State Hydrological Institute.

Investigation of hydrological phenomena and processes, water balance and moisture cycle. The scientific investigations carried out by the State Hydrological Institute cover a wide range of problems in hydrology: water balance and moisture cycle; river runoff; thermal and ice conditions; channel phenomena and processes; hydrological regime of lakes, reservoirs and swamps; quality of surface waters of the land; hydrological regime of meliorated territories; methods for hydrological computations and forecasts; influence of economic activity on water resources. In this article it is impossible to discuss all the types and results of scientific activity of the Hydrological Institute which merit attention with respect to the enumerated and some other problems in hydrology.

It is possible to discriminate three principal directions in water balance investigations. First, there are large-scale investigations whose purpose is to evaluate the principal water balance elements -- precipitation, river runoff and evaporation for long periods of time for considerable areas of basins of rivers, lakes, reservoirs, seas, territories of administrative regions and natural economic zones. We have already mentioned the results and value of such investigations and examples of these. The second direction is investigations carried out during the last decade at the State Hydrological Institute and under its scientific-methodological direction at the hydrometeorological observatories and at individual hydrological stations for the purpose of preparing operational water balances (annual, seasonal, monthly), based both on allowance for natural factors and data on the state of use of water resources in the national economy. The third direction is a detailed study, at water balance stations (runoff stations) and in representative basins, of elements of the water balance, their combination and interrelationship, degree of influence of different natural and anthropogenic factors.

The Valday Scientific Research Hydrological Laboratory imeni V. A. Uryvayev is the model polygon and water balance station of the State Hydrological Institute. This laboratory was created by its scientists and specialists with the participation of a number of leading scientific specialists of the State Hydrological Institute, to a considerable degree under the influence of the scientific ideas and with the direct organizational and scientific direction of Valerian Andreyevich Uryvayev.

During recent years the State Hydrological Institute has been devoting serious attention to investigations of the moisture cycle and study of the interrelationship between changes in liquid-water content in relation to atmospheric processes and changes in climatic conditions. Interesting investigations in this field are being made by M. I. Budyko, O. A. Drozdov and a number of other scientists at the institute.

Over the course of the entire 60-year period investigations of river runoff have occupied a central place in the activity of the State Hydrological Institute. These investigations cover a broad range of theoretical, experimental and applied problems. Specialists at the institute are formulating and developing the principles of the science of river runoff and in addition to theoretical studies are carrying out experimental investigations taking in the entire hydrological cycle -- falling of precipitation, forming of the snow cover, processes of snow thawing, formation of slope runoff, processes of infiltration and water exchange in the aeration zone, relationship between surface and ground water, losses in evaporation, channel runoff and its transformation.

A direct consequence of these investigations was the considerable progress attained in the understanding of the processes of formation of river runoff, in its quantitative estimation, in the creation and adoption of more perfect methods for computing the principal parameters of river runoff in practical water management. In this connection the work done by the Hydrological Institute directly and with the participation of interested scientific and planning organizations on evaluation of different methods used in hydrological computations is of exceptional importance, as is the creation of uniform norm-setting documents, mandatory for use by all planning organizations, for computing the principal hydrological characteristics (norm of annual runoff and its long-term variations, intra-annual distribution of runoff, maximum and minimum runoff and other characteristics).

In the mid-1950's there was a broad discussion in the USSR on two problems which are fundamental for the development of hydrological science: on the application of the methods of mathematical statistics and on the degree of influence of different agroengineering measures and other types of human activity on water resources. Extreme points of view appeared in these discussions and their adoption could exert unfavorable consequences in both theoretical and practical respects. The active position taken by the State Hydrological Institute in the matter of the legitimacy and necessity of applying the methods of mathematical statistics in hydrology, especially probability distribution curves with the simultaneous development of investigations of genetic peculiarities and conditions for the formation of river runoff, was correct and progressive.

The investigations made by the State Hydrological Institute for the purpose of evaluating the degree of influence of different types of human activity on river runoff and on water resources as a whole were of positive importance. These investigations, which during recent years have been developed to an exceptional degree, are enabling the State Hydrological Institure to make a major contribution to solution of major water management problems, including the shifting of part of the river runoff of northern rivers to the southern slope, the formulation of a plan for the protection of Leningrad against inundations, the development of construction for melioration work, etc. The studies carried out by the State Hydrological Institute for evaluating water resources and the possible effects of their territorial redistribution are of fundamental importance for the adoption of decisions on different variants for the shifting of river runoff, for planning and for subsequent operation of different water management structures and complexes of structures.

The methods for evaluating the influence of economic activity on water resources, developed by the Hydrological Institute, make it possible not only to evaluate the changes transpiring in river runoff, but also to prepare a forecast of the state of water resources for a long time in the future.

During the post-war years the Hydrological Institute devoted great attention to the development of hydrological research having the objective of assisting the fluorishing of agriculture, enhancing its effectiveness and increasing the yield of agricultural crops.

During the years 1963-1978 the institute carried out extensive investigations of the water, heat and salt balances of the irrigated lands of the Northern Caucasus, Rostovskaya Oblast, Kazakhstan and Central Asia. Simultaneously with the expeditionary work there were different experimental and theoretical investigations making it possible to formulate scientific and practical recommendations with respect to the irrigation norms and regime, proceeding on the basis of allowance for all the elements of the water and heat balance of irrigated fields.

In connection with the carrying out of melioration work in the Nonchernozem Zone of the RSFSR, by decision of the Party and government, the State Hydrological Institute is carrying out multisided investigations for the purpose of developing methods for calculating the water balance and its regulation for lands in the humid zone to be meliorated.

It can be asserted on a sound basis that to a considerable degree as a result of the investigations carried out by the State Hydrological Institute a new direction has been formed in the USSR in hydrology during the last 10-15 years -- the hydrology of meliorated lands. The results of long-term investigations in the arid zone applicable to the interests of melioration have been presented in different scientific publications, among which we should mention the monograph by S. I. Kharchenko entitled GIDROLOGIYA OROSHAYEMYKH ZEMEL' (Hydrology of Irrigated Lands) (1975).

Taking into account the peculiarities of the natural-climatic conditions in the territory of the USSR, the State Hydrological Institute is devoting serious attention to investigations of the ice and thermal regime of rivers, lakes and reservoirs. These investigations have made it possible to ascertain the nature of formation of ice within the water and frazil ice, study the processes of formation of the ice cover, its opening-up and destruction, formation of log and ice jams, ascertain the peculiarities of the thermal regime of many rivers and other water bodies having considerable importance for the national economy, and on this basis create and improve methods for predicting and computing ice conditions, as well as different ice phenomena and processes. Investigations for constructing and operating ice roads and crossings were highly effective.

A considerable place in the investigations of the State Hydrological Institute has been occupied, and is still occupied, by problems relating to study of the dynamics of water flows, channel processes and sediments. These investigations cover several directions, including study of the runoff of suspended and entrained sediments, river channel deformations, transformation of the shores of reservoirs, experimental investigations of the hydraulics of flows, channel-forming processes and movements of sediments both for the purpose of developing theory and also applicable to solution of specific water management problems.

The State Hydrological Institute has created a major laboratory complex for its experimental investigations and is carrying out different types of expeditionary and station work.

A major scientific achievement of the State Hydrological Institute is the development and successful use, for practical purposes, of a hydromorphological theory of channel processes. On the basis of this theory specialized recommendations for evaluating and computing channel processes in the construction of pipelines, electric power lines and other structures were formulated and are being applied extensively in construction planning.

The State Hydrological Institute plays a leading role in organizing the study of the hydrochemical regime and the quality of the surface waters of the land. The State Hydrological Institute was the initiator in development of methods and programs for large-scale hydrochemical observations in the network of hydrometeorological stations, analysis and generalization of these observations. During different years the institute has carried out multisided expeditionary hydrochemical investigations of lakes and reservoirs, has carried out detailed investigations of formation of the hydrochemical regime of surface waters, has carried out investigations of processes of mixing and dilution of waste water, and also in the field of study and evaluation of the influence exerted on the hydrochemical regime of water bodies by different types of economic activity and other investigations.

A distinguishing characteristic of the above-mentioned and many other types of scientific activity of the State Hydrological Institute is their practical direction. Such an approach not only does not lower the theoretical level of the investigations, but on the contrary, favors its growth.

In the course of the 60 years of existence of the State Hydrological Institute many outstanding scientists have worked within its walls. These include hydrologists of the older generation, such as V. C. Glushkov, M. A. Velikanov, V. M. Rodevich, I. V. Molchanov, D. L. Sokolovskiy, M. I. L'vovich, V. M. Makkaveyev, A. D. Dubakh, B. D. Zaykov, N. Ye. Kondrat'yev, G. I. Shamov, O. A. Alekin, and also hydrologists of the intermediate generation: V. A. Uryvayev, A. I. Chebotarev, A. A. Sokolov, K. P. Voskresenskiy, V. V. Ukhanov, V. V. Kupriyanov, O. A. Spengler, M. S. Protas'yev, A. P. Domanitskiy, A. M. Norvatov, Ye. M. Selyuk, K. Ye. Ivanov, A. V.

Karaushev, G. A. Alekseyev, V. G. Andriyanov, P. S. Kuzin, O. N. Borsuk, P. P. Voronkov and I. V. Popov.

At the present time, together with many hydrologists of the intermediate generation, a new generation is successfully developing the glorious traditions of the State Hydrological Institute, shaping new scientific directions, favoring general progress of Soviet hydrological science and its leading role in the international hydrology plan. Among the members of the new generation are I. A. Shiklomanov, V. A. Rumyantsev, S. I. Kharchenko, B. F. Snishchenko, and others.

The State Hydrological Institute is entering into a new stage in its activity at the height of its creative forces. Hydrometeorologists and water management workers in the Soviet Union wish the personnel of the institute new scientific attainments and their active introduction into practical work in the interests of further development of the national economy.

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PATTERNS IN THE REDISTRIBUTION OF ICE IN THE WATERS OF THE FOREIGN ARCTIC

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[Article by Candidate of Geographical Sciences V. I. Smirnov, Arctic and Antarctic Scientific Research Institute, submitted for publication 5 January 1979]

Abstract: The author has derived 22 dependences for changes in the areas of the Alaskan and Baffin ice masses during June-September on temperature, air pressure differences and other factors. The role of thermal and dynamic factors in these changes during different periods of the year is clarified.

[Text] For the seas of the North American and Greenland Arctic ideas on the mechanism of redistribution of ice conditions and the reasons for their interannual and seasonal variability earlier most frequently were of an approximate character since they rested on materials from sporadic observations. For most regions, due to the absence of observations, no such ideas could be formed at all.

The first attempt at ascertaining the peculiarities of ice conditions in the waters of the foreign Arctic was undertaken by the author in 1970 [1]. In the next study [2] a study was made of some patterns of change in ice cover and movements of ice masses, the times of formation and destruction of the ice and its other characteristics.

The seasonal redistributions of ice in Arctic Seas occurs for the most part in May-November and are governed by preceding and synchronous hydrometeorological processes.

The degree of influence of different factors on the redistribution of ice can be traced in the example of anomalous situations. For this purpose it is best to use data on hydrometeorological, synoptic and ice conditions in the sectors most difficult in ice respects, to which the Beaufort Sea can be assigned.

Anomalously favorable ice conditions were observed there in 1968; unfavorable conditions were observed in 1955. The favorable ice conditions were a result of the prolonged influence of the southern periphery of the high-pressure region, causing stable easterly and southeasterly air flows. With such a meteorological and synoptic situation the northwestern part of the Canadian Arctic Archipelago is under the influence of the easterly periphery of the high-pressure region, determining stable northerly and northwesterly flows and ice drift to the southeast. As a result, unfavorable ice conditions are created not only in the northwestern straits, but also in M'Clintock Channel and even in Baffin Bay.

In the case of active cyclonic activity over the Beaufort Sea the rear parts of the filling cyclones cause stable westerly and northwesterly winds and ice drift in the direction of the shore, that is, unfavorable ice conditions. However, in these cases the ice acquires great mobility and with a change in the wind to the easterly or southeasterly quadrants zones of rarefied ice or pure water are rapidly formed along the shore. They can be used routinely in the convoying of ships.

In addition, in Baffin Bay the West Greenland Current is of great importance in the change in ice conditions. Its intensification during the prenavigation period leads to a more rapid joining of the polynias for the northern and southern waters and accordingly to ice conditions more favorable with respect to navigation.

For a quantitative evaluation of the degree of influence of thermal and dynamic processes on the interannual variability of ice conditions in the seas of the foreign Arctic, as the index of the thermal effect in the last analysis we used the mean monthly air temperatures at Cape Barrow (t_a). As the index of dynamic processes we used the differences in the mean monthly air pressures for different measurement lines and the intensity of ice transport from the Arctic Basin into the Greenland Sea.

As an index of the variability of ice conditions we used the changes in the areas of ice masses, since they are related to ice content and other characteristics. For example, the area of the Alaskan ice mass in August (S_{VIII}), September (S_{IX}) and October (S_X) is related to the ice content of the Beaufort Sea in August, September and October (L_{VIII}, L_{IX}, L_X) by the following expressions:

$$S_{\mathrm{VIII}}=0{,}93\,L_{\mathrm{VIII}}-27,\ p=85\%,$$
$$p_N=61\%,\ \Delta S_{\mathrm{VIII}}=12\%;$$

$$S_{\mathrm{IX}}=0{,}69\,L_{\mathrm{IX}}-2,\ p=85\%,\ p_N=$$
$$=46\%,\ \Delta S_{\mathrm{IX}}=10\%;$$

$$S_{\mathrm{X}}=0{,}85\,L_{\mathrm{X}}-9,\ p=80\%,\ p_N=$$
$$=40\%,\ \Delta S_{\mathrm{X}}=10\%,$$

Table 1

Dependence of Type S = ax + b of Changes in Areas of Ice Masses (S%) on Different Hydrometeorological Factors (x)

№ п/п 1	Месяц 2	a	b	x	p	$p_{к}$	ΔS %	n
3 *Площадь аляскинского массива*								
1	июль 5	—9,6 —9,6	103,5 116,5	10 Ср. $t_{a\,VII}$ 11 при $t_{a\,VI}$ >0,5 $t_{a\,VI}$ <0,5°	81	50	7	16
2	то же 6	—7,0	—53,0	Ср. t_a 12 в I—VI	81	50	7	16
3	»	0,4 0,7	79,0 61,0	ΣΔ p в I—VI Б.—А. 16 $t_{a\,VI}$<0,5 $t_{a\,VI}$>0,5	75	50	7	16
4	»	—0,2	77,0	13 Σ $S_{Гр}$ в VI—VII	75	40	14	16
5	»	—5,4	—77,0	Ср. t_a в I—III	75	50	7	16
6	»	—5,2	1,0	10 Ср. t_a за предшествую- 14 щий год	81	56	9	16
7	август 7	—6,9	98,0	Σt_a в VI—VIII	73	53	11	15
8	то же 6	—7,8	72,0	Ср. t_a в VIII	80	67	13	15
9	»	—1,23	118,0	Ср. $S_{Гр}$ в X—IX	100	67	14	15
10	»	—0,33	65,9	Σ $S_{Гр}$ в VI—VII	87	67	12	15
11	»	—1,0	115,0	Ср. $S_{Гр}$ в X—VI	87	67	14	15
12	»	—5,0	31,0	Ср. t_a в I—VI	80	53	11	15
13	»	0,5 0,6	63,0 46,0	ΔΣ p за 15 I—VI Б.—А. 16 $S_{АМ\,VII}$>70 $S_{АМ\,VII}$<70	87	50	7	15
14	»	—3,5	—37,0	Ср. t_a в I—III	87	53	11	15
15	»	—12,0	—10,3	Ср. t_a за предшествую- 14 щий год	80	64	14	15
16	сентябрь 8	—1,7 —5,8	75,0 76,0	Σ t_a в VI—VIII $S_{АМ\,VIII}$>60 $S_{АМ\,VIII}$<60	86	50	7	14
17	то же 6	—0,77	87,0	Ср. $S_{Гр}$ в X—IX	80	50	12	14
18	»	—4,9	78,0	Ср. t_a в I—III	71	64	14	14
4 *Площадь баффинского массива*								
19	июнь 9	0,5	51	ΣΔ p в I—VI К.—А. 17	73	60	6	15
20	то же 6	6,1 2,1	162,5 80,0	10 Ср. t_a в I—VI при 11 ΣΔ p в I—VI К.—А.>0 11 при ΣΔ p в I—VI К.—А.<0	79	50	6	15
21	июль 5	0,52	26	ΣΔ p в I—VI К.—А. 17	81	56	6	16
22	то же 6	0,5	23	ΣΔ p в I—VI А.—Н. 18	81	56	6	16

where p is the guaranteed probability of the dependence, p_N is the guaranteed probability of the norm, ΔS is the admissible error.

In analyzing the guaranteed probability of the dependences, the admissible errors, taking into account the guaranteed probability of the norm in Table 1, the following conclusions can be drawn. The year-to-year variability of ice conditions in the Beaufort Sea and the eastern part of the Chukchi Sea in July to a considerable degree is governed by the variability of thermal processes (dependences 2 and 6). The main influence is exerted by the air temperature of the preceding winter and spring. The same is characteristic of Baffin Bay and Davis Strait in June (dependence 20).

In August in the Beaufort Sea and the eastern part of the Chukchi Sea and in July in Baffin Bay and in Davis Strait the predominant influence on the year-to-year variability of ice conditions begins to be exerted by dynamic processes (dependences 9-11, 13, 21, 22). Allowance for the preceding area, in particular, the Alaskan ice mass in July, increases the guaranteed probability of the dependences with a considerable decrease in the admissible error. For example, in the case of positive values of the pressure difference (dependence 13), when there is a prevalence of westerly and northwesterly transfer, the area of the Alaskan ice mass in August is usually greater than the mean long-term values. In the case of negative values of sums of the mean monthly pressure differences in January-July, causing primarily easterly and southeasterly transfer, the area of the ice mass is usually less than the mean long-term values. This dependence is well illustrated in the example of the redistribution of ice in the summer of 1968.

The intensity of ice transport in the Greenland Sea during the preceding period also exerts an influence on the variability of the area of the Alaskan ice mass in August (dependences 9, 10, 11). In the case of transport of ice exceeding the average, the area of the Alaskan ice mass in August is less than the mean long-term value; in the case of transport less than average -- the area is greater than the mean long-term value.

The influence of the intensity of transport is manifested to a lesser degree in the change in area of the Alaskan ice mass in July and September (dependences 4, 17).

In September the change in area of the Alaskan ice mass is caused primarily by the effect of air temperature in June-August. If the area of the ice mass in August is greater than 60%, the influence of air temperature on its year-to-year variability in September is manifested to a considerably lesser degree than in the case of an area of the ice mass in August less than 60%.

In general the mechanism of year-to-year variability of ice conditions can be represented in the following way. The ice of the Alaskan ice mass by July and in July still retains its monotonicity. This is manifested in the presence of ice breccia, in an average ice continuity greater in comparison with August, and in its relatively small year-to-year variability (the amplitude of changes in the area of the ice mass in July is 35%). The degree of monotonicity, as well as the year-to-year change in the area of the ice mass during this period, are determined, in particular, by the preceding thermal processes. Factors of a dynamic character seemingly prepare the ice for a more active redistribution in August. From June to July and August there is a gradual decrease in the area of the ice mass, number of fields and their extent and average continuity. The mean fragmentation of the ice cover, according to data supplied by Yu. A. Gorbunov and L. A. Timokhov, increases on the average from 7 units (40-60% of the fields) to 8 units (10-30% of the fields); fragments of fields and broken ice predominate.

All these processes in the long run cause a great mobility of the ice in August, and as a result, a great year-to-year variability of the area of the ice mass (amplitude 57%). And it is natural that the factors of dynamic effect on the ice begin to acquire a primary importance in the redistribution of ice conditions in August. For example, if the transport of ice from the Arctic basin into the Greenland Sea is increased, it can be assumed that there will occur (or already is occurring) an intensification of the transport drift of ice from the Beaufort Sea. In the long run the area of the Greenland eastern ice mass becomes greater than the mean long-term value and the area of the Alaskan ice mass becomes less. And vice versa, if the ice transport into the Greenland Sea is less than the mean long-term value, the area of the Greenland eastern ice mass also is less than the mean long-term value and the area of the Alaskan ice mass becomes greater.

In September, when ice formation begins and the formation of frazil ice is observed, the interannual changes in area of the Alaskan ice mass to a greater degree are caused by changes in air temperature. This is attributable to the fact that the ice loses its summer mobility and its reaction to the effect of dynamic factors is appreciably reduced.

The Baffin Bay ice mass to a certain degree is characterized by the features of the interannual variability of the area of the Alaskan ice mass. For example, in June, when the monolithic nature of the ice mass still persists, it is thermal effect factors which acquire the greatest importance in its interannual changes (dependence 20). In July, when the area of the ice mass, the mean continuity of the ice in it and the number of fields are reduced and the ice acquires a greater mobility, it is the dynamic effect factors which begin to acquire primary importance in changes in the area of the ice mass (dependences 21, 22).

Another merit of the derived dependences is that most of them are of prognostic importance. In preparation of a January background forecast of ice distribution it is possible to use dependences 6 and 15. In preparing

KEY TO TABLE 1

1. No.
2. Month
3. Area of Alaskan ice mass
4. Area of Baffin Bay ice mass
5. July
6. Same
7. August
8. September
9. June
10. Cp = mean
11. when
12. in
13. S_{Gr} (Gr = Greenland)
14. during preceding year
15. during
16. Barrow - Alert
17. Cambridge Bay - Alert
18. Alert - Nord

[t_a is the mean monthly air temperature at Point Barrow, °C; $\sum\Delta p$ is the sum of mean monthly pressure differences, mb; S_{Gr} is ice transport in thousands of km^2 into the Greenland Sea; n is the series of observation years.

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the March forecast it is possible to use dependences 5, 14, 18, and in the preparation of the June refinement -- the dependences 1-4, 7-13, 16, 17, 19-22.

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THE MAGNUS EFFECT FOR A SPHERICAL PARTICLE DURING DETACHMENT FROM A SOLID SURFACE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 112-113

[Article by Candidate of Physical and Mathematical Sciences N. N. Grishin, Institute of Water Problems, submitted for publication 15 January 1979]

Abstract: The paper presents the results of an experimental investigation of the Magnus effect in the case of nonstationary flow of a fluid around a spherical particle which has become detached from a solid surface. It was established that the values of the proportionality factor in the expression for the Magnus force decrease during some time after detachment and then are stabilized. The time required for reaching a stationary regime is of the order of magnitude of the mean saltation period for bottom sediments. The stabilized value of the proportionality factor then virtually coincides with that obtained earlier by M. A. Dement'yev for an air flow. An expression is derived making it possible to estimate the value of the Magnus force acting on bottom sediments rolling along the channel bottom.

[Text] The movement of bottom sediments in stream channels is usually accompanied by the rotation of the particles, giving rise to the Magnus effect [2, 3, 5]. The expression for the force $\vec{F}_\omega$ acting on a sphere with the radius R with the angular velocity $\vec{\omega}$ during its translational motion with the velocity U in a medium with the density ρ can be represented in the form

$$\bar{F}_\omega = \rho C_\omega \pi R^3 [\bar{\omega} \times \bar{U}].$$

The value of the proportionality factor C_ω has not yet been reliably determined. In [1] use was evidently made of the exaggerated value $C_\omega = 8/3$, obtained by the unwarranted use of the N. Ye. Zhukovskiy formula for the case of flow around a sphere. The few investigations of the Magnus force make it possible to state that $C_\omega = 1$ in the case of small values of the Reynolds number (for Stokes particles) [6] and $C_\omega = 0.23 \pm 0.02$ for values of the Reynolds number of about 10^4 [4]. These data were obtained for a steady regime of flow around a rotating sphere, whereas in the case of saltation movement of sediments the flow around the particles is essentially nonstationary. We note that in water flows with values of the Reynolds number corresponding to the movement of bottom sediments ($10-10^3$) the value of the Magnus force has to all intents and purposes not been estimated. In this study an experimental attempt has been made at such an evaluation for a nonstationary regime of flow around particles.

Spherical particles with mutually orthogonal diametral circles (for measuring angular velocity) plotted on them were rolled along a slant plane and then fell, rotating in a fixed fluid. After detachment from the plane a change in the horizontal velocity of the particles occurred under the influence of the forces of hydrodynamic resistance and the Magnus force:

$$\begin{aligned} &\frac{4}{3} \pi K^3 (\rho_s + \varepsilon\rho) \frac{dU_x}{dt} = \\ &= \frac{1}{2} \rho C_D \pi R^2 U_x |U_x| + \\ &+ \rho C_\omega \pi R^3 \omega_y U_z. \end{aligned} \tag{1}$$

Here $R = (7.0 \pm 0.1) \cdot 10^{-3}$ m; $\rho_S = (1.40 \pm 0.01) \cdot 10^3 \cdot$kg/m^3 is the density of the particles; $\varepsilon = 0.5$ is the combined mass coefficient for a sphere; C_D is the hydrodynamic resistance (drag) coefficient; U_x, U_z and ω_y are the components of the linear and angular velocities of the particles (the z-axis is directed vertically downward); t is time.

The changes in the velocities of the particles during the experiment were characterized by the following ranges of Reynolds numbers: $Re_x = 2RU_x/\nu = 0-640$; $Re_z = 2RU_z/\nu = 950-1780$; $Re_\omega = 2R^2\omega_y/\nu = 220-1100$. The values of the kinematic parameters entering into expression (1) were determined from the trajectories of particles obtained using a motion picture survey at a speed of 50 frames/sec.

The C_ω values computed using equation (1) indicated the presence of a dependence of the value of this coefficient on time transpiring after detachment of the particles from the plane along which they rolled (Fig. 1). The stabilization of the C_ω values occurred with t = 0.15-0.20 sec or with values of dimensionless time $\tau = tW/R = 12-16$ (where $W = 0.28 \pm 0.01$ m/sec is the steady rate of free falling of particles in the fluid).

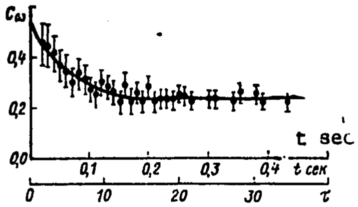

Fig. 1. Dependence of proportionality factor in expression for Magnus force on time elapsing after detachment of particle from solid surface: t is time; τ = tW/R is dimensionless time (R is particle radius, W is the steady rate of free falling of a particle in a fluid).

The point of intersection of the curve of the dependence $C_\omega(\tau)$ with the ordinate axis ($C_\omega(0) = 0.55 \pm 0.08$) can be interpreted as the value of the proportionality factor for a particle with zero time after detachment, that is, still rolling along a solid surface. The value C_ω not dependent on time corresponds to the attachment coefficient, is not constant, but increases during some time after detachment (nonstationarity period).

The results of this study can be used for estimates in describing the motion of bottom sediments having a rounded form since the experiments of M. A. Dement'yev [4] demonstrated that the dynamics of such sediments differs insignificantly from the dynamics of spherical particles. Thus, as a result of this investigation of the Magnus effect it was established that:

1. For evaluation of the value of the Magnus force acting on a particle rolling along the bottom it is possible to use the value of the coefficient $C_\omega = 0.55 \pm 0.08$.

2. The region of nonstationarity of the Magnus effect has the range of the mean saltation period for bottom sediments (0.15-0.25 sec [2,5]). Therefore, the value of the Magnus force acting on a particle detaching from the bottom decreases with time due to a decrease not only of the angular velocity of the particle [3], but also the value of the proportionality factor C_ω.

3. The stabilizing values $C_\omega = 0.24 \pm 0.02$ almost coincide with those determined earlier by M. A. Dement'yev [4] for an air flow.

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UDC 556.164"45":551.3.053

DETERMINATION OF MEAN ANNUAL RUNOFF FROM SLOPES WHEN TAKING ANTIEROSION MEASURES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 114-115

[Article by Candidate of Agricultural Sciences A. I. Gonchar and Candidate of Technical Sciences I. K. Sribnyy, Pridesnyanskaya Experimental Station for Contending With Soil Erosion and Ukrainian Scientific Research Institute of Hydraulic Engineering and Melioration, submitted for publication 22 January 1979]

Abstract: On the basis of their own investigations the authors propose a method for determining the mean annual runoff of water from slopes in dependence on the local characteristics of the slopes.

[Text] In the planning of water-retaining walls and ponds on slopes for the purpose of their moistening for increasing the yield of agricultural crops it is frequently necessary to know the mean annual runoff from the slopes.

However, its determination by the method adopted for small and intermediate rivers is extremely difficult because it was developed for the average conditions of river basins including reaches with different slopes, vegetation, soils, runoff from which can differ considerably from these mean conditions. For example, according to data from the Pridesnyanskaya Experimental Station (for contending with the erosion of soils), the mean annual spring runoff for 1948-1963 from the runoff areas at Pokoshichi village in Koropskiy Rayon in Chernigovskaya Oblast, occupied by forest, was 13 mm, and from fields was 60 mm [1], with the mean norm for the river basin being 80 mm [2, 3].

Therefore, data on the mean annual spring runoff for river basins can be used for determining runoff from the slopes taking into account only their economic use and local characteristics of relief. However, since there are an extremely great number of such factors and they are difficult to take into account, it is most correct to determine the mean annual runoff from slopes by analogy with observational data for runoff areas in different climatic zones, with a nonidentical sum of precipitation, different slopes,

Table 1

Runoff Norm from Runoff Areas Adopted as an Analogue in Pokoshichi Village in Dependence on Crops and Soil Working System for Slopes of 5° (Convex Slopes)

Characteristics of vegetation and slope surface	Runoff, mm	
	A^{pod}_{spr}	A^{pod}_{sum}
Late fall plowing along slope	60	--
Late fall plowing across slope	32	--
Waste land	33	--
Winter crops	68	7
Annual grasses	38	5
Perennial grasses	33	2
Hardwood forest	12	1
Plowed along slope	--	15
Plowed across slope	--	7
Spring crops	--	10

Table 2

Coefficient of Influence of Soils on Runoff in Comparison With Soils in Runoff Areas Used as Analogue

Soil characteristics	K_{soil}
Clayey	1.15
Clayey loam	1.0
Sandy loam	0.75

Table 3

Change in Runoff With Change in Slope by 1° in Dependence on Vegetation and Soil Working System, in %

Vegetation characteristics and soil working system	P_{slope}, %
Pasture with thin grass	2
Pasture with average grass	3
Plowed land along slope	4
Plowed land across slope	6

vegetation and soils when different methods are used for working them.

Despite the fact that the data on runoff for the Pridesnyanskaya Experimental Station were obtained using the results of observations in runoff areas with podzolic soils in the northern part of the Ukrainian SSR, these data with certain assumptions can be used for correcting the runoff of water from slopes in the basins of other rivers in the Ukrainian SSR. With these data taken into account, the following computation formulas are recommended for determining the mean annual runoff from slopes in mm;

a) from melt water

$$A_{spr\ mean} = A_{spr}/80\ A^{pod}_{spr}\ K_{\alpha}, \tag{1}$$

b) from summer rains and showers

$$A_{sum\ mean} = \sum H \geqslant 15\ \text{mm}/150\ A^{pod}_{sum}\ K_{soil}\ K_{\alpha}, \tag{2}$$

where $A_{spr\ mean}$ and $A_{sum\ mean}$ are the layers of mean annual runoff of water from slopes from spring snow melting and summer rains and showers respectively, in dependence on the soils and the systems for working them, vegetation, precipitation and surface slopes, mm; A_{spr} is the layer of mean annual spring runoff for the river basin where the particular point is situated; it is taken from the isoline map published in [2, 3], mm; A^{pod}_{spr} and A^{pod}_{sum} are the layers of mean annual runoff from spring snow melting and summer rains and showers respectively in dependence on vegetation and the system for working the soil in runoff areas in Pokoshichi village with podzolic soils with a surface slope of 5° which are used as an analogue, mm (Table 1); K_{soil} is a coefficient taking into account the change in runoff in dependence on the soils in the sector in comparison with the soils in the runoff areas, adopted as an analogue; use is made of the data in Table 2, prepared on the basis of the relationship of the runoff coefficients recommended in SN 435-72 for different soils [4]; K_{α} is the coefficient of influence of slopes on runoff and is determined using an empirical formula derived on the basis of experiments carried out by the Ukrainian Scientific Research Institute of Hydrology and Melioration [3] and which has the following form:

$$K_{\alpha} = 1 + 0.01\ P_{slope}\ (5 - I), \tag{3}$$

where P_{slope} is the relative change in runoff with a change in slope by 1° in dependence on the vegetation and the system for working the slope surface; it is used in accordance with the experiments carried out at the Ukrainian Scientific Research Institute of Hydrology and Melioration, in accordance with the data in Table 3, %; I is the slope, degrees; $\sum H \geqslant 15$ mm is the mean long-term sum of effective precipitation with a layer greater than 15 mm at a particular point, mm; it can be taken into account using data from the nearest meteorological station.

The processing of data from the Hydrometeorological Service for the right bank of the lowland part of the Ukrainian SSR from Korosten' to Odessa indicates that the mean long-term sum of rain and showers with precipitation in a layer greater than 15 mm changes relatively little from south to north and is approximately about 150 mm per year. Therefore, in the absence of these data $\sum H \geqslant 15$ mm can be assumed to equal approximately 150 mm.

If a sector of the slope is included in a multifield crop rotation it is necessary to sum the total runoff value for each crop in the crop rotation and obtain the annual average for the period of the crop rotation cycle.

Although the above-mentioned method for determining the runoff of water from slopes is also still imperfect, it is still more precise than other existing methods and makes possible a more correct allowance for local conditions in the drainage basins which exert a considerable influence on the mean annual runoff of water from slopes.

The cited method for computing water from slopes, based on observational data collected in runoff areas at Pokoshichi village in the Koropskiy Rayon of Chernigovskaya Oblast, taking into account the correction coefficients which take into account the dissimilar quantity of precipitation, soil and other local conditions, can be used in computations of water runoff from slopes in other regions of the lowland part of the Ukrainian SSR with different climatic and local drainage basin conditions.

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UDC 389.6:551.508.001.4

ENSURING THE UNIFORMITY OF MEASUREMENTS IN THE SYSTEM OPERATED BY THE STATE COMMITTEE ON HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 116-117

[Article by G. N. Kondrashov and L. V. Selivanov, All-Union Scientific Research Institute of the Metrological Service, submitted for publication 26 February 1979]

Abstract: The authors note the presence in the system of State Standards for ensuring the uniformity of measurements of recommendations directed to solution of this problem. It is also noted that in the system operated by the State Committee on Hydrometeorology and Environmental Monitoring in order to ensure uniformity of measurements it is necessary to carry out state tests of all means for measuring hydrometeorological data and metrological certification of all methods for carrying out measurements, including certification of methods for carrying out measurements presented in the INSTRUCTIONS FOR HYDROMETEOROLOGICAL STATIONS AND POSTS.

[Text] The problem of ensuring uniformity of measurements is solved at the present time in all branches of the national economy. The metrological services organized in the ministries and departments in measurements must ensure obtaining comparable and reliable information. The solution of the problem is possible only with the availability of certified methods for carrying out measurements and standard measurement apparatus and with the direct participation of all metrological agencies of the State Committee on Standards.

The State Committee on Hydrometeorology and Environmental Monitoring supplies the national economy of the country with information on the state of the environment. In the case of observations in the hydrometeorological network use is made of a great number of different special means and methods for measuring hydrometeorological data. Suffice it to mention that the variety of measurement instruments used is thousands. The description of most means for measuring hydrological data is given in the HANDBOOK ON HYDROMETEOROLOGICAL INSTRUMENTS AND APPARATUS [10]. Until recently the problems of development, release and use of means for measuring hydrometeorological data has been the task only of the Main Administration of the Hydrometeorological Service. All the norm-setting and technical documentation on the use of measurement means and methods has been reduced to the unified INSTRUCTIONS FOR HYDROMETEOROLOGICAL STATIONS AND POSTS. Individual systematic instructions have been developed for new measurement means and methods. However, the measurement means and methods have not always been incorporated into the all-union check lists.

The essence of the problem of ensuring the uniformity of measurements is that all the employed measurement means must have normalized metrological characteristics which are subjected to experimental checking and the methods for making measurements must be standard and certified. The principal directions in its solution and the specific recommendations are represented in a system of state standards for ensuring the uniformity of measurements (GSM system). The fundamental standards in the GSM system are 8.009; 8.010; 8.011; 8.001; 8.002 [2-6]. Standards 8.009 and 8.011 contain recommendations on the metrological characterstrics for which norms are to be set and the forms of representation of the measurement results. Standards 8.001 and 8.002 establish a uniform order for checking measurement methods by means of carrying out state tests during preparations for production and checking during production and in operation. The methods for carrying out the measurements must be certified in accordance with the recommendations of Standard 8.010.

In connection with the adoption of the system of State Standards for ensuring the uniformity of measurements, also extended to the means for measuring hydrometeorological data, at the present time studies are being made of problems relating to the state and metrological support of these measurement means. A preliminary evaluation of the state of measurement means used in hydrometeorological observations and investigations indicated that a high percentage of these measurement means satisfy modern requirements. However, some of these measurement means do not have metrological support because for the time being the necessary means and methods for testing and checking have not yet been determined for them.

The noted preliminary evaluation of the state of measurement means was made on the basis of published data [7, 10] and using data from an analysis of the state of metrological support of measurement means in the system of the State Committee on Hydrometeorology and Environmental Monitoring, in whose implementation the authors of this article took a direct part.

The problem of ensuring the uniformity of measurements in the system of the State Committee on Hydrometeorology and Environmental Monitoring can be solved by the joint participation of the agencies of the system operating under the State Committee on Hydrometeorology and Environmental Monitoring and the State Committee on Standards in work on solution of the problems related to the support of hydrometeorological observations and investigations by measurement means and methods meeting modern requirements. For any solution the organizations of the State Committee on Hydrometeorology and Environmental Monitoring must use only certified methods for carrying out measurements and certifying measurement means which have undergone state tests. In this connection it is extremely necessary in a planned order to re-examine successively the methods for carrying out the measurements described in the instructions and methodological regulations with respect to carrying out their certification and their inclusion in such norm-setting documents relating to metrological support, as well as to supplement the methods recommended for computation of the errors in the employed methods.

As an example we can mention the INSTRUCTIONS FOR HYDROMETEOROLOGICAL STATIONS AND POSTS, Issue 6, Part I, entitled "Hydrological Observations and Work on Rivers" [8]. In the preparation of this publication, the first chapter included #6, containing recommendations on the compilation of special plans and programs for investigations for studying the accuracy of the methods employed for measuring water discharge in rivers. The recommendations contained detailed instructions on determining the values of different components of measurement errors. At the present time there is an international standard (No 1088) which contains recommendations on computation of measurement errors in determining water discharge in rivers made by the "area - velocity" method [9]. The standard was developed by the International Standardization Organization. The "area - velocity" method is recommended in the Instructions as the basic method. Evidently, there is already sufficient research material for a complete certification of methods for measuring water discharges in rivers, including problems related to the computation of measurement errors.

Particular attention must be devoted to state tests of all means for the measurement of hydrometeorological data, since in carrying them out there is solution of the principal problems involved relating to the suitability of measurement means in accordance with the purpose and the satisfaction of the requirements on technical conditions for measurement means. In state tests there is a full volume of studies for evaluating all the characteristics of both measurement means in standard production and those newly prepared for production. In order to carry out state tests, and also to ensure the production and use of measurement means it is necessary to have such metrological support as will ensure working means for measurements with checking schemes, standards, methods and sample means for testing and checking.

Some of the measurement means have already undergone state tests. The state register for measuring instruments includes devices for checking UPG-110 hygrometers, GM-9-III bathythermographs, GM-28 mareographs, a central device for the AGMS-NN station, a registration and automation device for the M-108M station, RKZ-2 and RKZ-5-II radiosondes and other measuring instruments and systems. But this is only a small part of the measuring instruments (means) used in the system of the State Committee on Hydrometeorology and Environmental Monitoring.

The prospects for the development of hydrometeorological instrument making, including the development of measuring systems and work on many-sided automation of the State Committee on Hydrometeorology and Environmental Monitoring, are set forth in the publications of the Special Design Bureau "Gidrometpribor" and the Central Design Bureau of Hydrometeorological Instrument Making in the field of multisided automation of the State Committee on Hydrometeorology and Environmental Monitoring [1, 11]. An important stage in the work on supplying the hydrometeorological network with new modern measurement means is preparations for carrying out state tests. The carrying out of state tests of all means for measuring hydrometeorological data should ensure solution of the problem of uniformity of measurements in the system operating under the State Committee on Hydrometeorology and Environmental Monitoring.

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REVIEW OF MONOGRAPH BY V. R. ALEKSEYEV: NALEDI I NALEDNYYE PROTSESSY (VOPROSY KLASSIFIKATSII I TERMINOLOGII)(ICE ENCRUSTATIONS AND ICE ENCRUSTATION PROCESSES (PROBLEMS IN CLASSIFICATION AND TERMINOLOGY)), Novosibirsk, Nauka, 1978, 192 pages

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 118-119

[Review by Candidate of Geographical Sciences B. M. Krivonosov]

[Text] Ice encrustations are a natural phenomenon occurring widely in the Northeast, in Transbaykalia, in Central and Western Siberia, that is, in places where the climate is severe. Under these conditions ice encrustations are an element of the nival-glacial complex and play a major role in formation of landscapes and the balance of snow and ice resources.

The study of ice encrustations has now been defined as an independent scientific direction. Due to the efforts of professional geographers, glaciologists, hydrologists, permafrost specialists, pavement engineers and construction men much has been done for solving theoretical and practical problems of seasonal glaciation.

In the book by V. R. Alekseyev, which is reviewed here, the author examines forming of the concept "ice encrustation," presents the physical essence of formation of ice encrustation, gives a classification and defines the place of ice encrustations in the overall scheme of natural ice, explains the genetic unity of ice formations arising with the layer-by-layer freezing of water and clarifies the principles and content of the theory of ice encrustation processes as one of the branches of glaciology. It examines many of the problems characterizing the investigated object -- seasonal glaciation and to a definite degree there is a study of the influence of environmental factors on the development and intensity of ice encrustation formation. The book gives an interpretive lexicon of 700 glaciological concepts and terms relating to ice encrustations and the layer-by-layer freezing of water, which constitutes a "singular, quite complete inventory of the terms which the new scientific direction can use."

The book by V. R. Alekseyev is the first attempt at filling the gap in the regularization and standardization of terminology in this new scientific direction -- the study of ice encrustations, the science of seasonal glaciation. A work along such lines has appeared for the first time and its publication must be regarded as a definite contribution to solution of the problem of study of formation of ice encrustations. The presented material is illustrated by well-selected examples and is accompanied by numerous citations to source materials, which makes possible a more thorough study of individual aspects.

The bibliography, which includes 208 items, is evidence of the great amount of work carried out by the author in an analysis and generalization of the accumulated scientific information. The author was able to bring together scattered studies dealing with investigation of ice encrustations in different regions of the country and abroad in both theoretical and practical respects.

Another merit of the reviewed book is that it is written in clear and understandable language, supported by factual material, which can be used in the practical work of investigators of seasonal glaciation in all regions of the country.

At the same time, the book is not without its shortcomings. For example, in this book there is no reflection of an evaluation of the possible influence of seasonal glaciation on man's economic activity. Even in the interpretive lexicon not in a single one of the cited terms does it mention that an ice encrustation can be formed as a result of man's economic activity. However, in the literature of our time there are repeated mentions of this point. The author himself, in an examination of varieties of ice encrustations, cites such concepts as ice encrustations of industrial waters (p 112), technogenic ice encrustations (p 115), etc.

Therefore, we feel that the definition of an ice encrustation without any indication that it belongs to glacial phenomena and that it can be the product of man's economic activity does not reveal the entire content of the term at the present stage.

In the interpretive lexicon of glaciological terms the author does not include the term "eventual ice encrustation," although this matter was discussed as early as 1973 at a scientific conference on the problems involved in the formation of ice encrustations at Chita. The necessity for introducing this term is especially great in the relatively built-up areas of the Siberian region. A demonstration of this is the numerous examples of actual observations and facts set forth in published works. "Eventual ice encrustation" is a variety of ice encrustation when man, not being aware of this himself, facilitates its formation.

At a conference in Irkutsk (1978) it was proposed that the term "potential ice encrustation formation" be defined more precisely. It was emphasized that the formation of ice encrustations is possible only under special conditions, and not only in those places where there is water and where a negative temperature field is formed. Individual researchers feel that this requires an energy potential as well.

At the present time the literature contains indications that ice encrustations must be regarded as a complex phenomenon developing with definite combinations of geological, climatic, permafrost, hydrogeological and other conditions. It is characteristic that by virtue of existence of feedbacks ice encrustations themselves exert an influence on the environment. A role of more than a little importance in the formation of ice encrustations is exerted by the conditions of freezing of water in the terrain and therefore there is a correlation between seasonal glaciation and relief.

In our opinion in compiling an interpretive lexicon of glaciological terms for the new scientific direction it was necessary to include such terms as:

-- accumulation, although there is "accumulating capacity" (p 34),
-- aerial methods in the recognition of seasonal glaciation,
-- water,
-- precipitation,
-- water balance,
-- adsorption,
-- water divide,
-- geochronology,
-- permafrost study,
-- hydrogeology,
-- glaciology,
-- ground water,
-- valley ice encrustations,
-- microclimate of ice encrustation,
-- microrelief of ice encrustation,
-- settling ice and other terms which are necessary for researchers in their practical work.

The interpretation of individual terms causes doubt. For example, on p 131 as a distinguishing characteristic of a "hanging ice encrustation" it is stated that it is small in size and melts rapidly. Observations of hanging ice encrustations in the Gornyy Altay make it possible to disagree with such a definition. In the Altay existing hanging ice encrustations attain a great extent and thickness, in individual years persisting to August. In actuality, the distinguishing characteristic of hanging ice encrustations is that most frequently they collapse and melt at the foot of a slope.

There is an insufficiently clear formulation of the difference in the definitions of ice encrustations of "industrial water" (p 112), "production water" (p 112) and "technogenic" ice encrustations (p 115).

We hope that the book will be read with great interest by glaciologists, geomorphologists, climatologists, hydrologists and engineers concerned with the problems of seasonal glaciation, study of permafrost and formation of ice encrustations.

We note in conclusion that the publication of the book by V. R. Alekseyev ICE ENCRUSTATIONS AND ICE ENCRUSTATION PROCESSES (PROBLEMS IN CLASSIFICATION AND TERMINOLOGY) is an important stage in investigations in this direction, is forming it as an independent branch of glaciology.

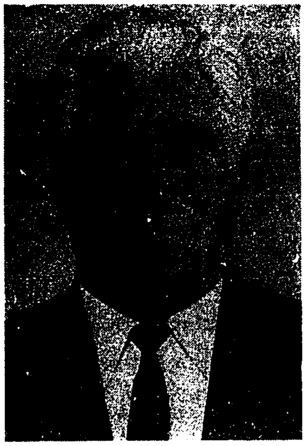
In general the book merits high marks and will be useful not only to researchers, but also to all those interested in the problems relating to the icing of ships, hydraulic structures, transportation-power systems and so forth.

SIXTIETH BIRTHDAY OF SERGEY KONSTANTINOVICH CHERKAVSKIY

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 120-121

[Article by the board of the USSR State Committee on Hydrometeorology and Environmental Monitoring]

[Text] Sergey Konstantinovich Cherkavskiy is marking his 60th birthday on 30 November 1979. He heads the Administration of Hydrometeorological Support of the National Economy and is a member of the board of the USSR State Committee on Hydrometeorology and Environmental Monitoring.



The work activity of S. K. Cherkavskiy began in 1943 on the fronts of the Great Fatherland War when after graduation from the Higher Military Hydrometeorological Institute he was designated to the post of assistant head of the Hydrometeorological Division of the Operations Section of the Second Guard Army staff. Until the end of the war he remained in the active army on the Stalingrad, Southern, Fourth Ukrainian and Third Belorussian fronts. For the successful implementation of his tasks he was awarded the order of the Red Star and many medals. In 1945 S. K. Cherkavskiy went to work in the Moscow Administration of the Hydrometeorological Service, and in June 1950 was sent to work in the central offices of the USSR Hydrometeorological Service, first as deputy head of the Scientific Research Section, then to the Administration of the Hydrometeorological Network.

In 1962 S. K. Cherkavskiy was assigned to the USSR Gosplan in the post of deputy head of the Water Resources Section, and in February 1963, at the request of the Main Administration of the Hydrometeorological Service, was returned to the Administration of the Hydrometeorological Network. In 1964 he was designated head of the Administration of Hydrometeorological Support of Agriculture, Water Management and Construction.

Over the course of almost three decades Sergey Konstantinovich, occupying leading posts in the Main Administration of the Hydrometeorological Service, devoted great attention to the development of the hydrometeorological network and participated in the development of a system for the collection, analysis and publication of data on surface water resources, data on the climate of the USSR and oblast handbooks.

For his participation in preparing the INSTRUCTIONS ON DETERMINING COMPUTED HYDROLOGICAL CHARACTERISTICS Sergey Konstantinovich was awarded a diploma and the V. G. Glushkov-V. A. Uryvayev Prize.

Sergey Konstantinovich has taken a major role in organizing work on preparation of the INVENTORY OF USSR SURFACE WATERS and in developing the structure of the published part of the State Water Inventory.

The REGULATIONS ON THE STATE INVENTORY OF WATERS AND THEIR USE were developed with his direct participation. These determine the sequence for conducting the state inventory of waters and their use and are mandatory for all ministries and departments and also for all state, cooperative and public enterprises, organizations and institutions.

For successes in hydrometeorological support of the national economy, in 1967 S. K. Cherkavskiy was awarded the Order of the Red Banner of Labor.

In addition to his great organizational work in the country, S. K. Cherkavskiy actively participates in international cooperation along the lines of UNESCO, the WMO and the Socialist Economic Block, being a deputy of the USSR Interdepartmental Committee on the International Hydrological Program.

During the period of implementation of the UNESCO program on the International Hydrological Decade (1965-1974) Sergey Konstantinovich repeatedly headed the Soviet delegation at sessions of the International Coordination Council on the IHD, participated in the activity of a number of UNESCO working groups and participated as an expert in working out the first and second phases of the UNESCO program for the International Hydrological Program (1975).

S. K. Cherkavskiy made a major contribution to the development of the method for evaluating the economic effect from the use of hydrometeorological information containing data on the current and anticipated hydrometeorological conditions, long-term climatic and hydrological characteristics, coming into increasingly broader use in practical planning of production and planning of construction. He is chairman of the Central Commission of the State Committee on Hydrometeorology on Methods for Evaluating Economic Effectiveness.

Sergey Konstantinovich Cherkavskiy is devoting much attention to the adoption of the leading experience of hydrometeorological science and practice at the USSR Exhibition of Achievements in the National Economy. Over the course of many years he has been deputy chairman of the Exhibition Commission of the State Committee on Hydrometeorology.

In 1976 he was awarded the gold medal of the All-Union Exhibition of Achievements in the National Economy for developing and implementation, for the first time in the USSR, of a complex program of hydrometeorological investigations of the route of the Baykal-Amur Railroad and zones of economic exploitation under complex physiographic conditions.

In congratulating Sergey Konstantinovich on this notable anniversary, we wish to hope for his good health and express the assurance that he will continue to make a significant contribution to the hydrometeorological support of the national economy of the Soviet Union.

SEVENTIETH BIRTHDAY OF ANDREY ANISIMOVICH GLOMOZDA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 121-122

[Article by the Board of the USSR State Committee on Hydrometeorology and Environmental Monitoring]

[Text] Andrey Anisimovich Glomozda, head of the Belorussian Republic Administration of Hydrometeorology and Environmental Monitoring, marks his 70th birthday and the 42d anniversary of work in the Hydrometeorological Service on 29 November 1979.

After graduating from the institute in 1937, A. A. Glomozda was sent as a hydrological engineer to the Belorussian (then the Smolensk) Administration of the Hydrometeorological Service and since that time (with a brief interruption) all his work activity has been associated with the Belorussian Hydrometeorological Service.

In 1943 Captain Glomozda became head of the Administration of the Hydrometeorological Service of the Western Front, and then the Belorussian Front, which was later transformed into the Administration of the Hydrometeorological Service Belorussian SSR. Andrey Anisimovich became head of the Hydrometeorological Service of Belorussia during the hardest years for the service. The German-Fascist occupiers had virtually destroyed the meteorological stations and hydrological posts and destroyed equipment and instruments. The service had actually ceased its activity. After liberation of the temporarily occupied territory it was necessary to begin all over. But at this time A. A. Glomozda particularly clearly manifested his organizational abilities. The Belorussian Hydrometeorological Service was rapidly reconstructed due to his energy, great work capacity, stubbornness and businesslike attitude, as well as direct participation in the work.

The developing national economy of Belorussia, the rapidly growing industry and agriculture, placed great problems before the hydrometeorologists of the republic. These tasks are being successfully solved under the direction and with the direct participation of A. A. Glomozda.

Andrey Anisimovich is devoting particular attention to the servicing of agriculture in the republic. On his initiative the forms of such servicing are becoming increasingly diversified and the servicing itself is most effective. Now all links in agricultural production are receiving such servicing. Depending on the current and anticipated agrometeorological conditions the Hydrometeorological Service supplies agricultural agencies with recommendations on the choice of the optimum agricultural engineering measures for obtaining high yields.

For his great attainments in the hydrometeorological servicing of agriculture and in study of the hydrometeorological regime of the territory of the republic the Administration of the Hydrometeorological Service of the Belorussian SSR in 1974 was awarded the Diploma of Honor of the Supreme Soviet Belorussian SSR and A. A. Glomozda was awarded the title of Meritorious Worker in Agriculture Belorussian SSR.

A new stage for the Hydrometeorological Service of Belorussia began in the second half of the 1960's when the Main Administration of the Hydrometeorological Service adopted a resolution that a scientific-technical experiment should be carried out at the base of the Administration of the Hydrometeorological Service Belorussian SSR for creating the country's first complex automated system for the collection, processing and dissemination of information. The service had to solve not only a number of complex technical problems, but also train personnel for successful operation of the new equipment. It was necessary to carry out all this work while maintaining and ensuring a high quality of observations, constantly broadening and improving the servicing of the national economy. The profound knowledge of Andrey Anisimovich of the personnel, the professional qualities of the specialists and their capabilities favored the correct disposition of personnel. Constant close contact with Party, Trade Union and Komsomol organizations and reliance on them assisted in mobilization of the Administration staff for solution of new complex problems. A. A. Glomozda repeatedly speaks before the staff, at the Main Administration of the Hydrometeorological Service, at international organizations, at conferences of specialists of the socialist countries, and writes articles on matters relating to automation. During this period Andrey Anisimovich has manifested his ability to discriminate from a great variety of problems the ones which are most important, which should have priority and demonstrated his ability to ensure their solution.

From the beginning of organizing of observations of environmental monitoring A. A. Glomozda has been devoting great attention to this type of work.

The Belorussian Hydrometeorological Service is one of the best in the USSR. It has repeatedly been victorious in socialist competition among the Administrations of the Hydrometeorological Service. On the basis of the results of work done in 1977 the Administration of the Hydrometeorological Service Belorussian SSR was awarded the Red Banner of Labor of the Central Committee CPSU, the Council of Ministers USSR, All-Union Central Council of Trade Unions and the Central Committee of the Komsomol; for the first half-year of 1978 -- the Red Banner of Labor of the Main Administration of the Hydrometeorological Service and the Central Committee of the Trade Union of Aviation Workers. This is also a great accomplishment of the head of the Belorussian Hydrometeorological Service.

Andrey Anisimovich does much work in representing the Belorussian Hydrometeorological Service in the World Meteorological Organization. He is chairman of the national committee of Belorussia for the International Hydrological Program.

A Communist since 1939, A. A. Glomozda, together with much operational-production and organizational activity, is actively participating in public life.

Andrey Anisimovich combines high demands on himself and subordinate workers with constant concern for improvement of their material and living conditions. He enjoys a great and merited authority among the personnel of the Administration of Hydrometeorology in Belorussia, in the direction of the State Committee on Hydrometeorology and Environmental Monitoring and in other departments. For successes in his work he has been awarded the Order of the October Revolution, two "Emblem of Honor" orders and medals, has been entered in the Book of Honor of the State Committee on Hydrometeorology and Environmental Monitoring, and has been awarded Diplomas of Honor by the USSR Administration of the Hydrometeorological Service and the Supreme Soviet Belorussian SSR.

Andrey Anisomovich meets his anniversary full of energy, with new creative thought, related, in particular, to the creation of an experimental automated system for the dissemination of hydrometeorological information to users in the Belorussian SSR. In congratulating Andrey Anisimovich, we wish him good health for long years, new successes in great and highly responsible work and creative accomplishments.

SIXTIETH BIRTHDAY OF KONSTANTIN PETROVICH VASIL'YEV

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 122-123

[Article by personnel of the USSR Hydrometeorological Scientific Research Center]

[Text] Konstantin Petrovich Vasil'yev, Soviet oceanologist, head of the Division of Sea Hydrological Forecasts at the USSR Hydrometeorological Center, marked his 60th birthday on 15 November.

Since December 1945, after graduating from the Higher Military Hydrometeorological Institute, K. P. Vasil'yev has been working at the USSR Hydrometeorological Center (formerly the Central Institute of Forecasts). He began his work activity at the institute in the post of engineer. Later he headed the scientific-auxiliary division, directed the body of graduate students, and was scientific secretary.

In 1955 K. P. Vasil'yev became a Candidate of Physical and Mathematical Sciences and was designated head of the laboratory for the servicing of navigation. Since 1970 he has headed the division of marine hydrological forecasts. In 1973 he defended his dissertation for award of the academic degree of Doctor of Geographical Sciences.

At the present time K. P. Vasil'yev is an outstanding specialist in the field of marine hydrological forecasts and the servicing of navigation. His vigorous activity and striving for a thorough study of the problems arising from practical work in the hydrometeorological support of navigation facilitated his becoming a leading scientist capable of formulating and solving major problems and directing bodies of scientific workers. At the same time, Konstantin Petrovich excellently knows about operational work on support of the fleet with hydrometeorological data.

In his studies K. P. Vasil'yev has made detailed investigations of problems relating to the influence of different hydrological parameters and the possibilities of taking this influence into account in computing the most advantageous approaches. He examined the problems involved in increasing the safety of navigation of ships and the problems closely associated with increasing the effectiveness of operation of the fleet.

K. P. Vasil'yev carried out fundamental studies for developing and practical day-to-day introduction of a new type of support of navigation -- servicing of sea ships with recommendations on selecting the most advantageous and safest oceanic routes in dependence on hydrometeorological conditions in the ocean.

A system for servicing ships with recommendations on the choice of the most advantageous and safest navigation routes for ships with centers at Leningrad, Murmansk, Riga, Odessa, Petropavlovsk-na-Kamchatskiy and Vladivostok was organized and is functioning in the country under his direction and with his direct participation.

Konstantin Petrovich was one of the first to carry out work on the use of the information received from artificial earth satellites for the purposes of oceanography. The investigations which he carried out made it possible to obtain specific indices for determining ice conditions in the seas and oceans. He proposed a method for recognizing the continuity of ice and its other characteristics on the basis of the structure and brightness of the ice image on the photograph.

K. P. Vasil'yev originally solved the problem of determining zones of storm-induced waves in little or completely unobserved regions of the world ocean from the appearance and structure of clouds on photographs taken from artificial earth satellites.

For the development of new methods for sea forecasts and their introduction into routine practice Konstantin Petrovich was awarded the Yu. M. Shokal'skiy Prize and also gold, silver and bronze medals of the All-Union Exhibition of Attainments in the National Economy. He is the author of 92 scientific studies.

K. P. Vasil'yev imparts his rich scientific and operational work experience to young specialists who are taking their first steps in science.

Konstantin Petrovich is carrying out much work under international cooperation programs in the field of marine meteorology and development of the combined global system of oceanic stations. In 1976 he was elected President of the Commission on Marine Meteorology of the WMO.

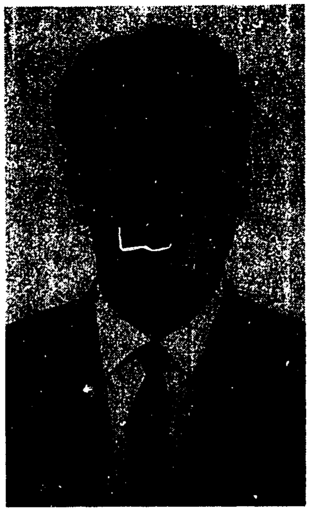
Konstantin Petrovich meets his birthday at the height of his creative forces. Specialists in the field of marine forecasts and work comrades, congratulating him on his birthday, wish him further successes in his many-sided activity for the well-being of our Motherland.

SIXTIETH BIRTHDAY OF YURIY IVANOVICH CHIRKOV

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 123-124

[Article by I. G. Gringof]

[Text] Professor Yuriy Ivanovich Chirkov, Doctor of Geographical Sciences, an outstanding professional agrometeorologist and teacher, was born on 25 November 1919. For more than 40 years he has been working productively in the field of meteorology and agrometeorology. He has carried out fundamental investigations on the theory of agricultural evaluation of climate, agroclimatic regionalization and the theoretical principles of agrometeorological forecasts.



A gifted nature and broad scientific erudition, exceptional dedication to work and purposefulness in work were manifested by Yuriy Ivanovich even before he became a graduate student, when while working as head of the Krasnodarskaya agrometeorology station, he took part in the investigations of the All-Union Institute of Oil Crops, where since 1949 he has been a member of the Scientific Council. He manifested his capabilities still more completely in active scientific and operational activity at the Central Institute of Forecasts (now the USSR Hydrometeorological Center), where after 1958 he worked as a senior scientific specialist. Beginning in 1962 he headed the section on agroclimatology and beginning in 1969 was head of the section on agrometeorological forecasts.

In 1958 Yu. I. Chirkov successfully defended his Candidate's dissertation, and in 1966 -- his Doctor's dissertation.

Yuriy Ivanovich clearly revealed his research talent during these years of stubborn work. He published about 200 scientific studies, among them the monograph AGROMETEOROLOGICHESKIYE USLOVIYA I PRODUKTIVNOST' KUKURUZY (Agrometeorological Conditions and Corn Productivity) (1969), which was an important link in the development of Soviet agrometeorology. This work has been republished in Yugoslavia.

In his investigations Yu. I. Chirkov revealed the peculiarities of the rate of development of plants in individual stages of organogenesis and applied these results in the development of methods for predicting the times of onset of the phases of development of agricultural crops. In ascertaining the relationships between the productivity of agricultural crops and meteorological factors he used a morphophysiological analysis, taking into account the photosynthetic activity of sown crops and the peculiarities of their phytoclimate under different plant cultivation conditions. In original work on methods for predicting the yield of grain and the vegetation mass of agricultural crops Yu. I. Chirkov employed a fundamentally new approach to allowance for the photosynthetic potential of sown areas and the biometric indices of plants. He gave a scientific validation of the biological and physical essence of the quantitative indices of development and formation of the yield of agricultural crops.

The scientific principles for evaluating the agroclimatic resources for the cultivation of corn formulated by Yu. I. Chirkov constituted the scientific-methodological basis for similar investigations applicable to other crops in different regions of the Soviet Union.

The results of the scientific investigations of Yuriy Ivanovich are being broadly and effectively used in practical activity.

In 1970 Yu. I. Chirkov was elected head of the Department of Meteorology and Climatology at the Moscow Agricultural Academy imeni K. A. Timiryazev. This marked the beginning of a new stage in his activity, directed to the improvement of agrometeorological training of future specialists for the agricultural production in our country. In accordance with the new course curriculum, he published a textbook for technical schools entitled OSNOVY

SEL'SKOKHOZYAYSTVENNOY METEOROLOGII (Principles of Agricultural Meteorology) (1975) and a textbook for agricultural colleges entitled AGROMETEOROLOGIYA (Agricultural Meteorology) (1979).

In accordance with a resolution of the Fifth Session of the Commission on Agricultural Meteorology of the WMO (Geneva, 1971), Yu. I. Chirkov prepared 10 sections for the international textbook AGROMETEOROLOGY, which was published in 1979.

Yu. I. Chirkov was the editor of 18 monographs, collections of scientific papers, methodological and academic aids. Under his direction 15 graduate students successfully defended their Candidate's dissertations.

The intense teaching activity of Yuriy Ivanovich is successfully combined with research activity. He is one of the directors of the international work AGROKLIMATICHESKIYE RESURSY SOTSIALISTICHESKIKH STRAN YEVROPY (Agroclimatic Resources of the Socialist Countries of Europe), in which he wrote the section "Agroclimatic Resources for Corn Production).

Yu. I. Chirkov does a great amount of scientific-organizational and public work.

Over a period of many years Yu. I. Chirkov worked in the expert commission of the Higher Certification Commission USSR, was chairman of the international working groups of the Commission on Agricultural Meteorology of the WMO, and took an active part in the work of many international conferences and meetings.

His good will and attention to people, combined with a business-like dedication, scientific soundness and pedagogic tact, earned him deep respect from the scientific community and students.

Yuriy Ivanovich meets his glorious birthday full of creative thought, energy and strength. The agrometeorologists of the Soviet Union warmly congratulate him, wish him health, new creative accomplishments and successes in his diversified and fertile activity for the welfare of our country.

CONFERENCES, MEETINGS AND SEMINARS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 125-127

[Article by M. A. Butuzova, I. L. Kalyuzhnyy and Sh. D. Fridman]

[Text] During the period 17-21 April 1979 an All-Union Conference on the Physics of Clouds and Their Artificial Modification was held at Nal'chik. The conference was organized by the Institute of Experimental Meteorology and the High-Mountain Geophysical Institute in accordance with a resolution of the Scientific Council on the Problem "Artificial Modification of Hydrometeorological Processes" of the USSR State Committee on Hydrometeorology and Environmental Monitoring.

The principal objective of the conference was the discussion of theoretical and experimental studies of the artificial modification of hydrometeorological processes (fundamental investigations of cloud physics, increase in precipitation, scattering of fogs, prevention of hail, modification of thunderstorms), and also programs for projects for increasing precipitation in different regions in the country (basin of Lake Sevan, basin of the Iori River, Northern Caucasus, steppe part of the Ukraine) in the interests of the national economy.

The conference was attended by 230 specialists from scientific institutes and organizations of the State Committee on Hydrometeorology, USSR Academy of Sciences, and also a number of other ministries and departments; 19 specialists from five socialist countries and among them Doctor B. Kozak -- Vice President of the Meteorological Service of the Hungarian People's Republic, Doctor Shamay -- Director of the Meteorological Institute of Bratislava (CzSSR), Professor G. Miloshev of the Geophysical Institute Academy of Sciences Bulgaria and also other participants representing the national meteorological services (Poland, Yugoslavia), scientific research institutes of the academies of sciences, universities and branch ministries and departments.

This forum of scientists was opened by Professor Yu. S. Sedunov, chairman of the organizing committee of the conference, first deputy chairman of the USSR State Committee on Hydrometeorology and Environmental Monitoring.

At two conference sections ("Cloud Physics" and "Artificial Modification of Clouds") there was presentation and discussion of 114 reports, including 10 reports of scientific workers from the socialist countries and 46 reports with visual displays.

Among the papers discussed at the first section we can mention four basic directions in theoretical and experimental investigations: thermodynamics of clouds and cloud systems, mathematical and physical modeling of cloud processes; microphysics of fogs, clouds and precipitation; technical means and methods for investigating different cloud processes; problems involved in the prediction of weather phenomena associated with cloud activity.

A considerable place in the work of the conference was occupied by reports on the mathematical and physical modeling of cloud processes and thermodynamics.

A major place in the reports of the scientists from the socialist countries was occupied by problems relating to the modeling of hail processes. In particular, a report by specialists from Bulgaria gave an analysis of hail phenomena on the basis of computations using a jet model of convective clouds. A stochastic model of gravitational coagulation was developed and prepared for experimental checking (Polish People's Republic).

The great number of reports devoted to mathematical modeling is attributable primarily to the progress in computers and the methods of modern mathematics, making possible an adequate representation in the models of the real processes transpiring in the atmosphere. The use of electronic computers provides considerable material and work savings, and also shortens the duration of the experiment.

At the conference there was broad representation of studies of technical means and methods for investigating cloud processes, including means and methods for routine monitoring of the parameters of the main meteorological values, as well as collection and automated processing of radar data.

Unfortunately, there was inadequate representation of theoretical investigations in the field of prediction of weather phenomena associated with cloud activity.

At the second section the emphasis was on the following directions: scattering and creation of clouds and fogs; artificial regulation of precipitation; hail prevention; control of hydrometeorological processes (suppression of thunderstorms, modification of weather of large areas); technical means for modification and problems involved in the planning of field experiments and evaluation of the results of such modification.

One of the timely problems discussed at the section was the problem of monitoring of artificial modification of clouds. A monitoring system and the prospects for its development was considered in the example of modification of convective clouds for the purpose of lessening of thunderstorm activity and hail, a monitoring system and the prospects for its development were examined.

The conference summarized the results of realization of scientific work in the field of an increase in precipitation. It was established that scientists are meeting with difficulties in the search for sufficiently effective methods and procedures for monitoring the results of modification of the atmosphere and evaluating their economic effectiveness.

Papers on the problem of modification of hail processes were broadly represented. In addition to the successes attained in the field of study of hail processes and the development of methods for modifying them, shortcomings were also noted. The latter are associated with the absence of a model of hail clouds which would make it possible, with a high degree of reliability, to predict the results of modification and inadequate attention to investigation of the processes transpiring in the cloud during the periods of generation, growth and falling of hail.

At the conference an extensive group of papers constituted reports on the ice-forming reagents and methods for their generation in which it was noted that until now it has not been possible to obtain new ice-forming substances which could become a replacement for expensive silver iodide, which is in short supply, and toxic lead iodide.

At the conference considerable attention was devoted to the methodological problems involved in planning of an experiment and evaluation of the results of modification of atmospheric processes. It was noted that attainments in the planning of the experiment were accompanied by shortcomings as well (for example, absence of a program for physical measurements for determining the cause-and-effect "modification-result" correlation). Unfortunately, it must be noted that there was no presentation of studies for evaluating the economic effectiveness of any current project.

At the conference, for the first time in the practice of the State Committee on Hydrometeorology, use was made of a "display" form of reports, in addition to the usual form. In this form of presentation the reports are not made from the stage. Instead their summaries, together with conclusions, necessary computations, graphs and diagrams were presented on stands. Being present near the stands, the authors of the reports and the conferees were able to discuss the content of the reports more deeply and thoroughly. This results in a great saving of time because several reports are discussed simultaneously.

In general, the conference transpired under conditions of high activity of the participants, who in the course of the work exchanged experience and the latest results of investigations in the field of cloud physics and artificial modification of clouds. It is believed that this conference will help in bringing closer the solution of many complex scientific problems.

The USSR Interdepartmental Committee on the International Hydrological Program, taking into account the importance of development of nuclear methods for studying natural waters, in 1978 established the national working group on nuclear methods in hydrology and hydrogeology. During the period 24-26 May 1979 it held in Moscow an All-Union Seminar on "Nuclear and Isotopic Methods for Investigating Natural Waters." Seventy reports were presented from scientific organizations of different departments. The USSR State Committee on Hydrometeorology and Environmental Monitoring was represented by specialists of the Institute of Applied Geophysics and the State Hydrological Institute.

As indicated by the discussion, the development of nuclear and isotopic methods for investigating the natural waters of the USSR is being carried out in three principal directions: a) along the lines of use of natural stable and radioactive isotopes; b) use of artificial indicators; c) use of sources of nuclear radiations.

A report of considerable interest from the point of view of the factors involved in the formation of natural waters was that by V. A. Polyakov and L. N. Kolesnikov (All-Union Scientific Research Institute of Hydrogeology and Geological Engineering -- VSEGINGEO) entitled "Formation of the Isotopic Composition of Hydrogen and Oxygen in Precipitation." On the basis of computer processing of regime observations of the concentration of D and ^{18}O in precipitation in different regions of the earth the authors demonstrated that in an examination of the mean annual relationships of these isotopes in precipitation of continental regions it is necessary to introduce an additional term into the Craig equation which characterizes the distance from the shores of the ocean, where precipitation is formed, to the place of its falling. In order to explain the mechanisms of separation of isotopes in precipitation B. V. Karasev (VSEGINGEO) (in a report entitled "The Craig Equation and the Mechanism for the Separation of Isotopes of Hydrogen and Oxygen in Precipitation") proposes use of a model of an isotope separation column. The joint use of the mechanisms of a diffusion column and Rayleigh condensation describes well the change in the composition of precipitation in the course of equilibrium fractionation processes.

In a report by V. T. Dubinchuk (VSEGINGEO), entitled "General Solution of the Problem of the Distribution of Isotopes of Uranium-Thorium Families in Ground Water," for the hydrogeological conditions characterizing the piston motion regime and the total mixing of water, the author gives systems of equations for the change in content of a given isotope of the radioactive family in the liquid and solid phases of rocks.

On this basis it is possible to obtain solutions of practical problems for specific hydrological conditions, including for the isotopic ratios of the uranium-thorium series.

Considerable attention was devoted to the problems involved in solving practical questions in hydrology and hydrogeology. The report by V. Ye. Vetshteyn and V. G. Artemchuk, entitled "Use of Stable Isotopes of Natural Waters for Solving Theoretical and Practical Problems in Hydrology and Hydrogeology," and also the report of L. G. Sokolovskiy, M. P. Yezhovoy and V. A. Polyakov (VSEGINGEO) entitled "Radioactive and Stable Isotopes in Solution of Regional Hydrogeological Problems," cited examples of the use of isotopic investigations in evaluating the conditions of supply, movement and discharge of ground water, the time and conditions of its formation.

P. I. Chalov, I. V. Tuzova and A. I. Tikhonov (IFiM Kirgiz Academy of Sciences) (Institute of Physics and Meteorology) have developed a method for constructing models of formation and circulation of ground water (report of the authors "Uranium Isotope Method for Constructing Models of Formation and Circulation of Ground Water"). On the basis of this method it is possible to determine the principal sources of formation of ground water flows, their filtration parameters and regions of mixing, and also to solve other problems in hydrogeology by means of use of isotopic information. The method was checked by means of a comparison of the isotopic model of formation of ground water in the Alarga-Alamedinskoye deposit with hydrogeological data and this reveals the convergence of the modeling results.

The possibilities of practical use of the radioactive method were pointed out in a report by V. S. Goncharov, A. N. Skomarovskiy and others (institute VSEGINGEO) entitled "Radioindicator Investigations of Filtering Through the Usoyskiy Barrier." On the basis of release of the radioindicator Co-60 in the upper pool behind the barrier in Sarezskoye Lake it was possible to obtain detailed spatial hydraulic interrelationships between Soyedineniye and Anton Bays with the appearance of water in the lower pool and it was possible to determine the rate of water movement in the barrier more precisely.

Stable and radioactive isotopes are in use in laboratory investigations of a number of complex hydrophysical processes of migration and infiltration of moisture. This has found its reflection in the reports of I. L. Kalyuzhnyy, S. A. Lavrov (State Hydrological Institute) entitled "Use of Stable and Radioactive Isotopes in an Investigation of the Migration of Moisture to the Freezing Front" and Z. N. Yusova, V. N. Kostenko and V. P. Seleznev (VSEGINGEO) entitled "A Filtration Isotopic Indicator Apparatus."

An interesting report was presented by Sh. D. Fridman (Institute of Applied Geophysics). It was entitled "Automated System for Remote Hydrological Observations and a Complex of Methods for Determining Moisture Reserves in the Snow and Soil Moisture Content." The proposed system combines observations carried out with: a) automated ground stations which use as the detectors of moisture reserves in the snow instruments which are based on the principle of registry of the flux of cosmic radiation;

b) aircraft stations for measuring the water reserve in the snow cover and soil moisture content employing instruments registering the natural gamma radiation of the earth; c) satellite stations registering the natural emission of snow or soils in the SHF spectral range for characterizing the moisture reserves in the snow, the state of the underlying surface and soil moisture content. Here much attention is also being devoted to the taking of photographs with a high spatial resolution of the snow cover and study of the reflectivity of the snow and soils in the visible and IR spectral ranges. Provision is made for the routine transmission of measurement data from all three levels via artificial earth satellites to the data collection and processing center. Mutual intercalibration of measuring instruments on coinciding runs will afford a possibility for investigating the snow cover and moisture content of soils continuously over great areas. The report gives a detailed analysis of the possibilities of all the methods enumerated above.

The seminar demonstrated the high scientific level and fertile development of nuclear and isotopic methods for investigating natural zones in our country. The results of the reported investigations are a contribution of Soviet scientists to the implementation of the International Hydrological Program.

The seminar materials will be published.

NOTES FROM ABROAD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 79 pp 127-128

[Article by V. I. Silkin]

[Text] As reported in MAP NEWSLETTER, No 1, 1979, in accordance with the resolutions of the International Council of Scientific Unions and its Scientific Committee on Solar-Terrestial Physics, during 1982-1985 a new scientific measure will be undertaken -- the Middle Atmosphere Program. Preparatory investigations under the program already began in 1979, which will make it possible, in particular, to employ for the observations the specific conditions of the Solar Maximum Year, falling in August 1979 - February 1981. In addition, in 1982 there will be the 100th anniversary of the First International Polar Year, from which later "grew" such historic events as the International Geophysical Year, International Quiet Sun Year and others, and the best way to mark this anniversary will be the implementation of a major new similar measure.

It is noted that the object of the program, the middle atmosphere, embracing for the most part the stratosphere and the mesosphere, is among the least studied regions of the earth's air envelope. The reasons for this are, first, that the physical processes transpiring here are characterized by a great complexity, and second, this region is partially inaccessible for satellite observations. The important role of the middle atmosphere is determined by the fact that it is precisely here that there is interaction of the energies arriving from two gigantic sources: on the one hand, the solar UV radiation is absorbed here by the atmosphere and chemically active elements are released; on the other hand, wave movements, developing under the influence of the troposphere, enter in this region into the stratosphere and mesosphere.

The principal objective of the program is the development of an adequate description of the structure and characteristics of the middle atmosphere at altitudes from 10 to 100 km over the underlying surface. Particular attention is being devoted to global parameters: density, pressure and temperature, composition, movements of different scale and interaction of all these parameters.

The program provides for both intensive observations, making it possible to study the interaction of fields and extensive observations, affording the possibility for studying the global picture. Provision is made for the formulation of theoretical models describing the dynamic and aeronomic aspects of the middle atmosphere. Since the troposphere below and the thermosphere above exert an influence on the stratosphere and mesosphere, a study of the middle atmosphere is being carried out in connection with investigation of these above- and below-lying regions of the air envelope.

All the physical and chemical processes transpiring in the middle atmosphere are examined in the aspect of long periods of time and segments of space so as to make possible conclusions concerning the climatic changes transpiring over a long period of time. Among the experiments constituting an important part of the Program is the systematic launching of meteorological rockets to the corresponding altitudes.

The first preparatory project of the Program -- coordinated investigations of behavior of the middle atmosphere in winter -- is already being carried out. The collected data make possible a clearer understanding of the energy budget, inertia, mechanism of transfer of thermal energy by large-scale movements in the middle atmosphere. Specialists are compiling daily and two-day synoptic charts of geopotential heights, temperature and winds from 100 to 0.01 mb (approximately 15-80 km) for the entire "winter" hemisphere, that is, from 15 November through 15 March in the Northern Hemisphere.

In the analysis use will be made of stratospheric and mesospheric data obtained from the satellites "TIROS N" and "NIMBUS G."

The second preparatory project will be study of the dynamics of equatorial waves (1979-1980), the third -- investigation of photochemical processes in the upper stratosphere and mesosphere, the fourth -- representation of meteorological and chemical variables in the form of mean monthly zonal sections.

Scientists of all the developed countries in the world, including the USSR, have agreed to participate in the Program.

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