JPRS L/10287

28 January 1982

USSR Report

METEOROLOGY AND HYDROLOGY

No. 11, November 1981

FBIS FOREIGN BROADCAST INFORMATION SERVICE

FOR OFFICIAL USE ONLY

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500020056-3

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

JPRS L/10287

28 January 1982

USSR REPORT

METEOROLOGY AND HYDROLOGY

No. 11, November 1981

Translations or abstracts of all articles of the Russian-language monthly journal METEOROLOGIYA I GIDROLOGIYA published in Moscow by Gidrometeoizdat.

CONTENTS

*Denotes items which have been abstracted.

* Denotes items which have been abstracted.

UDC 551.576:551.511+551.513

INFLUENCE OF UPPER-LEVEL CLOUDS ON ATMOSPHERIC THERMAL REGIME AND CIRCULATION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 23 Feb 81) pp 5-17

[Article by Ye. P. Borisenkov, professor, V. P. Meleshko, candidate of physical and mathematical sciences, and A. P. Sokolov, Main Geophysical Observatory]

[Text]

Abstract: A study was made of the response of components of the radiation balance of the earth-atmosphere system to changes in cloud cover at different levels. Numerical experiments were made with use of a model of general circulation of the atmosphere in which there was no upper-level cloud cover and its formation in the region of an anticyclonic disturbance was reproduced. A detailed analysis was made of the changes caused by cloud cover, the thermal regime and atmospheric circulation. Computations show that during the formation of upper-level cloud cover there is a change in the thermal regime of the atmosphere, which results in an attenuation of the anticyclonic disturbance in the lower half of the troposphere and its insignificant intensification in the upper troposphere and lower stratosphere.

1. Introduction. As is well known, the development of a number of negative phenomena over great areas and over the course of a prolonged time is related to the formation of a stable anticyclonic circulation. Over the territory of the USSR quasistationary anticyclonic formations in winter lead to the setting-in of anomalously cold weather, and in summer the development of arid conditions is associated with them. Cloud cover is usually absent in a region of anticyclones.

The authors of [2] mentioned some factors of natural and anthropogenic origin which are capable of leading to the formation of an upper-level cloud cover over an anticyclonic formation and causing its evolution. In this connection it is of interest to investigate to what degree these pressure formations are responsive to possible changes in the thermal regime caused by the formation of a cloud cover over them.

There are a great many studies in which an attempt has been made to evaluate the effects caused by the influence of cloud cover and radiation both on individual meteorological elements and on the thermal regime of the atmosphere as a whole (for example, see [1, 13] and others). In most of them the evaluations have been made without allowance for feedback mechanisms between the principal interacting physical processes and this circumstance makes very difficult the interpretation of the results applicable to the real atmosphere.

As is well known, cloud cover exerts a dual effect on radiation transfer in the atmosphere. As a result of the fact that the albedo of clouds on the average for the earth is considerably greater than the albedo of the underlying surface, an increase in cloud cover leads to a great reflection of solar radiation into space, a decrease in its absorption by the atmosphere and the underlying surface. This favors a cooling of the earth-atmosphere system. On the other hand, an increase in cloud cover causes a decrease in long-wave radiation passing into universal space as a result of a decrease in the effective temperature of radiation from the boundaries of clouds in comparison with a cloudless case. Thereby the second effect favors a relative heating of the atmosphere.

In the example of a one-dimensional radiational-convective model of the atmosphere Manabe and Wetherald [20] demonstrated that an increase in cloud cover of the lower and middle levels, having a relatively high radiation temperature and high albedo values, causes a considerable cooling of the atmosphere and underlying surface. With an increase in cloud altitude this dependence weakens and can even change sign. Thus, if upper-level cloud cover radiates as an ideally black body, its decrease can cause even heating of the troposphere and underlying surface as a result of a decrease in radiation into universal space by the atmosphere and an insignificant weakening of the solar radiation flux.

Roewe and Kuo [21] evaluated the influence of a cirrus cloud cover of different thickness on the rate of long-wave cooling of the troposphere and lower stratosphere. According to their computations, even very thin cirrus clouds substantially attenuate cooling of the lower troposphere. With the formation of clouds of considerable thickness the cooling of the troposphere in the middle latitudes decreases by 60% in comparison with cloudless conditions and increases in the stratosphere, especially in the tropics.

Qualitatively similar evaluations were obtained somewhat earlier by Fleming and Cox [18] on the basis of the results of measurements in the tropical atmosphere.

By means of computations using a relatively simple stationary model of the thermal regime in the atmosphere Ye. P. Borisenkov and L. K. Yefimova [2] made evaluations of the influence of upper-level cloud cover on the dynamics of an anticyclone. The computations indicated that a change in long-wave radiation as a result of the formation of a cloud cover causes a decrease in descending movements in the middle troposphere, which should favor an attenuation of anticyclonic circulation.

The objective of this investigation was a study of the possible thermodynamic evolution of an anticyclonic disturbance as a result of formation of upper-level cloud cover. The investigation is made using a model of general circulation of the atmosphere taking into account the principal physical processes transpiring in the atmosphere and the feedback mechanisms between them.

2. Atmospheric Model

In the experiments we used the model of general circulation of the atmosphere developed at the Main Geophysical Observatory imeni A. I. Voyeykov. A detailed description of the numerical algorithm, methods for taking physical processes into account and the results of modeling of the climatic state of the atmosphere for January is given in [7, 8]. Therefore, below we will describe it only briefly.

In the model use is made of a system of full equations in hydrothermodynamics in a σ-coordinate system ($\sigma = p/p_s$; p_s is the pressure at the earth's surface): the equations of motion for the horizontal velocity components, the equations for heat influx, moisture transfer and continuity equation for dry air and also a number of diagnostic relationships. The model is hemispherical, the integration region is represented on a plane by means of a stereographic projection having the principal scale at 60°. The mean interval of the square grid is 425 km. Vertically the model has three layers with a uniform σ interval.

In solving the system of equations we used a finite-difference scheme having a second order of approximation in space variables. For the adopted boundary conditions and in the absence of energy "inputs" and "outputs" the scheme ensures the conservation of mass, total energy and momentum.

The model takes into account the principal energy "inputs" and "outputs" operative in the real atmosphere.

a) Macroscale condensation and convection. Allowance for heat influxes associated with phase transformations of water in the atmosphere was introduced by the parameterization of two processes: water vapor condensation caused by ordered ascending movements and convection arising in moist unstable layers of the atmosphere. Condensation occurs if the moist air attains a critical relative humidity $k_{cr} = 0.9$. In computing the heat influxes caused by mesoscale convection use is made of a convective adaptation scheme in which the equilibrium gradient is assumed to be dependent on relative humidity and the moist adiabatic gradient [14].

b) Turbulent influxes of momentum, heat and moisture. In the model use was made of a scheme for computing the corresponding gains and losses of energy, based on empirical relationships derived by Deardorf [17]. The vertical exchange coefficient is dependent on temperature stratification in the atmospheric boundary layer.

In the model four types of underlying surfaces are distinguished:
-- surface of the continents, free of ice and snow; the air temperature at the surface is computed from the heat balance equation;
-- surface of the continents, covered with snow and ice; the temperature is also computed from the heat balance equation, but the heat flux into the soil and evaporation are considered negligible;
-- ocean surface, covered with ice; the temperature at the surface is computed from the heat balance equation, in which the heat flow through the ice is taken

into account with a stipulated water temperature beneath the ice;
-- surface of the oceans and seas, free of ice; the temperature at the surface is considered known, whereas the air is saturated.

c) Radiation and cloud cover. In this model the radiation heat influx caused by the transfer of short- and long-wave radiation in a cloudy atmosphere is computed [7].

In the computations of the transfer of short-wave radiation an allowance is made for its absorption by water vapor, carbon dioxide and clouds and scattering by air molecules and clouds. Absorption is taken into account in the near-IR region ($\lambda > 0.7 \mu m$) by means of the integral transmission function proposed in [4]. In the UV region ($\lambda < 0.7 \mu m$) an allowance is made only for scattering by air molecules. In the computation of the transfer of long-wave radiation use is made of the integral transmission function proposed in a study by Gradus, et al. [3]. This function takes into account absorption (emission) by water vapor and carbon dioxide.

The model describes two-layer cloud cover with fixed boundaries: $\Delta\sigma = 0.667-0.833$ for lower-level clouds and $\Delta\sigma = 0.333-0.667$ for upper-level clouds. Upper- and lower-level clouds are opaque for long-wave radiation and emit as ideally black bodies at their boundaries. The optical properties of clouds applicable to the transfer of short-wave radiation are indicated in Table 1.

It is assumed that the horizontal distribution of clouds in each layer is random, so that the fraction of the sky simultaneously covered by the clouds situated in two layers is equal to the product of the corresponding fractions of each layer. Computations of cloud cover are made from the fact of condensation in each integration interval. If condensation occurs at the levels $\sigma = 0.833$ or $\sigma = 0.5$, the the cloud cover in the corresponding layers of the atmosphere was assumed to be complete. In other cases it was absent. By means of summation of the quantity of clouds during the preceding 4 hours it was possible to compute its mean values separately for clouds of the upper and lower levels in each grid square. These values were used in computations of the radiation heat gains and losses.

Table 1

Optical Properties of Clouds in Relation to Transfer of Solar Radiation

Clouds	Albedo	Absorption	
		$\lambda < 0.7 \mu m$	$\lambda \geq 0.7 \mu m$
Upper level	0.25	0.0	0.01
Lower level	0.50	0.0	0.03

d) Horizontal diffusion. In the model use is made of a nonlinear diffusion scheme, the basis for which is the hypotheses of the theory of two-dimensional turbulence [6]. The coefficient of eddy viscosity is assumed to be proportional to the absolute value of the eddy gradient. This scheme quite effectively suppresses disturbances with a characteristic scale close to 2-3 grid intervals.

In the integration of the system of equations macroscale condensation, convective transfer of heat and moisture and diffusion are computed in each interval. The radiation and turbulent influxes of heat and moisture are again computed each 4 hours.

3. Formulation of Experiment

The problem of evaluating the influence of the external thermal effect on synoptic formations is quite complex and has not been solved at the present time. Our objective was to understand the mechanism of interaction between cloud cover and radiation as a result of formation of upper cloud cover over a region in which there is a predominance of anticyclonic weather conditions and to evaluate the influence of this interaction on the thermal regime, circulation and moisture cycle in the atmosphere. The models of general circulation of the atmosphere used in such an investigation must satisfy the following specific requirements:
-- the model must include the principal physical processes which can exert an influence on the studied synoptic object;
-- the model must correctly describe the amplitude and phase velocity of the studied disturbance.

The model of general circulation of the atmosphere presented in #2 fully corresponds to the first requirement. With respect to the second, it will be discussed below. It is also important to note that the statistical reliability of the experimental effect can be evaluated only on the basis of a major series of numerical computations with independent synoptic situations. The conclusions drawn from a limited set of synoptic situations must be regarded as preliminary.

The horizontal extent of the region selected for the experiment and its specific position were determined by two factors:
-- the grid interval used in the model of general circulation of the atmosphere;
-- the distribution of total and upper cloud cover in a region of an anticyclonic formation.

As is well known, the minimum scale of the disturbance, which can be described by the equations of the model, corresponds to a horizontal dimension $2\Delta s$ (Δs is the horizontal grid interval). The error in determining the amplitude and phase of such a disturbance can be 100%.

For an adequate description of the disturbance caused by the cloud effect, the characteristic dimension of this disturbance must include 4-5 grid squares. As indicated by estimates, the error in determining the phase velocity of such a disturbance can be 20-25%. Since the grid interval for the model in the middle latitudes is 500 km, the region in which the effect of upper-level cloud cover was considered had an area of 2500 x 2500 km (5 x 5 grid squares).

If the atmospheric model reproduces a considerable quantity of clouds over an anticyclonic disturbance, then evidently it does not make sense to evaluate the effect of the additional cloud cover since its influence on the thermal regime of the atmosphere will be known to be small.

As the initial state of the atmosphere we selected the synoptic situation for 1 July 1972. A detailed description of the weather conditions during this period is given in a number of publications [5, 11].

In the integration of the system of equations in hydrothermodynamics it is necessary at the initial moment to know the wind velocity, temperature and specific humidity at the principal σ-levels used in the model (σ_h = 0.167; 0.5; 0.833), pressure at the earth's surface, water temperature in the oceans and cloud cover. In constructing the initial fields the basis used is data on the field of geopotential at the standard isobaric surfaces (100, 200, 500, 700 gPa) and pressure at sea level. The algorithm for computing the initial fields, adjusted in a quasi-solenoidal approximation, was described in [7]. Since we did not have information on humidity, its distribution at the initial moment was assumed to be mean zonal for July conditions. In the integration of the system of equations with allowance for the mechanisms describing the gains and losses of moisture in these processes the distribution of humidity is adapted to the thermodynamic state of the atmosphere during the first day [23]. Cloud cover was absent at the initial moment. The distribution of water temperature at the surface of the oceans, albedo of the underlying surface and extent of the ice cover in the polar basin were taken from the climatic atlases for July.

The region in which upper-level cloud cover was stipulated was situated over the European part and the southeastern regions of the USSR. The results of the preliminary computations indicated that during the first 10 days there was a high-pressure ridge over this region with almost total absence of cloud cover (see Fig. 2).

Two numerical experiments were carried out in which the system of equations was integrated from the initial state to 10 days. In the first experiment, which we will call the control (CEX), two-level cloud cover was computed during the entire time of the forecast. In the second experiment, which we will call the cloud experiment (ClEX), over the selected region we stipulated the total upper-level cloud cover during the course of the entire forecast period. An analysis of the results of computations was made for the last 6 days, that is, beginning with the 5th day, when the influence of the heat influxes becomes substantial.

4. Response of Radiation Balance at Boundaries of Atmosphere to Cloud Cover Changes

In the studies of Cess [15], Ellis [19], Schneider [22] and others an evaluation was made of the response of the radiation balance of the earth-atmosphere system to changes in total cloud cover. The evaluations obtained by these authors differ substantially from one another not only qualitatively, but also in sign. These differences are caused by a number of factors and the most important of these are:

-- the resultant effect of interaction between cloud cover and radiation constitutes a small difference of two large values -- radiation into universal space and absorption by the earth-atmosphere system and therefore the total radiation balance is dependent on the accuracy with which each of the components is determined;

-- the nature of change of cloud cover at different levels relative to the change in total cloud cover, adopted in the investigations, is not the same. This is one of the principal factors responsible for substantial differences in evaluations of the influence of cloud cover on the radiation balance of the system.

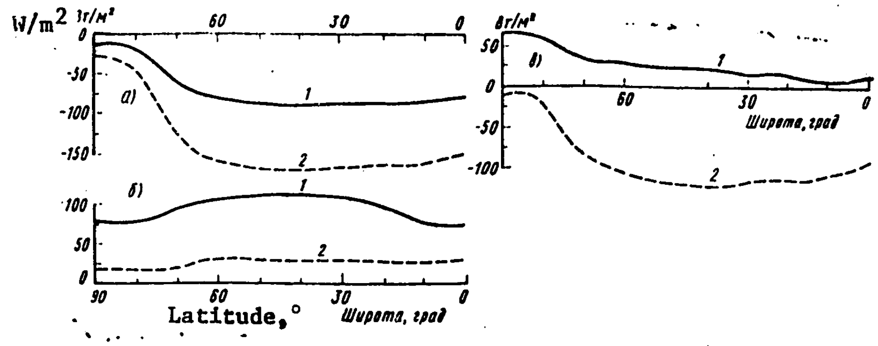


Fig. 1. Meridional distributions of change in reflected solar radiation (a), outgoing long-wave radiation (b) and full radiation balance (c) in the earth-atmosphere system (W/m^2) with a change in cloud cover at the upper (1) and lower (2) levels in the "clear - total cloud cover" interval for July conditions.

In this investigation, using a radiation scheme which was included in the model of general circulation of the atmosphere, we evaluate the changes in the radiation balance as a function of changes in only one cloud cover level. The computations were made using zonal climatic data on temperature and humidity at the standard isobaric surfaces [16]. The albedo of the underlying surface was taken from a study by Mukhenberg [10].

Assume that $\frac{\delta F}{\delta n_k} = \frac{\delta S}{\delta n_k} + \frac{\delta R}{\delta n_k}$

is the change in the radiation balance of the earth-atmosphere system relative to change in cloud cover of the k-th level; S is the algebraic sum of the fluxes of solar radiation reaching the upper boundary of the atmosphere and ascending fluxes of scattered and reflected radiation; R is the long-wave radiation escaping into universal space; n_k (k = 1, 2) is the cloud cover (the part of the heavens covered by clouds in tenths).

Changes in the radiation balance were computed for the conditions of July and variations of cloud cover within the limits of the "clear-total cloud cover" interval, that is, $\delta n_k = -1.0$.

Figure 1 shows the meridional distributions of changes in the balance of short- and long-wave radiation separately and the total balance of the earth's surface-atmosphere system as a function of change in upper- and lower-level cloud cover within the "clear-total cloud cover" interval.

It follows from Fig. 1a that an increase in cloud cover leads to a greater reflection of short-wave radiation into universal space as a result of an increase in planetary albedo. This effect causes a loss of thermal energy by the system and leads to a decrease in atmospheric temperature. The losses are greater in value with a change in lower-level clouds as a result of their greater albedo. On the other hand, an increase in cloud cover decreases the heat losses by the system due to the lesser radiation into universal space (see Fig. 1b), since the temperature of clouds on the average is lower than the temperature of the underlying surface.

The changes in long-wave radiation for upper-level cloud cover are approximately three times greater than the corresponding changes for lower-level cloud level. With respect to changes in the total balance of the earth's surface-atmosphere system (Fig. 1c), an increase in upper-level cloud cover in general causes some heating of the system at all latitudes, whereas an increase in lower-level clouds, on the contrary, causes its cooling.

The heat balance at the underlying surface is determined not only by the balance of short-wave radiation and effective radiation, but also by the turbulent flux of apparent and latent heat into the atmosphere and the heat flux into the soil (in the absence of thawing). However, with changes in cloud cover the total radiation balance is the principal factor determining the thermal regime of the underlying surface. Such computations were made for evaluating the change in the radiation balance near the underlying surface (figure not shown).

With an increase in cloud cover of any level the decrease in absorption of short-wave radiation at the underlying surface is greater than the increase in the flux caused by counterradiation of the clouds. As a result, with an increase in cloud cover the total radiation balance is reduced, which should lead to a decrease in temperature at the underlying surface. The only exception is the region of the high latitudes in which due to the small differences in the albedo of clouds and the underlying surface the absorption of short-wave radiation changes insignificantly and the dominant factor causing an increase in the radiation balance of the underlying surface is the counterradiation of the atmosphere and clouds. It must be emphasized that such a variation in changes of the radiation balance at the underlying surface is by no means always observed. For example, computations made for winter conditions show that an increase in cloud cover at the upper and lower levels favors an increase in the radiation balance over the greater part of the northern hemisphere due to exclusion of the zone to the south of 30°N. In the middle latitudes this increase is approximately 75 W/m^2 with a change in cloud cover at both levels.

We note in conclusion that in the interpretation of the results it is necessary to take into account the circumstance that the cited estimates were made neglecting the feedback mechanism, taking into account the influence of changing radiation fluxes on the characteristics of the atmosphere itself.

5. Results of Numerical Experiments

Upper-level cloud cover is the principal external parameter whose change causes a corresponding redistribution of the heat sources in the atmosphere. Accordingly, we will begin the discussion of the results with the distribution of cloud cover. As a convenience in the further discussion the region over which a total upper-level cloud cover is stipulated in the C1EX experiment will be called a polygon.

Figure 2 shows the mean values of total cloud cover computed in the CEX and C1EX experiments for the last 6 days of the forecasts, that is, from the 5th to the 10th days. The polygon is outlined with a thick broken line. In the control experiment an insignificant cloud cover is formed in the region of the polygon (see Fig. 2a). Moreover, a high-pressure ridge was situated over the polygon during the 10 days of the forecast.

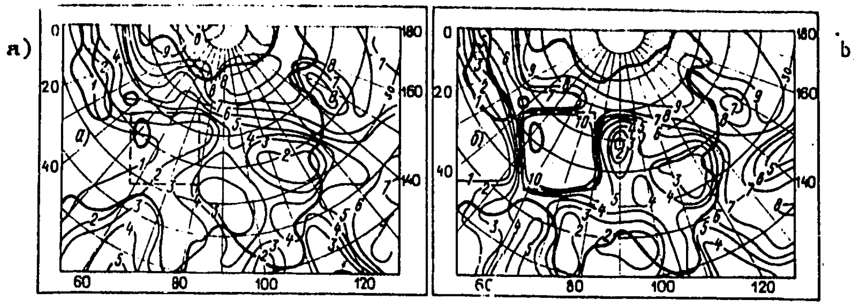


Fig. 2. Distributions of total cloud cover (in tenths), computed using data for six days of the forecast (5th-6th days) in CEX (a) and C1EX (b) experiments

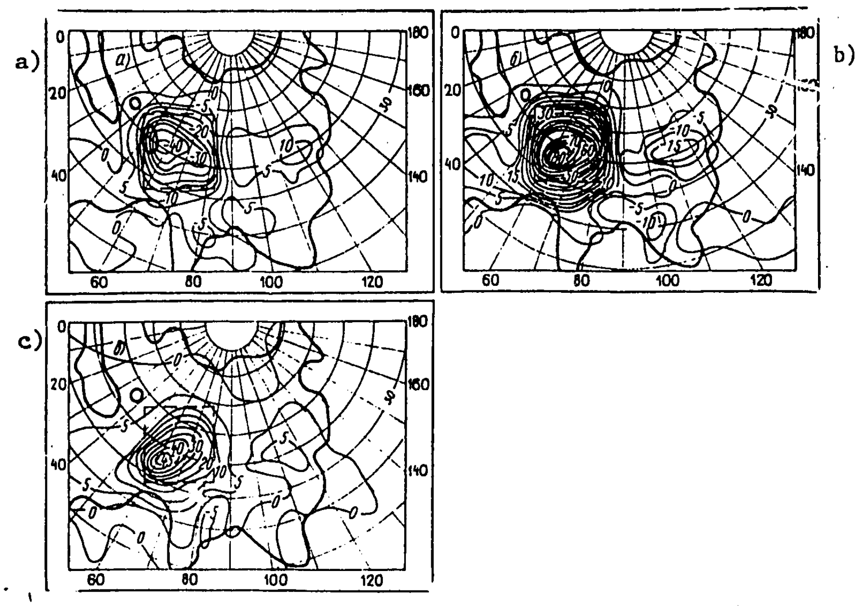


Fig. 3. Distributions of differences between reflected solar radiation (a), long-wave radiation (b) and total radiation balance (c) of earth-atmosphere system (W/m²) obtained using data from the experiments CEX and C1EX (C1EX-CEX) for 5th-10th days of forecast.

a) Thermal regime of atmosphere and underlying surface. Figure 3 shows the distributions of differences in reflected solar radiation, outgoing radiation and the total radiation balance, computed using data for two experiments (CEX-C1EX) for the 5th-10th days of the forecast.

It follows from Fig. 3a that as a result of formation of total upper-level cloud cover the reflection of short-wave radiation into universal space was increased by 30-40 W/m^2, which is approximately 50% of the total radiation balance of the system over the polygon in the control experiment. On the other hand, the long-wave radiation changed by a value approximately twice as great as the reflected radiation (Fig. 3b). Since these two effects have different signs, the resultant influence of upper cloud cover on the radiation balance is somewhat less and causes a heat influx to a column of the atmosphere equal to 40-45 W/m^2 (Fig. 3c), which corresponds to a change in the radiation heat influx by 0.3°C/day. With an increase in cloud cover there is a decrease in the value of the radiation balance at the earth by approximately 10 W/m^2.

Table 2

Mean Changes in Radiation Heat Influxes (°C/day) in Atmospheric Layers Caused by Change in Upper-Level Cloud Cover in "Clear-Total Cloud Cover" Interval

Atmospheric layer	Change in heat influxes		
	due to solar radiation	due to long-wave radiation	full influx
Above-cloud layer	0.09	-0.84	-0.75
Cloud layer	0.59	-1.10	-0.51
Under-cloud layer	0.16	2.02	2.13
Entire column of atmosphere	0.28	0.03	0.31

Thus, analysis only of the components of the radiation balance at the boundaries of the atmosphere without allowance for mechanisms with feedbacks shows that an increase in upper-level cloud cover should cause heating of the atmosphere.

Now we will examine how heating of the atmosphere is distributed vertically and what contribution to it is made by heat influxes as a result of short-wave and long-wave radiation in the polygon region. For this purpose we made computations of heat influxes in three layers of equal mass for the conditions of cloudless skies and a complete upper-level cloud cover. The computations were made using data on temperature, humidity and albedo of the underlying surface characteristic for the considered region. The upper layer of the atmosphere is situated above the cloud cover, the middle level is situated in the cloud layer and the lower layer is in the region below the clouds.

Table 2 gives the mean changes in the heat influxes caused by an increase in upper-level clouds. With an increase in cloud cover the heat influx due to short-wave radiation increases in all layers: in the upper layer -- as a result of the additional absorption of reflected radiation; in the middle layer -- due to the absorption of radiation scattered by the clouds; in the lower layer -- as a result of additional absorption of scattered radiation. With respect to change in heat influxes due to long-wave radiation, in the cloud layer and in the layer above the clouds there was an increase in cooling: in the first case -- as a result of an increase in radiation from the upper boundary of the layer (the cloud emits as an ideally black body and the fluxes in it change linearly from the upper to the lower boundary), in the second -- due to a decrease in radiation from the underlying layers of the atmosphere and the underlying surface.

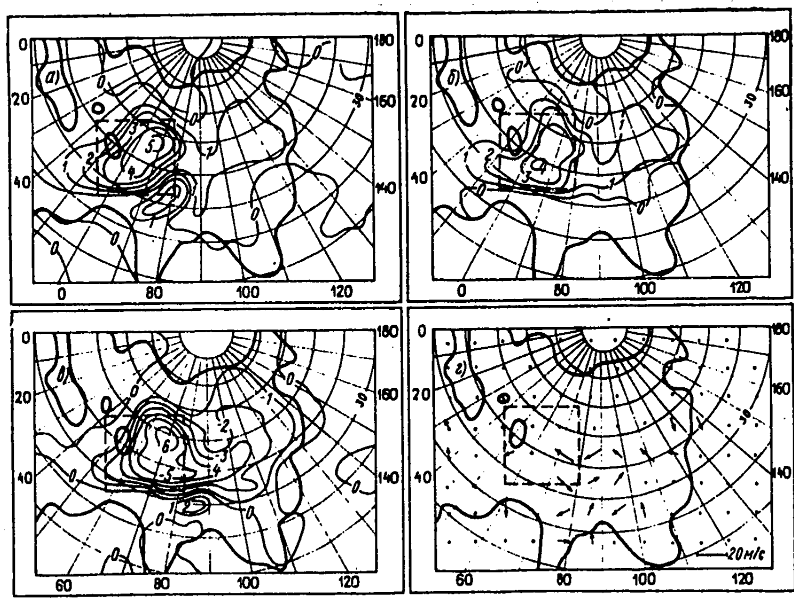


Fig. 4. Distribution of differences between temperatures (°C) at the level $\sigma = 0.833$ (a) and at the earth's surface (b), surface pressure (gPa) (c) and velocity vectors at level $\sigma = 0.5$ (d) obtained in the CEX and C1EX experiments (C1EX - CEX) during 5th-10th days of forecast.

The considerable heating of the layer under the clouds caused an increase in counterradiation from the lower boundary of the upper-level cloud cover. With an increase in the altitude of the lower boundary of these clouds the heating will be decreased because the descending flow becomes less.

Figure 4a gives the distribution of the differences between the temperatures computed in the experiment and the control experiment at the surface $\sigma = 0.833$. It follows from the figure that at this surface the temperature over the polygon is increased by 4-5°C. At the level $\sigma = 0.5$ this increase averaged 1°C, and at the level $\sigma = 0.167$ the temperature was decreased by 1-2°C. Due to the existence of east-west transfer in the middle latitudes the heat received by an air mass over the polygon is continuously transported by the main flow to the east. As a result, the region with a warmer air mass (relative to the control experiment) has a configuration elongated in an eastward direction.

Figure 4 shows the distribution of the temperature differences at the earth's surface between the two experiments. It is interesting to note that although the total radiation balance at the underlying surface decreases somewhat in the C1EX experiment the temperature nevertheless increases on the average by 2-3°. The reason is evidently that the heating of the lower layer of the atmosphere leads to a decrease in the temperature difference "upper boundary of the boundary layer - underlying surface" and thereby a substantial decrease in turbulent heat transfer into the atmosphere. If the change in this transfer in absolute value is greater than the change in the radiation balance, as follows from the heat balance equation, air temperature near the surface should increase.

b) Changes in pressure and wind velocity. Some temperature increase in the entire column of the atmosphere in the C1EX causes a decrease in density of the air mass and a pressure decrease near the earth's surface.

Figure 4c shows the distribution of changes in surface pressure as a result of formation of upper cloud cover. The region of pressure decrease extends far to the east and its configuration agrees with the region of temperature increase at the level $\sigma = 0.833$. The altitude of the 500 gPa surface increases by 1-2 dam over the considered region and to the east of it, and this agrees with the earlier noted temperature increase in the layer situated below this surface. With respect to mean vertical movements, their changes were very small ($\delta w \leqslant 1$ cm/sec), and the spatial distribution has a mottled unordered structure. In general, there is a tendency to an attenuation of descending movements over the polygon and to the east of it.

Figure 4d gives this distribution of the mean differences between the velocity vectors at the level $\sigma = 0.5$. The region of changes in the wind field is somewhat displaced to the east of the polygon. This is evidently attributable to the fact that adaptation of the wind field to changes in the field of mass occurs with some time lag equal to approximately one day. During this time the air mass can be displaced by 800-1500 km to the east. The changes in the velocity field have a somewhat irregular character and on their basis it is impossible with certainty to establish the character of evolution of circulation in the neighborhood of the polygon. It must be remembered that a considerable influence on the velocity vector field and its change in this region can be exerted by the peculiarities of relief. Similar irregular changes in the field of difference of the velocity vector occur at the level $\sigma = 0.833$.

c) Atmospheric moisture cycle. Since atmospheric moisture content and moistening of the underlying surface are small in value over the polygon, considerable changes in the intensity of precipitation can occur only in a case when sufficiently moist air arrives from other regions of the northern hemisphere. An analysis indicated that changes in the intensity of precipitation are very insignificant and have the character of white noise. This fact seems natural and agrees with the already noted insignificant change in the vertical velocity field.

With an increase in upper-level cloud cover the quantity of lower-level clouds decreases by 2-3 tenths. This is attributable to the fact that some heating of the lower troposphere and the absence of a moisture influx into the atmosphere cause a decrease in relative humidity over the polygon.

6. Summary

In this study we investigated the influence of upper-level cloud cover on the thermal regime and circulation of the atmosphere in the region of an anticyclonic formation. The evaluations were made using a model of general circulation of the atmosphere which takes into account the principal physical processes transpiring in the atmosphere. Two numerical experiments were carried out with integration of a system of equations for a time up to 10 days. An analysis of the results of computations for the last 6 days of the forecast indicated that the formation of upper-level cloud cover over the specially selected region causes the following changes in the thermal regime and circulation of the atmosphere.

a) the radiation balance of the earth-atmosphere system increases, which corresponds to an influx of thermal energy to the system. This influx, constituting approximately 50% of the total balance, is attributable for the most part to a decrease in long-wave radiation into universal space;

b) the changes in the radiation influx of heat are not the same vertically: the upper layer of the atmosphere, situated above the cloud, is cooled by 1-2°C; there is some heating of the middle troposphere; the layer under the clouds is subjected to considerable heating, attaining 4°C;

c) since the entire column of the atmosphere over the polygon on the average receives additional heat in the ClEX, pressure at the earth's surface decreases by 5-6 gPa; the region of falling of pressure to some degree in its configuration duplicates the region of an increase in temperatures at the level $\sigma = 0.833$. On the other hand, in the upper troposphere there is formation of a high-pressure region (but weaker);

d) the changes in the thermal regime and pressure cause corresponding changes in the velocity field. The region of these changes is somewhat displaced to the east of the polygon. In the lower half of the troposphere there is a poorly expressed tendency to an attenuation of descending vertical movements;

e) there are no appreciable changes in the field of precipitation; lower-level cloud cover decreases by 20-30% from the total cloud cover, which is associated with a decrease in relative air humidity in the neighborhood of the polygon.

Our analysis reveals that the formation of upper-level cloud cover leads to an attenuation of the anticyclonic formation in the lower half of the troposphere and its insignificant intensification in the upper troposphere and stratosphere. In general, however, the development of the process is such that favorable conditions are created for the appreciable attenuation of the anticyclone if the region in which the cloud cover is formed has sufficiently great dimensions. In the computations it was assumed that cloud cover is opaque for long-wave radiation. If the clouds transmit part of the radiation from the underlying layers of the atmosphere, the influence of upper-level cloud cover on the thermal regime of the atmosphere can be less. If the altitude of the clouds increases, whereas their albedo decreases, this leads to some intensification of the influence of clouds on the anticyclone in comparison with that considered.

The extent of the region with cloud cover and the time interval during which it persists are also exceptionally important circumstances in evaluating the influence of clouds.

This investigation must be regarded as preliminary because the experiments were carried out for one synoptic situation and the influence of cloud cover on the anticyclonic disturbance was studied over the course of a relatively short time interval.

BIBLIOGRAPHY

1. Belov, P. N. and Kivganov, A. F., "Changes in Temperature and Geopotential Caused by the Radiation Heat Influx," TRUDY MMTs (Transactions of the Moscow Meteorological Center), No 8, 1965.

2. Borisenkov, Ye. P. and Yefimova, L. K., "Theoretical Evaluation of the Influence of Cirrus Cloud Cover and Albedo of the Underlying Surface on Dynamics of Anticyclones," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 407, 1978.

3. Gradus, L. I., Niilisk, Kh. Yu. and Feygel'son, Ye. M., "Integral Transmission Function for Cloudy Conditions," IZV. AN SSSR: FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences: Physics of the Atmosphere and Ocean), No 4, 1968.

4. Yevseyeva, M. G. and Podol'skaya, E. L., "Integral Transmission Function in the Near Infrared Spectral Region," TRUDY LGMI (Transactions of the Leningrad Hydrometeorological Institute), No 49, 1974.

5. Kats, A. A., NEOBYCHNOYE LETO 1972 GODA (Unusual Summer of 1972), Leningrad, Gidrometeoizdat, 1973.

6. Leys, K. Ye., "Two-Dimensional Coefficients of Turbulent Viscosity," TRUDY VTOROGO TOKIYSKOGO SIMPOZIUMA PO CHISLENNYM METODAM PROGNOZOV POGODY (26 NOYABRYA-4 DEKABRYA 1968) (Transactions of the Second Tokio Symposium on Numerical Weather Forecasting Methods (26 November-4 December 1968)), Leningrad, Gidrometeoizdat, 1971.

7. Meleshko, V. P. and Shneyerov, B. Ye. (et al.), "Hydrodynamic Model of General Circulation of the Atmosphere," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 410, 1980.

8. Meleshko, V. P. and Shneyerov, B. Ye. (et al.), "Modeling of Atmospheric Circulation for January," TRUDY GGO, No 410, 1980.

9. Musayelyan, Sh. A., O PRIRODE NEKOTORYKH SVERKHDLITEL'NYKH ATMOSFERNYKH PROTSESSOV (Nature of Some Superlong Atmospheric Processes), Leningrad, Gidrometeoizdat, 1978.

10. Mukhenberg, V. V., "Albedo of the Earth's Land Surface," TRUDY GGO, No 193, 1967.

11. OSOBENNOSTI ZASUKHI 1972 NA UKRAINE (Features of the Drought of 1972 in the Ukraine), edited by K. T. Logvinov, Leningrad, Gidrometeoizdat, 1973.

12. Feygel'son, Ye. M., LUCHISTYY TEPLOOMEN V OBLAKAKH (Radiant Heat Exchange in Clouds), Leningrad, Gidrometeoizdat, 1970.

13. Santova, N. M., "Influence of Cloud Cover on Atmospheric Dynamics," IZV. AN SSSR: FIZIKA ATMOSFERY I OKEANA, Vol 14, No 10, 1978.

14. Benwell, C. R. R., et al., "The Bushby-Timpson 10-Level Model on a Fine Mesh," SCIENTIFIC PAPER, No 32, London, 1971.

15. Cess, R. D., "Climate Change: An Appraisal of Atmospheric Feedback Mechanisms Employing Zonal Climatology," J. ATMOS. SCI., Vol 33, 1976.

16. Crutcher, N. L. and Meserve, J. M., "Selected Level Heights, Temperature and Dew Points for the Northern Hemisphere," NAVAIR 50-1c-52, 1970, U.S. Navy Weather Serv., Washington, D. C.

17. Deardorf, T. W., "Empirical Dependence of the Eddy Coefficient for Heat Upon Stability Above the Lowest 50 m," J. APPL. METEOROL., Vol 6, No 4, 1967.

18. Fleming, J. R. and Cox, S. K., "Radiative Effects of Cirrus Clouds," J. ATMOS. SCI., Vol 31, 1974.

19. Ellis, J. S., CLOUDINESS, THE PLANETARY RADIATION BUDGET AND CLIMATE, Ph.D. THESIS, Colorado State University, 1978.

20. Manabe, S. and Wetherald, R. T., "Thermal Equilibrium of the Atmosphere With a Given Distribution of Relative Humidity," J. ATMOS. SCI., Vol 21, 1967.

21. Roewe, D. and Kuo-Nam Lion, "Influence of Cirrus Clouds on the Infrared Cooling Rate in the Troposphere and Lower Stratosphere," J. APPL. METEOROL., Vol 17, No 1, 1978.

22. Schneider, S. H., "Cloudiness as a Global Climatic Feedback Mechanism: The Effects on the Radiation Balance and Surface Temperature Variations in Cloudiness," J. ATMOS. SCI., Vol 29, 1972.

23. Smagorinsky, J., et al., "The Relative Importance of Variables in Initial Conditions for Dynamical Weather Prediction," TELLUS, Vol 22, 1970.

UDC 551.583.2:58

DENDROCLIMATOLOGY METHODS IN STUDYING HISTORY OF CLIMATE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 11 Mar 81) pp 18-29

[Article by A. Kh. Khrgian, professor, Moscow State University]

[Abstract] In this article an attempt has been made, in a few examples, to evaluate the contribution which climatologists can make in the interpretation of data on tree rings and the growth of cellulose. The author felt it necessary to ascertain what available climatic information can serve as a basis for dendroclimatology and how strong this basis is. This study is not so much an effort to ascertain new relationships between tree growth and climate as a desire to broaden the interaction between historical climatology and the study of tree rings. The following sections are included: research material; periodicity of growth; tree growth and sunspots; growth of cypress and some other data on climate of past centuries; tree growth and eruption of volcanoes; tree rings and modern changes in climate. The limited experience in the field of dendroclimatology indicates that the basis for this branch of science is a comparison of tree growt' and climatic data for the modern period (period of instrumental observations). There is a clear, but small positive correlation between the growth of cypress and precipitation and a negative correlation with summer temperature. The physical reasons for these correlations are clear. The correlations between tree growth and climate can be made more detailed by using trees of different species growing near observatories with long observation series and in climatic regions where modern changes in climate have already been well studied. This will help in overcoming the principal difficulty in dendroclimatology -- the still limited volume of initial independent data needed in establishing the principal numerical correlations. A study of the changes occurring after volcanic eruptions and investigation of the atmospheric turbidity caused by them could serve as an experiment for clarifying the "radiation-tree growth" correlation. A comparison with climatic events of past centuries, known from historical chronicles, is also important for dendroclimatology. It was not possible to find a reliable dependence between tree growth and an increase or decrease in solar activity during the period between 1949 and 1920. Tables 10; references 12: 8 Russian, 4 Western.

UDC 551.510.4:551.524.34(215-17)

EMPIRICAL ANALYSIS OF INFLUENCE OF CO_2 ON MODERN CHANGES IN MEAN ANNUAL AIR SURFACE TEMPERATURE IN NORTHERN HEMISPHERE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 31 Mar 81) pp 30-43

[Article by K. Ya. Vinnikov and P. Ya. Groysman, candidates of physical and mathematical sciences, State Hydrological Institute]

[Text]

Abstract: A very simple nonstationary model of the energy balance in the hemisphere which takes into account the thermal inertia of the climatic system, changes in albedo caused by variations in atmospheric transparency (turbidity), the influence of the CO_2 concentration on long-wave outgoing radiation and the feedback between albedo and temperature is used in studying the determinacy in change in the global thermal regime of the northern hemisphere during the period 1883-1977. The empirical estimates of the response of global air surface temperature in the northern hemisphere to a doubling of the CO_2 content in the atmosphere fall in the range from 2 to 3°C, which agrees satisfactorily with the most probable theoretical estimates of this parameter and confirms them as being realistic.

Introduction. It has been postulated in a number of studies that the principal factors in modern changes of global climate are the natural variations in the parameters of the aerosol layer of the stratosphere associated with volcanic activity and an anthropogenic increase in the carbon dioxide content in the atmosphere [3, and others]. Several attempts have been made to check this hypothesis on the basis of empirical data on climatic changes during the period of instrumental meteorological observations [3, 14, 33 and others].

The reality of the influence of changes in aerosol turbidity of the atmosphere, associated with volcanic activity, has been most convincingly demonstrated in the studies of M. I. Budyko [2], Lamb [22], Mitchell [27], Oliver [29] and Robock [33].

Serious arguments indicating that in addition to data on atmospheric transparency it is necessary to invoke the concept of a global anthropogenic warming as a result of an increase in the content of atmospheric carbon dioxide for explaining the changes in mean air temperature in the northern hemisphere during the period of instrumental observations were obtained in the investigations of M. I. Budyko [3], Baldwin, et al. [14], Miles and Gildersleeve [26]. However, no climatic effect of CO_2 was discovered in the studies of Robock [33] and Madden and Ramanathan [24].

The authors of [24], on the basis of the conclusions drawn in [25] and [32] on the nature of the seasonal variation of the response of the zonal thermal regime to change in atmospheric CO_2 content, without precluding an influence of variations of atmospheric transparency, substantially increased the intensity of the present "noise" against whose background they could detect no "signal." (The conclusions in [32] contradict both other theoretical [25, 36, and others] and empirical [6] estimates.)

The reasons for the negative conclusion concerning the role of CO_2 in climatic changes during the last century in [33], in the light of the results presented below, involve the use of an inadequately responsive model, inadequately reliable information concerning changes in atmospheric turbidity and exaggeration of inertia of the climatic system.

The purpose of this study is an empirical analysis of the determinacy of changes in the global thermal regime of the northern hemisphere during the period from 1883 through 1977, for which the most reliable evaluations of global climatic variables are available.

Description of Model

We will examine a very simple nonstationary model of the energy balance of the northern hemisphere for variables having an annual averaging period on the assumption of absence of energy exchange between the hemispheres:

$$q \frac{dT}{dt} = \frac{I_0}{4}[1 - \alpha(P(t),\ T)] - F(T,\ g(t)). \qquad (1)$$

Here T is the mean annual air surface temperature in the northern hemisphere in °C; t is time in years; q is a parameter characterizing the integral heat capacity of the climatic system; I_0 is the solar constant; α is the albedo of the earth-atmosphere system; P(t) is a characteristic of atmospheric aerosol turbidity; F is long-wave outgoing radiation;

C(t) is the CO_2 concentration in the atmosphere, C_0 = const.

We will use the following parameterization for albedo of the earth-atmosphere system.

$$\alpha(P, T) = \bar{\alpha} + \frac{\partial \alpha}{\partial P}(P - \bar{P}) + \frac{\partial \alpha}{\partial T}(T - \bar{T}). \qquad (2)$$

In this expression the line at the top denotes time averaging, $\partial\alpha/\partial P$ and $\partial\alpha/\partial T$ are parameters characterizing the response of albedo to change in atmospheric aerosol turbidity and the global thermal regime of the atmosphere.

By analogy with [2, 3], the outgoing radiation will be represented as a linear function of temperature

$$F(T, g) = \gamma(g)(a + bT), \tag{3}$$

where
$$\gamma(g) = \left(1 + \Delta T \frac{4b}{I_0(1-\bar{a})\ln 2} \ln g\right)^{-1},$$

ΔT is a parameter of model response characterizing the change in mean annual air temperature with a doubling of the atmospheric CO_2 content, estimated without allowance for the feedback between temperature and albedo of the system.

The expression for $\gamma(g)$ was derived on the assumption that the additional heat influx caused by the CO_2 greenhouse effect is proportional to the logarithm of its relative concentration, that is, ln g.

With allowance for (2)-(3), expression (1) is an ordinary linear differential equation for T, whose coefficients are dependent on the choice of the four parameters of the model q, $\partial\alpha/\partial T$, $\partial\alpha/\partial P$, ΔT and on the variables P(t) and g(t).

Its solution is written in the following form:

$$T(t) - \bar{T} = T_0 A_1(t) + \frac{\partial\alpha}{\partial P} A_2(t) + \Delta T A_3(t), \tag{4}$$

where $T_0 = T(0) - \bar{T}$,

$$A_1(t) = \exp\left[-\left(\frac{I_0}{4}\frac{\partial\alpha}{\partial T} + b\right)\frac{t}{q} + \frac{b}{q}\int_0^t (1 - \gamma(\tau))\,d\tau\right],$$

$$A_2(t) = -\int_0^t \frac{I_0}{4q}(P(\tau) - \bar{P}) \exp\left[-\left(\frac{I_0}{4}\frac{\partial\alpha}{\partial T} + b\right)\frac{t-\tau}{q} + \frac{b}{q}\int_\tau^t (1 - \gamma(s))\,ds\right] d\tau,$$

$$A_3(t) = \int_0^t \frac{b\gamma(\tau)\ln g(\tau)}{q\ln 2} \exp\left[-\left(\frac{I_0}{4}\frac{\partial\alpha}{\partial T} + b\right)\frac{t-\tau}{q} + \frac{b}{q}\int_\tau^t (1 - \gamma(s))\,ds\right] d\tau.$$

Characteristics of Empirical Data

The principal object of the investigation is the changes in the mean annual air surface temperature of the northern hemisphere during the period from 1883 through 1977 (75). Two independent evaluations of this global climatic variable can be obtained when using the materials of studies by K. Ya. Vinnikov, et al. [7] and Yamamoto [37, 38]. The correlation coefficient between the series, equal to 0.87, can be considered quite high, especially if it is taken into account that in [7] January is considered the first month of the year, whereas when obtaining the mean annual values from the seasonal data for the second series the first month of each year was December of the preceding year. The series [7], not characterizing the entire northern hemisphere, but its extraequatorial region 17.5-87.5°N, has a standard variability of 0.23°C. Comparison of the series [7] with the materials in the study of Ye. S. Rubinshteyn [11] and some theoretical evaluations reveals that the standard variability of the mean annual air temperature of the northern hemisphere, most probably is 20% less and is about 0.19°C. In turn, use of the optimum interpolation in the investigation of Yamamoto [37, 38] leads to an understatement of the standard variability of the evaluations hypothetically by a factor of 2, which is a consequence of inadequate coverage of a considerable part of the northern hemisphere with meteorological data.

Prior to use the evaluations of the mean annual air surface temperature of the northern hemisphere [7, 37, 38] were reduced to one and the same dispersion value, equal to 0.0344 degree^2 for the period 1883-1977(75). The true value of the dispersion can differ from the adopted value in any direction.

Two instrumental series were used in describing changes in the optical characteristics of the atmosphere in the short-wave spectral region. The first of these (1) represents the data published by Z. I. Pivovarova on the secular variation of the relative anomalies of the mean annual intensity of direct solar radiation in a cloudless sky based on measurements of approximately 13 actinometric stations located in the zone 40-62°N [10]. The second -- (2) -- gives similar data obtained in a study by Bryson and Goodman [15], who evaluated the secular variation of the mean annual aerosol optical mass of the atmosphere according to data from 42 actinometric stations located in the latitude zone 20-65°N.

In addition, as auxiliary characteristics we analyzed series of indices of volcanic dust content of the atmosphere obtained by Lamb [22] -- (3) and similar estimates of dust content made by Mitchell [27, 33] -- (4). Both Lamb and Mitchell proceeded on the basis of the concept that the decrease in atmospheric transparency is associated with hard particles entering the atmosphere during eruptions. During the 1970's the concept of a sulfate aerosol layer of the stratosphere [5 and elsewhere] was developed and it became clear that the principal climate-forming role is not played by volcanic dust, but by stratospheric aerosol, consisting of very tiny droplets of sulfuric acid forming primarily from the gas components of volcanic effluent. There is also evidence indicating that the quantity of background stratospheric aerosol at the present time is rapidly increasing under the influence of anthropogenic discharge of some chemical substances into the atmosphere.

Since the discharge of solid components evidently does not always correspond to the entry of gaseous sulfur compounds into the atmosphere and the change in the optical mass of stratospheric aerosol, the discrepancies between the indices of volcanic dust content or the estimates of the dust mass, on the one hand, and the characteristics of atmospheric transparency obtained using data from measurements of direct solar radiation in the network of actinometric stations, on the other hand, are very substantial.

Table 1 gives a matrix of the correlation coefficients of the enumerated transparency (turbidity) characteristics of the atmosphere.

Table 1

Matrix of Correlation Coefficients and Mean Square Values of Characteristics of the Mean Annual Atmospheric Transparency (Turbidity) Given in Text

Number of characteristic	1	2	3	4
1	1	-0.68	-0.37	-0.38
2		1	0.43	0.31
3			1	0.87
4				1
Standard deviation	0.035	0.016	67.3	8.2
Dimensionality	-----	-----	----	10^6 tons

The correlation coefficients, evaluated using data for the period 1883-1977, are rather low and indicate an inadequacy and inaccuracy of the information at our disposal. Giving preference to the characteristics of atmospheric transparency 1 and 2, independently obtained on the basis of actinometric observations, we will represent them in Fig. 1 and will select them as a basis for further analysis.

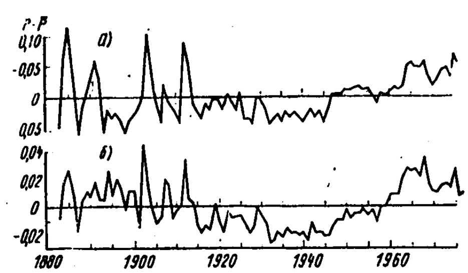


Fig. 1. Secular variation of characteristics of atmospheric transparency (turbidity) $P - \bar{P}$. a) Data from Z. I. Pivovarova [10], b) According to Bryson and Goodman [15].

For describing the changes in atmospheric carbon dioxide in the atmosphere during the period from 1883 through 1977 use was made of the following approximating expression proposed by E. K. Byutner

$$C(t) = 290 + 1,533 \times \times \exp(0,0287(t-1860)), \quad (5)$$

where t is the number of the year, C is the volumetric concentration of CO_2, expressed in millionths, $million^{-1}$.

The basis for this expression is materials from modern monitoring of the atmospheric CO_2 content [30 and elsewhere] and the assumption that C (1860) = 290 $mill^{-1}$, which corresponds to the mean value obtained on the basis of measurements made in the 19th century [23].

Choice of Parameters of Model

The model contains a whole series of parameters whose choice is unrelated to the introduction of additional errors and whose values we know quite well: I_0, α, T, a, b. We use the following values: I_0 = 1380 W/m^2, α = 0.31, $\overline{T}$ = 14.4°C, a = 208 W/m^2, b = 2 W/(m^2·°C). If we select C_0 = 305 $million^{-1}$, the indicated parameters ensure a closeness of the mean air surface temperature of the northern hemisphere obtained from (1) for the period from 1883 through 1977 to the indicated value 14.4°C. The determination of these parameters for the northern hemisphere is based on materials from studies [1, 9, 12, 18]. The results of the subsequent analysis are influenced only by the appropriate choice of the required h parameter value. Evaluation of thermal inertia parameter. The parameter q -- the heat capacity of the global climatic system of the northern hemisphere -- can be determined empirically in accordance with the method proposed by M. I. Budyko [2]. For this we will use empirical data on the annual variation of the mean air surface temperatures for the northern hemisphere T(t), its albedo $\alpha(t)$ and the influx of solar radiation at the outer boundary of the atmosphere Q(t).

In accordance with the well-known definition, we introduce the radiation temperature

$$T_R(t) = Q(t)[1-\alpha(t)]/b - a/b, \quad (6)$$

which would be realized on the assumption that q = 0, $\gamma = 1$, and we will write the equation for the energy balance of the northern hemisphere in the form

$$\frac{dT(t-\tau)}{dt} = -\frac{b}{q}\left[T(t) - T_R(t)\right], \quad (7)$$

where τ is a parameter characterizing the lag in changes in the heat content of the global climatic system of the northern hemisphere from the changes in surface air temperature.

We will represent $T_R(t)$ in the form of a periodic function with the annual period:

$$T_R(t) - \overline{T}_R = A_R \sin 2\pi t, \quad (8)$$

where A_R is the amplitude, t is time in years.

Then

$$T(t) - T = A \sin(2\pi t - \varphi), \quad (9)$$

where A, the amplitude, and φ, the phase, are determined by the system of equations

$$\begin{cases} \operatorname{tg}\varphi = (\sin 2\pi\tau + b/2\pi q)^{-1}\cos 2\pi\tau \\ A = A_R \frac{b}{2\pi q}\left[\left(\frac{b}{2\pi q}\right)^2 + 1 + \frac{b}{\pi q}\sin 2\pi\tau\right]^{-0,5}. \end{cases} \qquad (10)$$

Using (6), (8) and (9), on the basis of empirical data in [12, 18] we find A_R = 40°C, A = 6.7°C and φ = 0.53 rad = 31°.

Substituting these values into (10), we obtain an empirical evaluation of the parameters of the model q = 1.7 W·year/(m^2·°C) and τ = 0.15 year.

Henceforth we will use the rounded-off value q = 2 W·year/(m^2·°C). Taking into account that τ is substantially less than a year, in equation (1) this value was assumed equal to zero.

The problem of the thermal inertia of the global climatic system and allowance for it in computations of modern changes in climate has been discussed in a number of studies.

According to the empirical estimates made by M. I. Budyko [2], the inertia time during which the difference between T and T_R in the case of a jumplike change in T_R decreases by a factor of e is 2.5 years, which corresponds to q $\approx$ 5 W·year/(m^2·°C).

According to the estimates made by Oliver [29], the inertia constant is from 6.5 to 10 years, and accordingly, q varies from 13 to 20 W·year/(m^2·°C).

A lower q value for the global climatic system, of the order of 2.5-3 W·year/(m^2·°C), can be obtained from materials of studies by Manabe and Stouffer [25], which takes into account the upper quasihomogeneous layer of the ocean with a constant thickness 68 m. A planet similar to the earth, consisting only of an ocean with such a quasihomogeneous layer, would have q $\approx$ 9-10 W·year/(m^2·°C).

A convincing explanation of the fact that the integral value q for the global climatic system is several times less than the mean weighted value of the heat capacities of the ocean-atmosphere and land-atmosphere systems was given in a study by Thompson and Schneider [34].

A whole series of studies [21, 34 and others] used different hypotheses concerning the nature of heat exchange between the upper quasihomogeneous layer and the deep layers of the ocean and drew the conclusion that there was a substantially greater inertia of the climatic system. On the basis of the hypotheses we do not feel that it is possible to neglect the refined empirical evaluation q $\approx$ 2 W·year/(m^2·°C).

Choice of parameter $\partial\alpha/\partial T$. This parameter characterizes the feedback in the global climatic system between temperature and albedo, realized primarily through the change in area of sea polar ice and the continental snow cover. There are no empirical evaluations for this parameter and therefore, for determining it, we will use the results of numerical experiments with models of the theory of climate on the basis of a study of response of the global climatic system.

If we introduce a new parameter, the amplification factor K, equal to the ratio of the evaluation of response of the globally averaged air surface temperature, obtained with this feedback taken into account, to the evaluation of response obtained without taking this feedback into account, it is possible to write the approximate expression

$$\frac{\partial \alpha}{\partial T} \approx -4b(1-1/K)/I_0. \tag{11}$$

The authors of [16, 35] gave the most complete analysis of the theoretical evaluations of response of climate to the change in atmospheric CO_2 content. Watts [35] cites the value K = 1.25 as the soundest. The report [16] gave the most reliable evaluations of the response of mean temperature with a doubling of the atmospheric CO_2 content, equal to 3.0 and 2.4°C respectively. Their ratio also gives the value K = 1.25. Substituting this value into (11), we obtain the evaluation $\partial\alpha/\partial T \approx -0.0012\ (°C)^{-1}$, which is also used in the subsequent computations. Then it was established that the choice of this parameter in a very broad range exerts no influence on the collected empirical evaluations of response of the global climatic system.

A priori evaluations $\partial\alpha/\partial P$. If as P(t) we use the data of Z. I. Pivovarova [10], we can obtain an a priori $\partial\alpha/\partial P$ evaluation, proceeding on the basis of simple reasonings similar to those presented in [5]. Assume that P(t) are the relative changes in direct solar radiation. We will assume that the changes in total radiation in the case of a cloudless sky constitute on the average 0.16 of the changes in direct radiation [13]. Neglecting the changes in albedo caused by changes in the aerosol layer of the stratosphere over clouds, we have an evaluation of the order of $\partial\alpha/\partial P \approx -0.04$.

If P(t) is the aerosol component of the optical mass of the atmosphere, which is observed with use of the data from Bryson and Goodman [15], the approximate $\partial\alpha/\partial P$ evaluations can be obtained using data from the studies of Pollack, et al. [31] ($\partial\alpha/\partial P \approx 0.07$), Ohring [28] ($\partial\alpha/\partial P \approx 0.057$-$0.081$) or can be found in a study by Harshvardan [20] ($\partial\alpha/\partial P = 0.14$), etc.

Below we will attempt to obtain empirical $\partial\alpha/\partial P$ evaluations the same as evaluations of the ΔT parameter. As already mentioned, theoretical evaluations of the latter have been subjected to broad discussion and analysis in [4, 16, 35].

Empirical Evaluation of Parameters of Response of Global Climatic System

Evaluation method. Having at our disposal empirical data on the variables T(t), P(t) and g(t) for 1883-1977, we will evaluate the unknown parameters $\partial\alpha/\partial P$ and ΔT, assuming the K and q parameters to be known precisely. Equation (4) is linear relative to T_0, $\partial\alpha/\partial P$ and almost linear relative to ΔT. The ΔT parameter enters into the functions A_1, A_2 and A_3 only through $\gamma(t)$ -- a value differing little from unity in the course of the considered period. A statistical evaluation of the parameters T_0, $\partial\alpha/\partial P$ and ΔT was made in two stages. In the first stage it was assumed that $\gamma(t) \equiv 1$ and the first approximation of the unknown parameters was determined. In the second stage the determined ΔT evaluation was substituted into $\gamma(t)$ and the evaluation procedure was repeated. The results were final and did not change in subsequent iterations.

With fixed q and K values the functions $A_2(t)$ and $A_3(t)$ constitute the result of smoothing of the time series of $P(t) - \overline{P}$ and $\ln g(t)$ values. In the absence of other reasonable alternatives we will assume that the function g(t) is known to us precisely. A similar hypothesis is obviously not suitable for P(t), as is indicated by the comparison made above of different evaluations of this variable. We will therefore assume that by using the empirical evaluations $\tilde{P}(t)$ we can compute $\tilde{A}_2(t) = A_2(t) + \delta(t)$, that is, the function $\tilde{A}_2(t)$, differing from the true $A_2(t)$ value by $\delta(t)$, the error summing all the errors in the empirical evaluation P(t). These errors are large, both at the beginning of the studied period, when the number of the actinometric stations was small, and at its end, when the measurements of many long-series stations were unsuitable for use as a result of local anthropogenic contamination of the atmosphere.

In this situation the evaluation of the parameters T_0, $\partial\alpha/\partial P$ and ΔT from (4) according to empirical data by the least squares method (LSM) is incorrect since the LSM evaluations of the sought-for parameters will be biased. Asymptotically unbiased evaluations can be obtained only when using not only $\tilde{A}_2(t)$, but also additional information concerning the $A_2(t)$ function, which would make it possible to reduce the influence of the function of errors $\delta(t)$. We have such information since we had at our disposal two, if not completely independent, then independently obtained series of characteristics of atmospheric transparency $\tilde{P}(t)$.

We will assume that the errors $\delta(t)$ for $\tilde{A}_2(t)$, computed from the $\tilde{P}(t)$ series from [10] and [15], are independent, whereas the similar errors in $A_3(t)$, caused by the inaccuracy in determining g(t), are small or zero. Then the justifiable asymptotically unbiased evaluations for T_0, $\partial\alpha/\partial P$ and ΔT can be obtained by using the method of an instrumental (auxiliary) variable (IVM) [6, 8, 17, 19].

We will use the subscripts "P" and "B" in denoting the series $\tilde{A}_2(t)$ and $\delta(t)$ for $\tilde{P}(t)$, obtained from [10] and [15] respectively. We will rewrite equation (4) in the form

[П = P]

$$T(t) - \overline{T} = T_0 A_1(t) + \frac{\partial\alpha}{\partial P}(\tilde{A}_{2П}(t) - \delta_П(t)) - \Delta T A_3(t), \tag{12}$$

where T(t), $A_1(t)$, etc. (t = 0, 1, 2,..., N - 1) are vectors of the dimensionality N and we will multiply scalarly by the vectors $A_1(t)$, $\tilde{A}_{2B}(t)$ and $A_3(t)$.

Taking into account that

[П = P, Б = B]

$$\operatorname{cov}(\delta_П, A_1) = \operatorname{cov}(\delta_П, A_3) = \operatorname{cov}(\delta_П, \tilde{A}_{2Б}) = 0, \tag{13}$$

we obtain

$$\begin{cases} \operatorname{cov}(T, A_1) = T_0 \operatorname{cov}(A_1, A_1) + \frac{\partial\alpha}{\partial P}\operatorname{cov}(\tilde{A}_{2П}, A_1) + \Delta T \operatorname{cov}(A_3, A_1) \\ \operatorname{cov}(T, \tilde{A}_{2Б}) = T_0 \operatorname{cov}(A_1, \tilde{A}_{2Б}) + \frac{\partial\alpha}{\partial P}\operatorname{cov}(\tilde{A}_{2П}, \tilde{A}_{2Б}) + \\ \qquad + \Delta T \operatorname{cov}(A_1, \tilde{A}_{2Б}) \\ \operatorname{cov}(T, A_3) = T_0 \operatorname{cov}(A_1, A_3) + \frac{\partial\alpha}{\partial P}\operatorname{cov}(\tilde{A}_{2П}, A_3) + \Delta T \operatorname{cov}(A_3, A_3). \end{cases} \tag{14}$$

Since the errors in empirical data on air temperature and atmospheric transparency are uncorrelated, all the covariations in (14) can be evaluated, and accordingly it is possible to obtain evaluations of the parameters T_0, $\partial\alpha/\partial P$ and ΔT, which are the IVM evaluations. We note that if in (14) it is assumed that $\tilde{A}_{2B} = \tilde{A}_{2P}$ we again return to the LSM evaluations.

If as the basic characteristic of atmospheric transparency we use the series obtained by Bryson and Goodman [15], and as the instrumental variable we use the function $\tilde{A}_{2P}(t)$, computed from the series $\tilde{P}(t)$ published by Z. I. Pivovarova [10], we obtain another evaluation of the parameters T_0, $\partial\alpha/\partial P$ and ΔT. In this case the evaluations of the parameters T_0 and ΔT may not coincide as a result of selective variability. The value of the T_0 parameter in all the evaluation parameters changes little and varies around the value -0.2°C. The evaluation of this parameter is of no value for this investigation.

Empirical evaluations of the parameters $\partial\alpha/\partial P$ and ΔT. Table 2 gives the results of the IVM evaluations of the parameters of response of the global climatic system of the northern hemisphere. The evaluations are based on a temperature series [7]. The evaluations obtained with the use of a $\tilde{P}(t)$ series obtained by Pivovarova [10] as basic (but the series in [15] for computing the instrumental variable) are denoted by the letter A, whereas the evaluations based on the $\tilde{P}(t)$ series obtained by Bryson and Goodman [15] (series [10] -- auxiliary) are denoted by the letter B.

The evaluations I relate to the hypothesis that both factors and changes in transparency and CO_2 content in the atmosphere exert an influence on the thermal regime of the hemisphere. The evaluations II represent an alternative hypothesis in which it is postulated that the CO_2 concentration exerts no influence on climate, that is, $\Delta T \equiv 0$.

Taking into account the increase in response of the model to the feedback mechanism between albedo and temperature as characteristics of the response of the global climatic system it is necessary to use the values $\Delta T_c = K\Delta T$ and

$$\Delta T_p = -\sigma_p K \frac{\partial \alpha}{\partial P} \frac{I_0}{4b},$$

where σ_p is the standard variability of the $\tilde{P}(t)$ value represented in Table 1.

The evaluations of response were accompanied by computation of a number of statistical characteristics: ρ is the correlation coefficient between the empirical series $\tilde{T}(t)$ and the series $T(t)$, reproduced using the model (4) on the basis of the IVM evaluations of the parameters; α_M is the standard variability of the $T(t)$ series reproduced by the model; d is the standard variability of the series $\varepsilon(t) = \tilde{T}(t) - T(t)$ of nonclosures between the empirical data and the evaluations of mean temperature of the hemisphere reproduced by the model; r_s is the rank correlation coefficient of the series of nonclosures $\varepsilon(t)$ with a natural series of numbers; r_1 is the first serial correlation coefficient of the series of nonclosures $\varepsilon(t)$.

The latter two characteristics serve for evaluation of the measure of randomness and unordered nature of the series of nonclosures $\varepsilon(t)$. In particular, if there is a monotonic trend in $\varepsilon(t)$, r_s differs significantly from zero. In our case with $|r_s| \leqslant 0.2$ the $\varepsilon(t)$ series can be considered unordered and does not contain a trend at the 95% significance level.

Table 2

Empirical Estimates of Parameters of Response of Model and Climatic System When Using Series $\tilde{T}(t)$ and $\tilde{P}(t)$ From [7, 10, 15]; k = 1.25 q = 2 W·year/(m²·°C)

Гипо-теза 1)	Вари-ант 2)	Параметры модели 3)		Параметры климатической системы 4)		Статистические характеристики 5)				
		ΔT °C	$\partial \alpha/\partial P$	ΔT_c °C	ΔT_p °C	ρ	$\check{\sigma}_м$	$d°$	r_s	r_1
I	А	2,5	−0,033	3,1	0,25	0,69	0,19	0,15	0,04	0,39
	Б	1,7	0,053	2,1	−0,18	0,76	0,17	0,13	0,00	0,32
II	А	0	−0,024	0	0,18	0,38	0,14	0,19	0,73	0,69
	Б	0	0,028	0	−0,10	0,57	0,09	0,16	0,63	0,60

KEY:

1. Hypothesis
2. Variant
3. Model parameters
4. Parameters of climatic system
5. Statistical characteristics

For the evaluations IA and IB the r_s and r_1 values, and also the results of the analysis of the correlation and spectral functions indicate that the nonclosures of the $\varepsilon(t)$ model have the character of red noise. The principal reason for the autocorrelation nature of the $\varepsilon(t)$ series is a smoothing of the errors of the $\tilde{P}(t)$ series as a result of the inertia of the climate system. Thus, statistical extrapolation of $\varepsilon(t)$ is unthinkable.

Analysis of the data in Table 2 indicates that hypothesis II on the absence of the influence of changes in the atmospheric CO_2 concentration on climate is refuted by the F test with a probability exceeding 99%, regardless of which of the $\tilde{P}(t)$ series [10] or [15] is used as basic. In addition, with $\Delta T \equiv 0$ and an IVM evaluation of the parameters T_0 and $\partial\alpha/\partial P$, as indicated by the data given in the lines IIA and IIB of this table, the nonclosures $\varepsilon(t) = \tilde{T}(t) - T(t)$ are nonrandom time series. The r_s = 0.6-0.7 values indicate the presence of a powerful monotonically increasing trend in $\varepsilon(t)$. This means that there is another factor still not taken into account causing a systematic change in temperature $\tilde{T}(t)$.

The inclusion in the model, in addition to the influence of changes in atmospheric transparency, of the influence of carbon dioxide increases the fraction of the dispersion of the $\tilde{T}(t)$ series described by the model by 25-30%. In this case the nonclosures of the $\varepsilon(t)$ model represent unpredictable noise. These conclusions apply to an identical degree to the variants A and B. The ΔT parameter in these cases was equal to 2.5° and 1.7°C.

Estimates of the ΔT_c value, equal to 3.1° and 2.1°, agree extremely satisfactorily with the theoretical evaluations of the influence of doubling of the atmospheric CO_2 content on the global thermal regime and indicate that the latter are realistic.

The empirical evaluations of the $\partial\alpha/\partial P$ parameter are of independent interest. A comparison of these evaluations with the theoretical evaluations cited earlier is extremely difficult due to the great uncertainty in the theoretical evaluations.

At this stage it is evidently possible to be content with the observed coincidence of orders of magnitude. The $|\Delta T_p|$ evaluations IA and IB are close to one another and average $\sim 0.2°C$. They characterize the temperature change caused by the change in atmospheric transparency (turbidity) P by a value equal to the standard variability of the $\tilde{P}(t)$ series.

All these computations were repeated for data on the change in air temperature in the northern hemisphere obtained by Yamamoto [37, 38]. With these same qualitative conclusions the evaluations of the response of ΔT and $\partial\alpha/\partial P$ were 20% lower than those presented in Table 2.

Similar computations with the use of the series of Z. I. Pivovarova [10] and Bryson and Goodman [15] as characteristics of atmospheric transparency, and the series of Lamb [22] or Mitchell [27] as instrumental variables, give evaluations of the response parameters not differing substantially from those given in Table 2, but having greater selective variability.

On the other hand, the use of the Lamb [22] and Mitchell [27] series as the principal characteristics of change in atmospheric transparency leads to a qualitatively opposite conclusion -- on the absence of an appreciable influence of CO_2 on climatic change during the last 100 years. But in these cases an analysis of series of errors of the $\varepsilon(t)$ model reveals the presence of systematic components in them which do not disappear even when taking into account the influence of carbon dioxide, which forces us to refute these estimates.

Due to the fact that the descriptions of the changes in atmospheric turbidity by the data in [22, 27] are considerably less realistic and accurate than the data in [10, 15] we will give preference to the conclusions obtained when using the latter. The use of the data in [27] probably was one of the reasons for the conclusion drawn by Robock in [33] that there is no appreciable influence of CO_2 on climate during the period of instrumental meteorological observations.

However, for the data in [10] and [15] the conditions cov (δ_P, δ_B) = cov (δ_P, A_3) = cov $(\delta_B, A_3) = 0$ probably are not satisfied precisely, but instead approximately. The authors of these investigations could use coinciding actinometric stations; in addition, it is impossible to exclude the hypothesis that the local anthropogenic contamination of the atmosphere did not identically and simultaneously distort the $\tilde{P}(t)$ series from [10] and [15]. This could introduce a systematic error into δ_P and δ_B, disrupt the condition cov $(\delta, A_3) = 0$, and accordingly, distort the ΔT evaluation. The use of the series [22] and [27] as an instrumental variable revealed that the influence of violation of this condition is small.

A confidence evaluation of the parameters of response of the climatic system was made taking into account the autocorrelation nature of a series of errors of the $\varepsilon(t)$ model and the absence of precise information on variations of atmospheric transparency. For the two point evaluations of the parameter $\Delta T_c = 3.1°$ and $2.1°C$ which are of the greatest interest (see Table 2) the 95% confidence intervals were (2.0°; 4.3°) and (1.1°;3.0°) respectively. Since the most probable value ΔT_c should fall in the region of intersection of these intervals it can be concluded that with a doubling of the atmospheric CO_2 content the mean annual air surface temperature for the northern hemisphere varies by a value from 2.0 to 3.0°C.

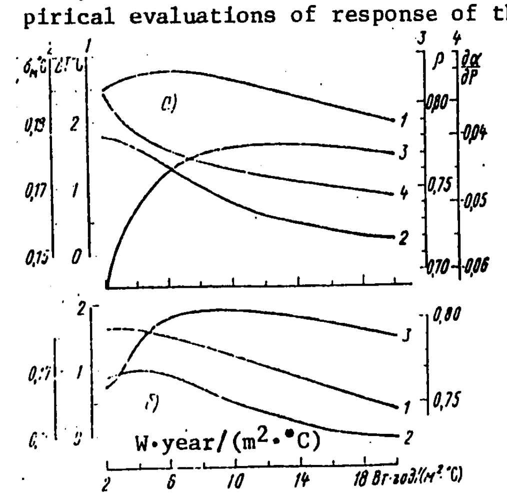
Influence of choice of other parameters on evaluations of $\partial\alpha/\partial P$ and ΔT. Figure 2 shows the results of evaluation of the influence of choice of the inertia parameter q on evaluations of the response of the climatic system. With K = 1.25 the q values vary in the range from 2 to 20 W·year/(m^2·°C). Figure 2a gives the estimates obtained when using as the main $\tilde{P}(t)$ series that obtained by Pivovarova [10], and in Fig. 2b -- that obtained by Bryson and Goodman [15]. At the same time, the figure shows the dependence of the standard variability σ_M of the T(t) evaluations and the correlation coefficient ρ of the T(t) and $\tilde{T}(t)$ series on q.

We note the fact that an increase in q leads to an increase in ρ to values close to 0.8 with q $\approx$ 10 W·year/(m^2·°C). This does not mean that the value q = 2 W·year/m^2· degree was selected incorrectly. The $\tilde{P}(t)$ data simply include such great random errors that the strong smoothing of the $\tilde{P}(t)$ series creates in $\tilde{A}_2(t)$ the illusion of an increase in model accuracy. This effect evidently explains the high empirical value of the inertia parameter found by Oliver in [29]. The standard variability of the T(t) series decreases considerably with an increase in q, and with large q the dispersion of the T(t) series is greatly understated.

When using as the basic series the Z. I. Pivovarova series in [10], the ΔT parameter has little dependence on the choice of q and $\partial\alpha/\partial P$ doubles in absolute value with an increase in q by an order of magnitude.

On the other hand, in the results of an analysis based on use of the Bryson and Goodman series [15], the ΔT evaluation decreases rapidly with an increase in q, whereas $\partial\alpha/\partial P$ is not dependent on the choice of q, and therefore this value is not represented on the graph.

Thus, the choice of the inertia parameter q can exert a strong influence on the empirical evaluations of response of the climatic system and cannot be arbitrary.



On the other hand, as indicated by computations, the choice of the amplification parameter K, exerting an influence on the evaluations of $\partial\alpha/\partial P$ and ΔT with all q, leaves virtually constant the evaluations of the ΔT_c and ΔT_p values, that is, the total response of the model with allowance for influence of the feedback between albedo and the thermal regime. Similarly exerting an influence on the evaluations is the dispersion of the empirical series $\tilde{T}(t)$, inadequately well known. Evaluations of the response parameter are directly proportional to the mean square variability of the $\tilde{T}(t)$ series.

Fig. 2. Dependence of IMV evaluations of parameters of model on choice of q with K = 1.25. The figures over the y-axes correspond to the numbers of the curves.

Computation of Changes in Surface Temperature of Northern Hemisphere During Period 1883-1977

Figure 3 shows the results of reproduction (by means of a model) of the change in surface air temperature in the northern hemisphere during the period 1883-1977 with allowance for the joint influence of changes in CO_2 content and atmospheric transparency.

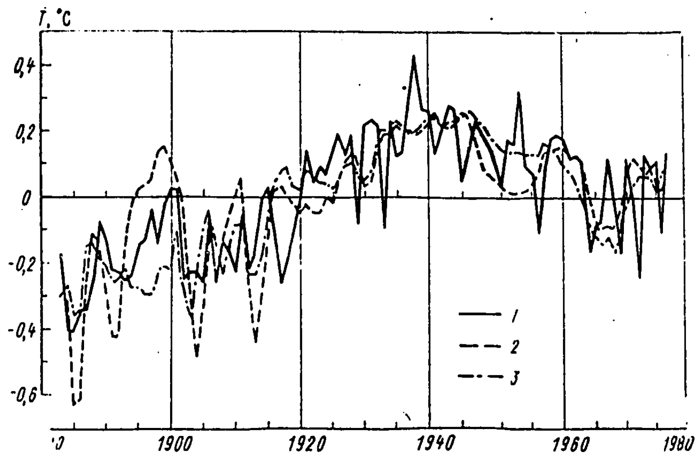


Fig. 3. Reproduction of secular variation of mean annual air surface temperature in northern hemisphere with allowance for the influence of changes in atmospheric CO_2 content. 1) empirical data according to data in [7], 2) computations using data on changes in atmospheric transparency (turbidity) published by Z. I. Pivovarova [10], 3) computations using data by Bryson and Goodman [15].

Without having precise values of the T(t) series we are unable to judge where the truth lies, but the closeness of the curves represented in Fig. 3 is without question. An encouraging fact is an unquestionable increase in the "accuracy" of the model in the second half of the period, when, it can be hoped, the accuracy of data on all climatic variables substantially increased. The somewhat exaggerated variability of the T(t) series, obtained from the $\tilde{P}(t)$ series of Pivovarova [10], is probably evidence of an exaggerated variability of the characteristic of atmospheric transparency, not evidence of an understatement in the determination of the parameter of inertia of the climatic system in our model. On the other hand, the excessive smoothness of the shape of the T(t) curves reproduced in the studies of Oliver [29] and Robock [33] is evidence of an exaggeration of the inertia in their models.

Assuming that $P(t) \equiv$ const and in (4) using the evaluations ΔT_c = 2.1-3.1°C, we draw the conclusion that an anthropogenic increase in atmospheric CO_2 content caused an increase in the mean annual air surface temperature in the northern hemisphere by 0.4-0.6°C in comparison with the mid-1880's. This warming is partially masked by the influence of variations of atmospheric transparency.

Summary

Our analysis of the empirical data indicated that the time series for mean annual air surface temperature in the northern hemisphere during the last hundred years contains definite components governed by variation of atmospheric transparency and an increase in atmospheric CO_2 content. Our empirical estimates of the response of the global surface thermal regime of the atmosphere in the northern hemisphere to a doubling of the atmospheric CO_2 content are in the range from 2 to 3°C.

The first empirical estimates of the response of air surface temperature to change in atmospheric CO_2 content were obtained in the studies of Miles and Gildersleeve [26] and M. I. Budyko [3]. These estimates, obtained by simpler methods, are close to the estimates in our study. The good agreement of known theoretical estimates of the ΔT_c value with the empirical values indicates that they are realistic and on their basis it is possible to examine the impending changes in the global thermal regime in relation to the anthropogenic increase in atmospheric CO_2 content.

For this purpose the diagnostic model (1)-(4) can be used as a prognostic model on the assumption that the variations in atmospheric transparency are unpredictable and are a source of noise. It is necessary to refine the role of heat exchange between the upper quasihomogeneous layer and the deeper layers of the ocean.

The authors express appreciation to M. I. Budyko and E. K. Byutner for discussion of formulation of the problem and the first results. They also express great appreciation to Z. I. Pivovarova and R. Yamamoto, who in digital form presented data on the secular variation of atmospheric transparency and surface air temperature in the northern hemisphere.

BIBLIOGRAPHY

1. Beyeva, I. M. and Vinnikov, K. Ya., "Dependence of Outgoing Radiation of the Earth-Atmosphere System on Temperature and Cloud Cover," TRUDY GGI (Transactions of the State Hydrological Institute), No 271, 1981.

2. Budyko, M. I., IZMENENIYA KLIMATA (Climatic Changes), Leningrad, Gidrometeoizdat, 1974.

3. Budyko, M. I., KLIMAT V PROSHLOM I BUDUSHCHEM (Climate in the Past and Future), Leningrad, Gidrometeoizdat, 1980.

4. Budyko, M. I., et al., "Anthropogenic Changes in Global Climate," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 8, 1981.

5. Budyko, M. I., et al., KLIMAT I VOZDEYSTVIYA NA AEROZOL'NYY SLOY STRATOSFERY (Climate and Effects on the Aerosol Layer of the Stratosphere), Leningrad, Gidrometeoizdat, 1974.

6. Vinnikov, K. Ya. and Groysman, P. Ya., "Empirical Model of Modern Changes in Climate," METEOROLOGIYA I GIDROLOGIYA, No 3, 1979.

7. Vinnikov, K. Ya., et al., "Modern Changes in Climate in the Northern Hemisphere," METEOROLOGIYA I GIDROLOGIYA, No 6, 1980.

8. Kendall, M. J. and Stuart, A., STATISTICHESKIYE VYVODY I SVYAZI (Statistical Conclusions and Correlations), Moscow, Nauka, 1973.

9. North, G. P. and Koukli, J. L., "Simple Seasonal Models of Climate," METEOROLOGIYA I GIDROLOGIYA, No 5, 1978.

10. Pivovarova, Z. I., RADIATSIONNYYE KHARAKTERISTIKI KLIMATA SSSR (Radiation Characteristics of USSR Climate), Leningrad, Gidrometeoizdat, 1977.

11. Rubinshteyn, Ye. S., STRUKTURA KOLEBANIY TEMPERATURY VOZDUKHA NA SEVERNOM POLUSHARII (Structure of Air Temperature Variations in the Northern Hemisphere), Leningrad, Gidrometeoizdat, 1973.

12. Spirina, L. P., "Latitudinal Norms of Atmospheric Pressure and Air Temperature in the Northern Hemisphere," TRUDY GGO (Transactions of the Main Geophysical Observatory), No 258, 1970.

13. Shifrin, K. S., "Radiation Effect of the Dust Layer," AKTINOMETRIYA I ATMOSFERNAYA OPTIKA (Actinometry and Atmospheric Optics), Leningrad, Gidrometeoizdat, 1969.

14. Baldwin, B., Pollack, J. B., Summers, A., Toon, O. B., Sagan, C. and Van Camp, W., "Stratospheric Aerosols and Climatic Change," NATURE, Vol 263, 1976.

15. Bryson, R. A. and Goodman, B. M., "Volcanic Activity and Climatic Changes," SCIENCE, Vol 207, 1980.

16. CARBON DIOXIDE AND CLIMATE: A SCIENTIFIC ASSESSMENT, Nat. Acad. of Sci., Washington, D. C., 1979.

17. Durbin, J., "Errors in Variables," REV. INST. INTERNAT. STATIST., Vol 22, No 1-3, 1954.

18. Ellis, J. S., Vonder Haar, T. H., "Zonal Average Earth Radiation Budget Measurements From Satellites for Climate Studies," ATMOS. SCI. PAPER No. 240, Colorado State University, Fort Collins, Colorado, 1976.

19. Geary, R. S., "Determination of Linear Relations Between Systematic Parts of Variables With Errors of Observation the Variances of Which Are Unknown," ECONOMETRICA, Vol 17, No 1, 1949.

20. Harshvardan, --, "Perturbation of the Zonal Radiation Balance by a Stratospheric Aerosol Layer," J. ATMOS. SCI., Vol 36, 1979.

21. Hunt, B. G. and Wells, N. C., "An Assessment of the Possible Future Climatic Impact of Carbon Dioxide Increases Based on a Coupled One-Dimensional Atmospheric-Oceanic Model," J. GEOPHYS. RES., Vol 84, No C2, 1979.

22. Lamb, H. H., "Volcanic Dust in the Atmosphere; With a Chronology and Assessment of Its Meteorological Significance," PHIL. TRANS. ROY. SOC. LONDON A, Vol 266, No 1178, 1970.

23. Machta, L., ATMOSPHERIC MEASUREMENTS OF CARBON DIOXIDE. CONF-770385, Workshop on the Global Effects of Carbon Dioxide From Fossil Fuels, edited by P. Elliot and L. Machta, 1979.

24. Madden, R. A. and Ramanathan, V., "Detecting Climate Change Due to Increasing Carbon Dioxide," SCIENCE, Vol 209, No 4458, 1980.

25. Manabe, S. and Stouffer, R. J., "Sensitivity of a Global Climate Model to an Increase of CO_2 Concentration in the Atmosphere," J. GEOPHYS. RES., Vol 85, No C10, 1980.

26. Miles, M. K. and Gildersleeve, P. B., "A Statistical Study of the Likely Causative Factors in the Climatic Fluctuations of the Last 100 Years," METEOROL. MAGAZ., Vol 106, 1977.

27. Mitchell, J. M., Jr., "A Reassessment of Atmospheric Pollution as a Cause of Long-Term Changes of Global Temperature," THE CHANGING GLOBAL ENVIRONMENT, edited by S. F. Singer, Holland, 1975.

28. Ohring, G., "The Effect of Aerosols on the Temperatures of a Zonal Average Climate Model," PAGEOPH., Vol 117, 1979.

29. Oliver, R. C., "On the Response of Hemispheric Mean Temperature to Stratospheric Dust: An Empirical Approach," J. APPL. METEOROL., Vol 15, No 9, 1976.

30. Pearman, G. I., "Atmospheric CO_2 Concentration Measurements. A Review of Methodologies, Existing Programmes and Available Data," WMO Project of Research and Monitoring of Atmospheric CO_2, 1980, WMO, Report No 3.

31. Pollack, J. B., Toon, O. B., Sagan, C., Summers, A., Baldwin, B., Van Camp, W., "Volcanic Explosions and Climatic Change: A Theoretical Assessment," J. GEOPHYS. RES., Vol 81, No 6, 1976.

32. Ramanathan, V., Lian, M. S. and Cess, R. D., "Increased Atmospheric CO_2, Zonal and Seasonal Estimates of the Effect on the Radiation Balance and Surface Temperature," J. GEOPHYS. RES., Vol 84, No C8, 1979.

33. Robock, A., "Internally and Externally Caused Climate Change," J. ATMOS. SCI., Vol 35, No 6, 1978.

34. Thompson, S. L. and Schneider, S. H., "A Seasonal Zonal Energy Balance Climate Model With an Interactive Lower Layer," J. GEOPHYS. RES., Vol 84, No C5, 1979.

35. Watts, R. G., "Climate Models and CO_2-Induced Climatic Changes," CLIMATIC CHANGE, Vol 2, No 4, 1980.

36. Wetherald, R. T. and Manabe, S., "Influence of Seasonal Variation Upon the Sensitivity of a Model Climate," J. GEOPHYS. RES., Vol 86, No C2, 1981.

37. Yamamoto, R., "Variability of Northern Hemisphere Mean Surface Air Temperature During Recent 200 Years," presented at Int. Meeting on Statistical Climatology, Hachioji, Nov 29-Dec 1, 1979.

38. Yamamoto, R. and Hoshiai, M., "Fluctuations of the Northern Hemisphere Mean Surface Air Temperature During Recent 100 Years, Estimated by Optimum Interpolation," J. METEOROL. SOC. JAPAN, Ser II, Vol 58, No 3, 1980.

UDC 532.526.4:536.242

TEMPERATURE DISTRIBUTION IN TURBULENT NEAR-WALL CURRENTS WITH ALLOWANCE FOR AIRFLOW STRATIFICATION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 9 Mar 81) pp 44-48

[Article by A. G. Yurov, Hydromechanics Institute, Ukrainian Academy of Sciences]

[Abstract] One of the characteristics of the turbulent boundary layer, to a considerable degree determining the interaction between the atmosphere and ocean, is the temperature distribution in the air flow over a water surface. Specialists at the Hydromechanics Institute, Ukrainian Academy of Sciences, have carried out experimental laboratory investigations, whose results are presented here, for investigating this characteristic under conditions of a very unstably stratified boundary layer forming during the interaction of the surface of a heated evaporating fluid and an oncoming flow of cold air. The experiment was carried out in a low-velocity wind tunnel with a low level of initial turbulence in which cells with heated water served as the lower wall of the working sector. The wind velocity was varied in the range 0.4-1.4 m/sec. (The design and description of the laboratory apparatus and the method employed in such work have been described by the author in earlier papers.) On the basis of use of a Reynolds analogy and employing a semiempirical two-layer model of turbulent near-wall currents the author was able to derive expressions for the temperature distribution, with allowance for stratification, for the currents at smooth and slightly rough surfaces. Figures 2; references 16: 14 Russian, 2 Western.

UDC 551.509.314:551.54

EVALUATION OF STATISTICAL INTERRELATIONSHIP OF HORIZONTAL AND VERTICAL RESOLUTIONS IN GEOPOTENTIAL FIELD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 9 Mar 81) pp 49-53

[Article by V. I. Martem'yanov, candidate of physical and mathematical sciences, Central Asian Regional Scientific Research Institute]

[Abstract] In describing atmospheric processes within the framework of different models it is necessary to take into account the interrelationship of horizontal and vertical resolutions in the fields of meteorological parameters. It can be governed both by the physical nature of the considered process and by its mathematical model and computation procedures employed. The shortest wave which can be resolved has the length Δs (Δp), equal to double the size of the interval in a regular grid δs (δp). In this article the author examines the interrelationship of horizontal and vertical resolutions only relative to some properties of the statistical structure of the fields of meteorological parameters. The concept of statistical equivalence of these resolutions is introduced under the condition of an equality of the corresponding values of the correlation coefficients $RH(\Delta s)$ and $RH(\Delta p)$. On the basis of this approach, for the winter and summer seasons in the middle and tropical latitudes it was possible to estimate the necessary vertical computation levels in hydrodynamic schemes for predicting the geopotential field as a function of the horizontal interval δs of a regular grid of points. The method proposed here is not tied in to any specific prediction scheme. The special features of a specific scheme may require a set of computation levels which is optimum for it and which differs somewhat from the set of levels used in in this paper. Figures 2, tables 1; references 8: 6 Russian, 2 Western.

UDC 551.594.253:537.241

CHARGE SEPARATION WITH PARTIAL COALESCENCE OF DROPLETS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 31 Mar 81) pp 54-57

[Article by S. V. Lopatenko and S. M. Kontush, candidate of physical and mathematical sciences, Odessa State University]

[Text]

Abstract: The authors modeled the charging process accompanying collisions of uncharged droplets of unlike sizes in the presence of a "bridge" between them and its subsequent breaking, which in the absence of an external electric field makes it possible to generate charged droplets. This requires use of the method of breakdown of a jet into monodisperse droplets. On the basis of a great quantity of experimental data it is concluded that in the investigated case the mechanism of charging of droplets is similar to the mechanism of charging in the presence of external electric fields.

Numerous investigations have established an extremely important role of collision of droplets in the development of atmospheric electric processes [4, 7, 11]. When droplets collide with one another, in addition to coalescence and recoil there is also an intermediate case -- recoil with partial coalescence [8, 16]. The separation of charges accompanying the collision of droplets in an electric field was investigated in [13, 15]. It is of interest to investigate charging during the collision of droplets with partial coalescence in the absence of external electric fields and in weak electric fields because such conditions are frequently observed in the atmosphere.

Recently quite detailed investigations have been made of the phenomenon of partial coalescence of droplets in the range of sizes and velocities corresponding, for example, to the falling of raindrops [3, 16]. These studies have revealed that with partial coalescence a temporary "bridge" is formed between droplets and there is a redistribution of their masses. Then this bridge is broken and the size of the escaping droplet is reduced. However, the patterns of such charging of droplets have not been investigated due to the short lifetime of the partial coalescence phenomenon itself, because in this case it is difficult to use traditional methods of charge measurement.

In the modeling of hydrodynamic and electric processes transpiring with the partial coalescence of droplets and reproduction of the modeling process over the course of a sufficiently long time it is possible to use the phenomenon of breakdown of a jet into droplets. The possibility of such modeling can be substantiated by introducing a similarity criterion. The parameters of the process of forming and charging of droplets are: σ is the surface tension of the solution, $kg \cdot sec^{-2}$; η is the dynamic viscosity of the solution, $kg \cdot m^{-1} \cdot sec^{-1}$; v is the rate of elongation of the bridge, $m \cdot sec^{-1}$; r is the radius of the forming droplet, m; t is the time of droplet formation, sec; ρ is the bulk resistivity of the solution, sec; χ is the surface potential of the solution, $kg^{1/2} \cdot m^{1/2} \cdot sec^{-1}$; Q is droplet charge, $kg^{1/2} \cdot m^{3/2} \cdot sec^{-1}$.

From these parameters it is possible to write the following similarity criterion:

$$\Pi_1 = \frac{\eta v}{\sigma}, \quad \Pi_2 = \frac{t}{\rho}, \quad \Pi_3 = \frac{Q}{r\chi}.$$

The first of these criteria quite clearly describes the process of fragmentation of a fluid into droplets [6, 14] and accordingly, establishes the similarity of the mechanical fragmentation processes. The second gives the important relationship between the characteristic times of the processes of charging and formation of a droplet, determining one or another degree of disruption of the electrical state of the fluid at the time of its destruction. The last criterion describes the process of charging of a droplet of a particular size to some charge with the presence of a surface potential at the surface of the fluid. The equality of the corresponding similarity criteria is the condition of similarity of two phenomena, that is

[M = model; H = real scale] $$\frac{\eta_M v_M}{\sigma_M} = \frac{\eta_H v_H}{\sigma_H}, \quad \frac{t_M}{\rho_M} = \frac{t_H}{\rho_H}, \quad \frac{Q_M}{r_M \chi_M} = \frac{Q_H}{r_H \chi_H}.$$

For one and the same solution $\eta_{mod} = \eta_{real}$, $\sigma_{mod} = \sigma_{real}$, $\rho_{mod} = \rho_{real}$, $\chi_{mod} = \chi_{real}$. Accordingly, it follows from the derived equalities that $v_{mod} = v_{real}$, $t_{mod} = t_{real}$ and if $r_{mod} = r_{real}$ it can then be assumed that the charges of the forming droplets are also equal, that is, $Q_{mod} = Q_{real}$.

Numerous investigations (for example, see [1, 2, 12]) confirm that the process of formation of an escaping droplet is similar to the process observed during the disintegration of a jet in the generator of monodisperse droplets (GMD) and that the times of formation of droplets in both cases can become commensurable by selecting a suitable frequency of GMD operation. In addition, the possibility of modeling of the charging of droplets in the case of recoil with partial coalescence by the process of disintegration of a jet in the absence of external electric fields is based on the experimental investigations described below which demonstrated that:

a) the charge of the droplets remains constant for particular concentrations of electrolyte and droplet size and is not dependent on the method for droplet formation and breaking of the "bridge";

b) the principal processes responsible for the electrification of the droplets transpire at the discontinuity of the fluid-gas phases, that is, electrokinetic processes at the fluid-solid state discontinuity exert no substantial influence on the charging process.

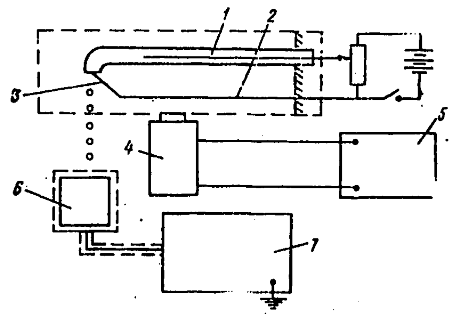
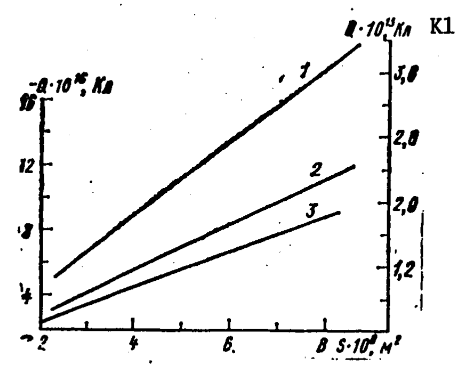


Fig. 1. Diagram of experimental apparatus. 1) capillary, 2) flexible metal plate, 3) needle, 4) electromagnet with metal core, 5) LF signal generator; 6) droplet collector (Faraday cylinder); 7) electrometer.



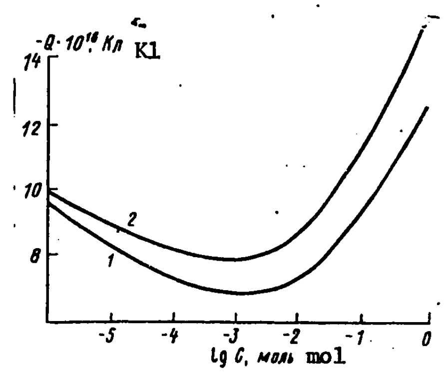


Fig. 2. Dependence of droplet charge on their surface area. Frequency of generation of droplets -- 34 sec^{-1}, copper needle. 1) artificial charge, $C = 10^{-4}$ mol KCl, U = 20 V; 2) natural charge, $C = 10^{-1}$ mol KBr; 3) natural charge $C = 10^{-5}$ mol NaCl.

Fig. 3. Influence of electrolyte concentration on droplet charge. Droplet diameter $1.5 \cdot 10^{-4}$m, Nichrome needle, frequency of generation of droplets 31 sec^{-1} 1) NaCl; 2) NaI.

In order to realize the proposed modeling method we assembled an experimental apparatus whose diagram is shown in Fig. 1. As the apparatus creating the monodisperse droplets we used a GMD with a vibrating needle periodically immersed in the fluid and upon emergence from it drawing out a fluid bridge from which the droplet is formed [1]. The chain of droplets from the GMD was directed into an electrically insulated collector. Between the collector and the ground the electric current was measured with a sensitive electrometer. We found that the droplets have an identical charge and therefore the charge of one droplet is found by dividing the measured current by the number of droplets entering the collector in a unit time. By feeding a regulated potential difference from a d-c source to the solution and the needle it is possible to accomplish artificial charging of the droplets. The size of the droplets was determined using a microscope after their precipitation on a backing covered with a thin layer of vaseline and transformer oil. In order to avoid the influence of external electric fields the apparatus was carefully screened and grounded. The error in measuring the magnitude of the charge of the droplets in the process of their generation did not exceed 3%. In the experiments we used aqueous solutions of salts present in cloud and rain droplets.

The following conclusions can be drawn from the numerous experimental data collected.

1. With the feeding of a d-c voltage to the needle and fluid the droplet acquires a charge proportional to the product of the density of the surface charge χ and the area of the droplet surface S (Fig. 2, curve 1), which agrees with the results from studies [5, 9].

2. The charge of the droplets forming as a result of disintegration of nonstationary bridges of aqueous solutions of inorganic electrolytes in the absence of external electric fields is negative and its value is described by a dependence of the type $Q = \chi \cdot S$ (Fig. 2, curves 2, 3).

Although the charging of the droplets in both cases is described by one and the same law, the density of the surface charge of fluid is governed by different factors: in the first case -- by the separation of charges in the fluid under the influence of a d-c voltage fed to the fluid and needle, and in the second case -- by the adsorption of ions and the orientation of dipoles at the moving discontinuity of the fluid-gas phases. Accordingly, the mechanism of development of charge surface density is not of decisive importance for the process of droplet charging.

3. The variation of dependence of droplet charge on the concentration of solution of electrolyte in the case of natural charging of droplets (Fig. 3) agrees completely with the variation of the dependence of the potential jump at the discontinuity of the solution-air phases on the electrolyte concentration [10] of one and the same type.

4. The feeding of the potential difference from a source of d-c voltage to the needle and solution indicated that the absolute droplet charge is determined by its capacitance C multiplied by the surface potential value U, that is, $Q = CU$. The determined dependence agrees with the results of studies [5, 9].

Accordingly, the value of the droplet charge is proportional to the fluid surface potential at the time of droplet formation.

It follows from the above that:

-- both the artificial and the natural charging of droplets conforms to the induction theory of charging;
-- the charging at the time of collision of droplets with partial coalescence can be interpreted as the charging of a fluid with some natural potential jump at the moving solution-air discontinuity.

Thus, with the collision of two droplets of noncomparable size (with diameters of 10^{-3} and 10^{-4} m respectively) with partial coalescence there is a redistribution of masses. The diameter of the smaller, escaping droplet is approximately $7 \cdot 10^{-5}$ m [3]. The lifetime of the bridge between the droplets at the time of their collision is commensurable with the time of formation of droplets at a given frequency of GMD operation. Accordingly, the charge of a droplet can be estimated by knowing its size, chemical composition of the fluid or the surface potential χ. An estimate of the charge of the escaping smaller water droplet with $\chi = -0.1$ V [10] gives a value of about $-4 \cdot 10^{-16}$ Kl.

The results may be useful in computing the electrification of precipitation because the collision of uncharged droplets of a particular chemical composition with the formation of a bridge and its subsequent breaking leads to the generation of charged droplets. On the basis of the collected data and further investigations it is possible to give recommendations on the artificial stimulation of some processes leading to a change in the state of clouds.

BIBLIOGRAPHY

1. Vol'f, V. R., "Investigation of the Vibrator Method for Producing Homogeneous Small Droplets and Solid Particles," PRIBORY DLYA NAUCHNYKH ISSLEDOVANIY (Instruments for Scientific Research), No 10, 1961.

2. Kolpakov, A. V. and Kontush, S. M., "Anomalous Type of Recoil in the Collision of Water Droplets of Noncomparable Size," FIZIKA AERODISPERSNYKH SISTEM (Physics of Aerodisperse Systems), No 12, 1975.

3. Kolpakov, A. V. and Kontush, S. M., "Some Laws of Interaction of Droplets," FIZIKA AERODISPERSNYKH SISTEM, No 14, 1976.

4. Krasnogorskaya, N. V., ELEKTRICHESTVO NIZHNIKH SLOYEV ATMOSFERY I METODY YEGO IZMERENIYA (Electricity of the Lower Layers of the Atmosphere and Methods for Measuring It), Leningrad, Gidrometeoizdat, 1972.

5. Leb, L., STATICHESKAYA ELEKTRIZATSIYA (Static Electrification), Moscow-Leningrad, Gosenergoizdat, 1963.

6. Lipatov, G. N. and Kontush, S. M., "Operation of a Generator of Monodisperse Droplets With a Vibrating Needle," FIZIKA AERODISPERSNYKH SISTEM, No 9, 1973.

7. Muchnik, V. M., FIZIKA GROZY (Thunderstorm Physics), Leningrad, Gidrometeoizdat, 1974.

8. Solov'yev, A. D., "Coalescence of Droplets During Collision," TRUDY TsAO (Transactions of the Central Aerological Observatory), No 89, 1969.

9. Tammet, Kh. F., "Induction Electrification During Spraying of Fluids," UCH. ZAPISKI TARTUSKOGO GOSUNIVERSITETA (Scientific Notes of Tartu State University), No 140, 1963.

10. Frumkin, A. N., Iofa, Z. A. and Gerovich, M. A., "On the Problem of the Potential Difference at a Water-Gas Discontinuity," ZHURNAL FIZICHESKOY KHIMII (Journal of Physical Chemistry), Vol 30, No 7, 1956.

11. Chalmers, J. A., ATMOSFERNOYE ELEKTRICHESTVO (Atmospheric Electricity), Leningrad, Gidrometeoizdat, 1974.

12. Abbott, C. E. and Cannon, T. W., "A Droplet Generator With Electronic Control of Size, Production Rate and Charge," REV. SCI. INSTR., Vol 43, No 9, 1972.

13. Al-Saed, S. M. and Saunders, C. P. R., "Electric Charge Transfer Between Colliding Water Drops," J. GEOPHYS. RES., Vol 81, No 15, 1976.

14. Hidy, G. M. and Brock, J. R., THE DYNAMICS OF AEROCOLLOIDAL SYSTEMS, Pergamon Press, 1970.

15. Jennings, S. G. and Latham, J., "The Charging of Water Drops Falling and Colliding in an Electric Field," ARCH. METEOROL. GEOPHYS. BIOKL. SER. A, Vol 21, 1972.

16. Whelpdate, D. M. and List, R., "The Coalescence Process in Raindrop Growth," J. GEOPHYS. RES., Vol 76, No 12, 1971.

UDC 551.52(571.62)

EVALUATING SPATIAL-TEMPORAL VARIABILITY OF HEAT AND WATER BALANCE COMPONENTS IN EASTERN SECTOR OF BAYKAL-AMUR RAILROAD ROUTE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 31 Mar 81) pp 58-70

[Article by V. N. Adamenko, doctor of geographical sciences, A. L. Bogdanov and P. V. Novorotskiy, Limnological Institute, USSR Academy of Sciences, and Khabarovsk Multidiscipline Scientific Research Institute]

[Abstract] On the basis of remote methods for measuring albedo and temperature of the underlying surface it was possible to estimate the spatial variability of albedo, radiation temperature and the radiation balance for characteristic types of landscapes in the eastern part of the route of the Baykal-Amur Railroad line. The field studies were made in mid-August 1977 using a helicopter. The surveys were made at midday at an average height of 50-100 m. Between 10 and 100 measurements were made for each of the selected landscapes in order to ensure the collection of representative data. (Fig. 1 is a schematic map of types of underlying surface in the area; Table 1 gives the radiation and thermal characteristics of these different surfaces.) The study revealed that allowance for changes in albedo and temperature of the underlying surface determined by remote methods makes it possible to evaluate the radiation balance components in moderately rugged areas. The highest radiation balance for the eastern part of the area is characteristic for water surfaces and the minimum is characteristic of rocky areas. During the warm season the micro- and mesoscale spatial inhomogeneity of components of the heat and water balances is comparable with or close to the macroscale inhomogeneity. Allowance for the influence of exposure in an evaluation of the spatial inhomogeneity of heat and water exchange is especially important for northern slopes, whereas on the southern slopes under the considered conditions it is close to lowland conditions. The energy fluxes on the eastern slopes are 3-8% greater than on the western slopes. A study of the supplies of heat and moisture in this area revealed that the nature of the underlying surface substantially changes the structure of the heat balance. Figures 5, tables 4; references: 20 Russian.

UDC 551.467.03(261)

NEW METHODS FOR ICE FORECASTS FOR THE NORTHWESTERN ATLANTIC

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 11 Feb 81) pp 71-76

[Article by B. A. Kogan and N. F. Orlov, candidates of geographical sciences, Murmansk Affiliate, Arctic and Antarctic Scientific Research Institute]

[Text]

Abstract: The article gives the results of investigations for finding new methods of ice prediction for the Davis and Denmark Straits and Labrador Sea. The basis for the proposed methods is the physicostatistical relationships between individual ice characteristics and hydrometeorological factors. The features of these methods and the possibilities of their use in solving different problems in the national economy are pointed out.

The regions of the Northwestern Atlantic have long been zones of active navigation and fishing. The success and safety of marine work in this region are dependent to a great extent on the ice conditions prevailing here. Ice prognostic information is of special importance for fishing organizations under the modern conditions of introduction of economic zones and licensed catching. Until recently there were extremely few methods for predicting ice conditions in the considered region. For the winter months there are no such methods, whereas for the summer season they are in need of improvement. The hydrometeorological support of fishing work in the Labrador Sea and Davis Strait has been accomplished primarily by the method developed in 1965 [3], which makes it possible to obtain prognostic information on the ice content and the position of the ice edge in the region in April-July. However, the guaranteed probability of these data does not always satisfy the increasing demands of practical work. The individual dependences recently proposed for evaluating the Baffin Bay ice mass area [6] can be used only in refining the principal March forecast.

It follows from a brief review of the studies that the considered problem required further development. In this connection, during the last five-year period a number of investigations have been carried out in which on the basis of more complete observational data there has been an analysis of the processes of development of ice conditions in seas of the Northwestern Atlantic and new methods for sea ice forecasts have been proposed.

The principal results of these investigations are discussed in this article.

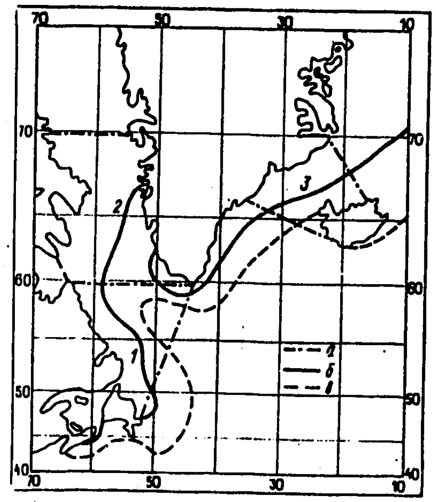


Fig. 1. Region of investigations and zone covered by ice in cold season of year. Boundaries of regions (a): 1) Labrador Sea, 2) Davis Strait, 3) Denmark Strait, b) mean and c) maximum boundary of occurrence of floating ice.

The basis for the developed methods was the asynchronous physicostatistical relationships (established by correlation analysis) between individual ice characteristics and the hydrometeorological processes responsible for the redistribution of ice in the Northwestern Atlantic. Among these, in particular, we should mention the peculiarities of change in the thermal state of the ocean and atmosphere in the near-lying regions during the months preceding the ice period, variations in the circulation of air masses and the transport of ice from the polar regions into the North Atlantic.

The selected most informative predictors make it possible to predict the mean monthly ice content values and the position of the ice edge in the seas of the Northwestern Atlantic with an advance period from 2 to 8-10 months, and for the Labrador Sea -- also provide mean 10-day information on the distribution of ice. The probable success and guaranteed probability of the recommended regression equations is 70-90%, and their advantage over climatic forecasts attains 15-20%.

For the practical use of the new methods detailed recommendations have been prepared on the preparation of initial data and the carrying out of prognostic computations. It must be emphasized that as the initial information use is made only of actual values without data from background meteorological forecasts and all computations are made on an electronic computer. Such an approach not only favors an increase in the reliability of the results, but also accelerates their output, not requiring great expenditures of labor. Thus, with use of the proposed methods it becomes possible to predict the ice content and position of the ice edge for three important regions: Davis Strait, Denmark Strait and the Labrador Sea, and for seasons for which forecasts had not been previously prepared. Now we will discuss in somewhat greater detail the features of each of the methods mentioned above.

The proposed method for forecasting ice conditions in Davis Strait and the Labrador Sea [5] makes it possible to compute the mean monthly ice content of these regions for the entire ice period from January through July with an advance period from two to ten months. As the predictors use is made of the coefficients of expansion of the fields of air temperature, water temperature and atmospheric pressure for optimally defined regions of the northern hemisphere and for weather ships, and also the characteristics of the ice content of the region during the preceding period. The optimum grid region was selected after a preliminary investigation of the features of regional atmospheric processes during the formation of the ice cover and the history of their development in the hemisphere. It was found, for example, that a positive surface atmospheric pressure anomaly in the Spitzbergen region foreshadows severe ice conditions in the Northwestern Atlantic in the next cold season. The localization of positive air temperature anomalies over the Pacific Ocean during the preceding year is characteristic for favorable ice conditions in the considered zone of the ocean for the future season, etc. Such regions, in which the changes of meteorological elements occurred sooner and were expressed more appreciably, were used as a grid region for the reading of data and the discrimination of informative predictors. In the algorithm of the computation scheme for determining the mean monthly ice content of the region provision is made for correcting the coefficients of the regression equations prior to each preparation of a forecast, allowance for the influence exerted on ice conditions by hydrometeorological factors at different time scales and adaptation of the scheme to the climatic trends in the form represented in Fig. 2.

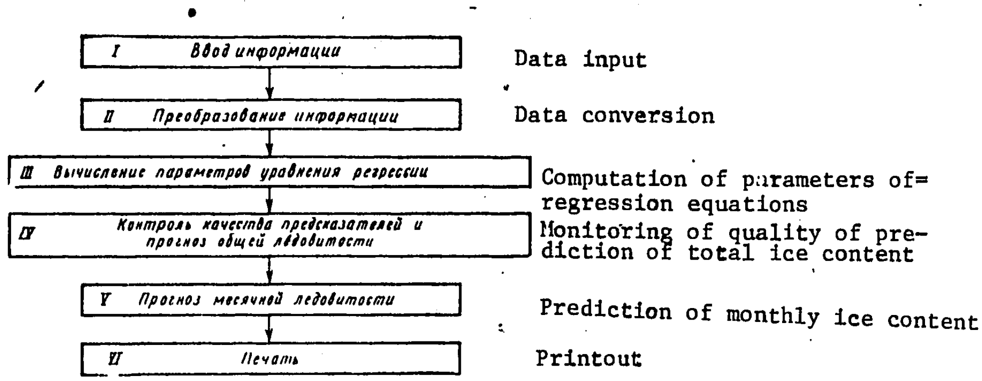


Fig. 2. Block diagram of forecast of ice conditions in regions of Northwestern Atlantic Ocean.

In block I there is magnetic tape registry of information on the predictors X and ice content L for the entire observation period. The values of the predictors and ice content are averaged with a period of 3 months.

Prior to each forecast the information X and L is supplemented by current observations. At the same time provision is made for the possibility of eliminating from the X and L masses all information for the earlier years. Such a procedure will make it possible to optimize the volume of the sample for the forecast and in part to exclude the influence of long-period changes in climatic conditions on the coefficients of the prognostic equations.

A transformation of the data occurs in block II. The data masses are sorted in two stipulated classes. This is followed by computations of the covariational R and covariant R^* matrices, an equation of the form $(R^* - \lambda R)\mu = 0$ is solved and the secondary indicators of T are found.

In block III there is solution of a system of normal equations with a free term in the form $\hat{b} = (T'T)^{-1}T'L$, where as the variable L use is made of data on the ice content of the region and T are secondary indicators corresponding to the maximum eigenvalue of the correlation matrix λ_1.

In block IV computations are made of the total ice content of the region for the stipulated period L_{pred} and the nonclosure of the prognostic equation $\varepsilon(t) = L_{act} - L_{pred}$ and the multiple correlation coefficient ρ are determined.

In block V there is an approximation of ice content by months for the period of growth (destruction) of the ice cover. The total ice content for the entire period, mean monthly ice content of the region and the parameters of the prognostic equation are printed out.

However, the prediction of the ice content of the Northwestern Atlantic gives only a general idea concerning impending ice conditions in the region without revealing the boundaries of occurrence of floating ice. Accordingly, thereafter a method was developed for the long-range forecasting of the position of the ice edge in the Labrador Sea during the winter months from December through March, that is, during the period of ice formation when the ice attains its most easterly position and in many respects governs the success of fishing and navigation. For prognostic computations by this method use is made of actual data on water and air temperature in the region of weather ships A, B, C, I, J, air temperature and pressure anomalies for individual regions and air temperature at three shore stations: Baker Lake, Eureka and Prince Christiansund for February-October of the preceding year. The advance time of the forecast is 4-5 months. Accordingly, already at the onset of September it is possible to prepare a forecast of the ice edge position in the Labrador Sea for December-January, and early in November -- for February-March. All the computations on a "Minsk-32" computer are made in 10-15 minutes. The predicted position of the ice edge for each month is plotted on a digigraph for each month and the results of the computations are fed out in a tabulated form convenient for practical use.

The program provides for annual correction of the regression equations by the receipt of new hydrometeorological and ice information. Thus, the proposed method for predicting the mean monthly position of the ice edge for the first time makes it possible to obtain necessary information on the occurrence of ice in the Labrador Sea during winter. This can be useful in solving various problems of importance to the national economy. The mean guaranteed success of these forecasts for 1979-1980 was 81%.

In addition to study of the physicostatistical means for long-range forecasting of the ice edge position in the Labrador Sea, a study was made of the possibility of using the dynamic-statistical method proposed by Yu. M. Alekhin. In solving the formulated method use was made of a 10-15-year series of observations of the ice edge with a forecast advance time of 5-8 months. The computations were made separately for each parallel each degree of latitude in the zone 50-60°N. The guaranteed success of the results was 80-90%; the mean guaranteed probability of the experimental forecasts of the ice edge for the winter months of 1979-1980 was 92%.

In addition to the considered methods, for the Labrador Sea a method was also developed for the short-range forecasting of the position of the ice edge for an advance time up to 10 days [4]. It takes into account ice inertia, ice drift along the Labrador Current and the dynamic state of the atmosphere over the region. In order to decrease the influence of observational errors and short-period variations the mean 10-day anomalies of ice edge position were smoothed by the moving averages method with an averaging period of 30 days. The autoregression equations which were written initially make it possible to evaluate the fluctuations of the edge caused by macroscale processes.

Then computations were made of the differences between the actual position of the ice edge and its position determined using the autoregression equation. The nonclosures of the autoregression model of the forecast were adopted as a variable value subject to prediction. As the principal predictors in this stage use was made of processes on a synoptic scale, in particular, the values of the Laplacian of atmospheric pressure over the region and the mean 10-day ice edge position, taken at the distance of the spatial correlation radius of the edge in the direction of the source of the Labrador Current. The autoregression equation for the ice edge and the determined relationships between the nonclosure and the indicated synoptic scale indices constituted a scheme for predicting the position of the ice edge for a 10-day period. A forecast of the mean 10-day ice edge position was made for the zone 50-56°N. Tests of the method on the basis of independent materials indicated its adequate reliability (guaranteed success 88%) and it has now been adopted for routine hydrometeorological support.

The northern regions of the Atlantic, such as the zone of Denmark Strait, for which ice forecasts were not earlier prepared, are poorly studied but important for navigation and fishing.

As a result of the investigations made it was possible to define the principal features of the ice regime in the strait and a method was proposed for long-range forecasting of the ice content and ice edge position for April-August [1]. As indicated by an analysis, the great variability of ice conditions in this region is determined to a great extent by the simultaneous influence of the waters of the Atlantic and Arctic Oceans, variations of atmospheric circulation and a number of other factors. In particular, in the method for predicting ice content and ice edge position as the initial information use is made of data on water temperature in the neighborhood of weather ships A, B, K, E, intensity of the Icelandic Low and air temperature at the shore stations Barentsburg, Cape Tobin and Jan Mayen for the autumn-winter period. These predictors make it possible to predict ice conditions in the strait for each month of the spring-summer season (April-August) with an advance time of 2-6 months. Prediction of the edge is printed out for six parallels for the zone 65-70°N. Operational tests of this method have shown that it can be used in practical work. Similar work was also carried out for predicting the ice content and the ice edge position in Denmark Strait in the autumn-winter months [2].

The availability of new prognostic ice information for the regions of the Northwestern Atlantic will assist marine and fishing organizations in correct planning of the distribution of the fishing and transportation fleets, in planning the safest crossing routes, in evaluating the desirability of buying licenses for the taking of fish, etc.

For example, in the Labrador Sea the greatest concentration of fish schools is usually noted in its shelf zone.

An eastward movement of the ice boundary leads to a reduction of the regions of fishing and makes it necessary to move the ships beyond the limits of the shelf. Accordingly, timely information on the possible position of the ice edge in the sea can favor the adoption of a sound decision concerning relocating of the fleet or carrying out licensed catching.

For most fishing and transport ships ice also constitutes a direct danger, especially under conditions of storms, fogs and poor visibility frequently observed in the northwestern regions of the Atlantic. Accordingly, timely knowledge concerning ice conditions in the considered zone of the ocean will also favor a decrease in damage to ships and an increase in the effectiveness of navigation.

BIBLIOGRAPHY

1. Kogan, B. A., Nikol'skaya, N. A. and Zuyev, A. N., "Prediction of Ice Content and Position of Ice Edge in Denmark Strait in Spring-Summer," PROBLEMY ARKTIKI I ANTARKTIKI (Problems of the Arctic and Antarctic), No 52, 1977.

2. Kogan, B. A. and Zuyev, A. N., "Possibilities of Predicting Ice Content and Position of the Ice Edge in Denmark Strait During Autumn-Winter," TRUDY AANII (Transactions of the Arctic and Antarctic Scientific Research Institute), Vol 348, 1980.

3. Lebedev, A. A., "Variability of Ice Conditions in Northwestern Atlantic," TRUDY GOIN (Transactions of the State Oceanographic Institute), No 87, 1965.

4. Orlov, N. F., "Method for Predicting Position of the Ice Edge for Ten Days in the Labrador Sea," TRUDY AANII, Vol 348, 1980.

5. Orlov, N. F., "Experience in Applying Image Recognition Theory for Long-Range Forecasting of Ice Conditions in the Northwestern Atlantic," TEZISY DOKLADOV IV VSESOYUZNOY KONFERENTSII PO PROMYSLOVOY OKEANOLOGII (Summaries of Reports at the Fourth All-Union Conference on Oceanology of Fisheries), Murmansk, 1977.

6. Smirnov, V. I., "Patterns in the Redistribution of Ice in the Waters of the Foreign Arctic," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 11, 1979.

UDC 551.456

MECHANISMS OF FORMATION OF UPPER QUASIHOMOGENEOUS LAYER IN OCEAN

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 26 Feb 81) pp 77-82

[Article by V. D. Zholudev, Kabardino-Balkarskiy State University]

[Text]

Abstract: Within the framework of the proposed similarity theory for the upper layer of the ocean it was possible to establish a correlation between a laboratory study of the upper quasihomogeneous layer (UQL), observations of its state under the conditions prevailing in the open ocean and numerical modeling using one-dimensional models. The article gives an example of computations of the characteristics of the UQL for a storm situation observed in the middle latitudes, taking into account the intradiurnal variability of insolation.

The investigations of Garwood [19] and the method which he proposed for dimensionless comparison of different integral models of the upper quasihomogeneous layer (UQL) of the ocean cast light on many unclear problems relating to the theory of one-dimensional oceanic models. Below we describe one of the approaches to formulation of a similarity theory for the upper layer of the ocean which can be used in a study of the layer of convective-wind mixing for the conditions prevailing both in the open ocean and in a laboratory experiment.

Mechanical mixing. We will assume that the set of determining parameters describing the nonstationary state of the UQL is as follows: thickness of the UQL h, scale of turbulent velocity, equal to the friction velocity in the water v_*, intensity of turbulence b, vertical turbulent kinematic heat flow from the fluid surface into the depths Γ_0 (positive if the flow is directed downward), velocity of entrainment w_*, temperature jump $\Delta T = T_0 - T_h$ (T_0 and T_h are water temperatures in the UQL and at the upper boundary of the thermocline), Coriolis parameter f and buoyancy parameter αg (α is the coefficient of thermal expansion of water, g is the acceleration of free falling). It follows from the Π-theorem [2] for the dimensionless velocity of entrainment $w_e = w_*/v_*$ that

$$w_e = \Phi(\alpha g h \Gamma_0/v_*^3,\ \ \alpha g h \Delta T/v_*^2,\ \ fh/v_*,\ \ b/v_*^2), \tag{1}$$

where Φ is a universal function of the similarity parameters: Richardson flow number Rf_0, global Richardson number Ri_*, the parameter Ro^{-1}, inverse of the Rossby number for the boundary layer, and the dimensionless parameter E_*.

The theory of dimensionalities does not give a specific functional correlation for the relationship (1) and therefore it is first necessary to examine self-similar cases of this general correlation, studied by different researchers. If the formula derived in [21] is refined for the dimensionless velocity of entrainment as a function of the Richardson number $Rf\_ = w_e Ri_* = c_{KP}$ thus [13]:

$$Rf_h = w_e (Ri_*/c_{KP} + E_*/c_E) = 1, \qquad (2)$$

then on the assumption that for well-developed mechanical mixing $b = cm\ v^2$ [11], we arrive at the expression derived and checked applicable to the data of Kato and Phillips in [3]. It better describes the results of the mentioned experiments with mixing of a closed volume of fluid under the influence of the imparted shearing stress and also correctly takes into account the self-similar regime of propagation of the turbulence front in a homogeneous fluid when with a temperature (to be more precise, density) jump equal to zero at the lower boundary of the UQL we have $w_e = c_E/c_M$ [1, 23].

The self-similar case for purely wind mixing $Ro^{-1} = c_R$, following from (1) on the assumption of a complete self-similarity of the function Φ_1, and the expression $Ro^{-1} = \Phi_1(w_e,\ Rf_0,\ Ri_*,\ E_*)$, following from (1) with respect to the similarity parameters enclosed in the parentheses, and the correlation of the velocity scale with the Ekman theory of drift currents have been studied in [14, 24], whereas the case $Rf_0 = c_{KT}$ was studied in [9, 17, 22].

It is confirmed by observations in the open ocean [20, 25] that the h values correlate statistically well with the scale v_*/f for the moments of a purely wind effect on the ocean. On the other hand, the periods of decrease in the thickness of the QHL correlate with the values of the Monin-Obukhov oceanic scale $v_*^3/\alpha g \Gamma_0$, decreasing simultaneously with h [17, 18], so that the correlation

$$1 - Ro^{-1}/c_R - Rf_0/c_{KT} = 0, \qquad (3)$$

following from these investigations should reflect the periods of antientrainment, that is, when $dh/dt \leqslant 0$. It is possible to derive a formula from (3) for computing the minimum thickness of the UQL h_m with heating in a quasistationary case [12]: $c_R v_*/f = h_m(1 + c_R \alpha g \Gamma_0/c_{KT} f v_*^2)$.

The generalizing expression, not contradicting (2) and (3),

$$w_e (Ri_*/c_{KP} + E_*/c_E) = 1 - Ro^{-1}/c_R - Rf_0/c_{KT} \qquad (4)$$

represents the equation for the balance of turbulent energy in the UQL in integral form. (Everywhere in the text the parameters designated with the subscript C are constants.)

Convective mixing. Assuming an invariance of expression (4) relative to the parameters determining the dynamics of mixing in the UQL in the case of well-developed turbulence, regardless of what its cause may be -- mechanical or convective factors, introducing the convective scale of turbulent velocity $v_0 = (\alpha gh \mid \Gamma_0 \mid)^{1/3}$ and assuming that $b - c_C c_E v_0^2$, we obtain

$$\frac{w_*}{v_0}\left(\frac{\alpha gh\Delta T}{v_0^2 c_{KPC}} + c_C\right) = -\frac{\alpha gh\Gamma_0}{v_0^3 c_{KTC}}. \quad (5)$$

Here the difference $1 - Ro^{-1}/c_R$ is neglected because it is assumed that being in the field of free convection, with large negative values of the stability parameter Rf_0 the role of mechanical turbulence in the vertical transfer of momentum and heat can be neglected; in this case the v* parameter drops out of the similarity formulas [11] and it follows from observations that the scale v_0 is important [20]. The nondependence of the thickness of the planetary boundary layer on the Coriolis parameter under free convection conditions indicates absence of any appreciable correlation between the thickness of the oceanic surface layer of mixing and latitude [10].

A. Penetrating convection. Neglecting the additive constant c_C in (5) and assuming $c_T = c_{KPC}/c_{KTC}$, from [13, 26] we derive that

$$\Gamma_- = \Delta T w_* = -c_T \Gamma_0, \quad (6)$$

where Γ_- is the entraining heat flow at the lower boundary of the UQL.

If c_C is taken into account, then with $c_C c_{KPC} = c_{TZ}$ the following expression follows from (5)

$$\Delta T w_* = -c_T \Gamma_0 \left(1 + c_{TZ} w_* \Gamma_0^{2/3} / c_T \Gamma_0 (\alpha gh)^{1/3}\right), \quad (7)$$

which is equivalent to the expression for free convection derived from energy considerations [13, 27].

B. Nonpenetrating convection. With $\Delta T = 0$, from the equating of the expression in parentheses on the right-hand side of (7) to zero, we derive an expression for the velocity of the downward movement of the lower boundary of the UQL in the presence of free convection in a homogeneous fluid [4], but the heat flow Γ_- from the determination of (6) is equal to zero, as is described by [7], but, we emphasize, $c_T \neq 0$.

A self-similar surface of the balance of turbulent energy in the system of self-similar coordinates Rf_-, Ro^{-1}, Rf_0, proposed in [19], can be constructed on the basis of equations (4) and (5); in this case it is necessary to neglect the constants c_M/c_E, c_C and take into account that the entraining heat flow and the Ro^{-1} parameter are nonnegative. The line of intersection of these two planes will represent the boundary of transition of the mixing process from forced to free convection. The points c_{KP}, c_{KT}, c_R and the segments of the straight lines connecting them represent cases of complete self-similarity of the process with respect to the corresponding similarity parameters. Part of the plane $c_{KP}c_{KT}c_R$ should reflect the mechanical mixing (with heating in a case $Rf_0 > 0$). The segment $c_R c_{KT}$ is the "antientrainment trajectory," and it can be used in processing observational data in the ocean in order to find, in particular, the c_R and c_{KT} values (see Fig. 1). Cases of forced convection with cooling will be given by the part of the surface $c_R c_{KT} c_{KP}$ extending into the region of negative Rf_0 values.

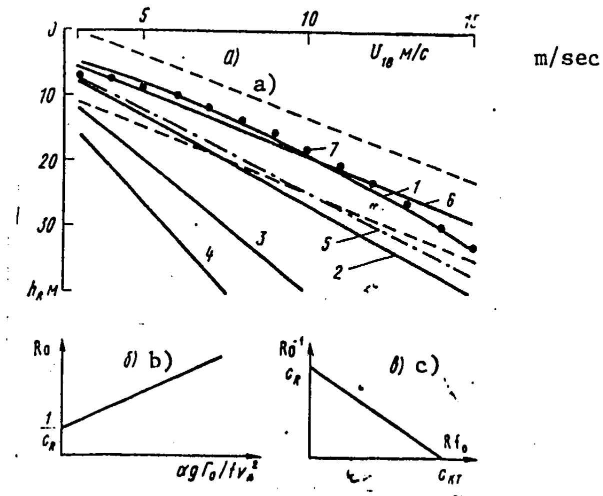


Fig. 1. Thickness of UQL as function of wind velocity. a) computations using formula $h_R = c_R v_*/f$ with a variable drag coefficient for computing wind shearing stress: $10^3 C_D = 0.77+0.068\ U_{18}$ [6] and $c_R = 0.15$ (1), and also computations with constant $C_D = 1.5 \cdot 10^{-3}$ and with coefficient c_R equal to 0.2 (2); 0.3 (3); 0.4 (4) and with $C_D = 1.3 \cdot 10^{-3}$ with $c_R = 0.2$ (5). Regression dependences [25]: linear 0.2+ 1.92 U_{18}, (6) and quadratic $0.2+0.120\ U_{18}^2$ (7). The dashed line represents the standard deviation (6.1 m) from the straight line 6, b, c) methods for determining the coefficients c_R and c_{KT} from results of in situ observations.

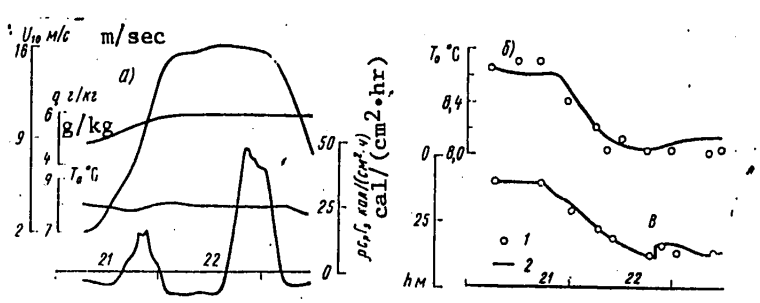


Fig. 2. Storm, station Papa, 21-23 June 1970 [16]. a) stipulated atmospheric parameters: wind velocity, specific humidity and air temperature and also resultant heat flow through water surface with allowance for sought-for temperature of UQL and intradiurnal change of insolation; b) observed values of temperature and thickness of UQL (1), and also computed from model of upper layer with allowance for rotation with $c_{KT} = c_{KP} = 3.0$; $c_R = 0.2$; $c_T = 0.3$ (2). Note the jumplike decrease in thickness of UQL at time B -- transition from free nighttime convection to daytime heating.

Evaluation of constants. The described similarity theory makes it possible to conclude that the constants entering into the determining relationships (4) and (5) can be determined in an experimental and (or) theoretical study of special cases of the process of mixing in the UQL.

In order to evaluate the constant c_R we will use the results [25] of determination of the thickness of the QHL as functions of wind force at a height of 18 m at the weather station Papa (50°N, 145°W). Figure 1 shows the dependences $Ro^{-1} = c_R$ in comparison with the results in [25], from which it is obvious that the use of c_R values greater than 0.2 can lead to overestimates of the thickness of the UQL or to erroneous conclusions concerning the influence exerted on the dynamic state of the UQL by other parameters.

From the observations in [17] it is possible to estimate the value $c_{KT} = 2.7$.

Due to the paucity of the data in the numerical experiments for the time being we will use $c_{KT} = c_{KP}$ [22] and the value of the latter was evaluated by the authors of [21] with a 30% scatter: $c_{KP} = 2.5$. Adhering to [23], we select $c_M/c_E = 3.6$. We will assume the constant c_T to be equal to 0.3 and $c_{TZ} = 2.6$ [27].

Reaction of ocean to atmospheric effects. As an illustration of the presented theory in Fig. 2 we give the results of computations of the temperature and thickness of the UQL for a storm situation for weather station Papa on 21-23 June 1970 (see [16]). In the computations we used the known equations of a one-dimensional integral model of the upper layer of the ocean with parameterization of temperature in the thermocline by a linear profile [13]. The entrained heat flow at the lower boundary of the QHL (Γ_{-}) was determined from (4) and (5) during entrainment and it was assumed equal to zero in the case of antientrainment. In order to determine the resultant heat flow at the ocean surface Γ_0 from the sought-for temperature of the ocean surface and atmospheric characteristics we made use of the equation for the heat balance at the ocean surface; the turbulent flows of apparent and latent heat were found from integral aerodynamic formulas [10] with coefficients of turbulent exchange equal to the drag coefficient of the sea surface, linearly dependent on mean wind velocity at the anemometer level [6]. The figure shows that the results are encouraging. Using a similar model of the upper layer of the ocean, the author of [7] studied the seasonal cyclic variability, whereas in [5] use was made of expression (2) and with application of the equations of motion a study was made of the reaction of a stratified ocean to a tropical cyclone.

Figure 3 shows computations of the thickness of the UQL in the case of purely wind mixing ($\Gamma_0 = 0$) for a wind force with a normal distribution in time. For comparison with the model computations of Denman [15], who used a model of the UQL not taking rotation into account, we selected the following initial values for temperature and thickness of the UQL: $T_0 = 8.5°C$, $h = 10$ m, and a temperature at the upper boundary of the thermocline of 8.0°C. The temperature profile in the thermocline is linear, with a vertical gradient of $-0.0385°C \cdot m^{-1}$. It can be seen from the results of computations that by an adjustment of the empirical constants it is entirely possible to achieve a satisfactory agreement of the results for essentially different models of the UQL. In a study of the real interaction between the ocean and the atmosphere the heat flows at the water-air discontinuity, having a masking influence on evolution of the upper layer of the ocean, are highly important, so that it is difficult for researchers to separate the factors causing a particular character of behavior of the UQL, and therefore it is difficult to select a proper physical model.

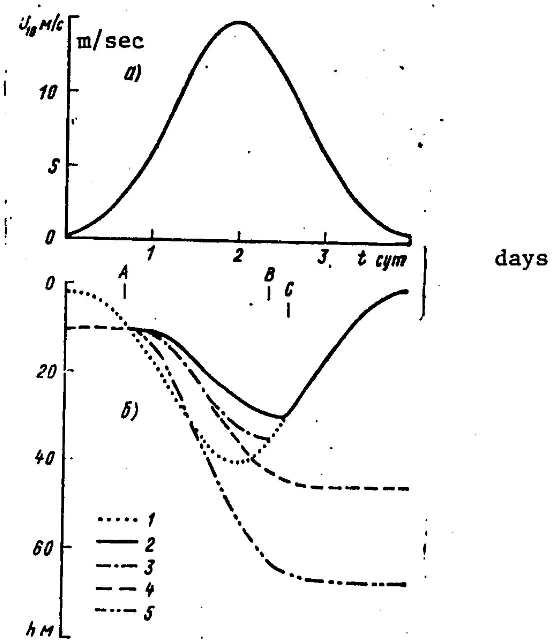


Fig. 3. Purely wind mixing ($\Gamma_0 = 0$). a) change in wind velocity at 10-m level in conformity to law $U_{10}/U_m = \exp(-0.5((t - a)/sec)^2)$ with $U_m = 15$ m/sec, a = 2 days, c = 0.75 day; b) thickness of UQL. Computations taking rotation into account (f = $10^{-4}sec^{-1}$); stationary case $h_R = 0.2v_*/f$ (1), computation using model with c_{KP} = 2.0 (2) and c_{KP} = 6.0 (3). With rotation neglected: c_{KP} + 2.0 (4) and c_{KP} = 6.0 (5). According to the model with rotation the initial moment corresponded to point A, when h_R = 10 m. We note the almost complete coincidence of the results for different models over the course of two days (segment AB). At the times B and C there is a change in the entrainment process to an antientrainment process within the framework of a model with rotation taken into account, whereas for a model with f = 0 during the entire considered period there is a deepening of the UQL.

Conclusions. The proposed approach to formulation of a similarity theory for the upper layer of the ocean makes it possible to establish a relationship between laboratory investigations for study of mixing of the fluid under the influence of a source of turbulence, make observations of the behavior of the UQL under the conditions prevailing in the open ocean and model the local interaction between the ocean and the atmosphere. The values of the empirical constants determined in an examination of self-similar cases must evidently differ not too greatly from their values for a general case.

BIBLIOGRAPHY

1. Barenblatt, G. I., "Strong Interaction of Gravitational Waves and Turbulence," IZV. AN SSSR: FIZIKA ATMOSFERY I OKEANA (News of the USSR Academy of Sciences: Physics of the Atmosphere and Ocean), Vol 13, No 8, 1977.

2. Barenblatt, G. I., PODOBIYE, AVTOMODEL'NOST', PROMEZHUTOCHNAYA ASIMPTOTIKA (Similarity, Self-Similar Behavior, Intermediate Asymptotic Behavior), Leningrad, Gidrometeoizdat, 1978.

3. Belevich, M. Yu. and Chalikov, D. V., "Development of the Turbulent Boundary Layer in a Stratified Fluid," IZV. AN SSSR: FIZIKA ATMOSFERY I OKEANA, Vol 14, No 5, 1978.

4. Voropayev, S. I., Gavrilin, B. L., Zatsepin, A. G. and Fedorov, K. N., "Laboratory Investigation of Penetrating Convection in a Stratified Fluid Cooled From the Surface," ISSLEDOVANIYE IZMENICHIVOSTI FIZICHESKIKH PROTSESSOV V OKEANE (Investigation of Variability of Physical Processes in the Ocean), Moscow, IO AN SSSR, 1978.

5. Ginis, I. D. and Dikinov, Kh. Zh., "Slow Relaxation of the Thermal Track of a Tropical Cyclone in the Ocean," DOKLADY AN SSSR (Reports of the USSR Academy of Sciences), 1981 (in press).

6. Dikinov, Kh. Zh. and Zholudev, V. D., "Computations of the Drag Coefficient and Wind Stress at the Ocean Surface," OKEANOLOGIYA (Oceanology), Vol 20, No 5, 1980.

7. Zholudev, V. D., "Generalized One-Dimensional Model of the Upper Layer of the Ocean. Part I: Preliminary Results," Nal'chik, 1980. Manuscript deposited at the All-Union Institute of Scientific and Technical Information, 27 Oct 80, No 4522-80.

8. Zubov, N. N., L'DY ARKTIKI (Arctic Ice), Moscow, Izd-vo Glavsevmorputi, 1945.

9. Kitaygorodskiy, S. A., "Computation of Thickness of the Wind Mixing Layer in the Ocean," IZV. AN SSSR: SERIYA GEOFIZICH., No 3, 1960.

10. Kraus, Ye. B., VZAIMODEYSTVIYE ATMOSFERY I OKEANA (Interaction Between the Atmosphere and Ocean), Leningrad, Gidrometeoizdat, 1976.

11. Monin, A. S. and Yaglom, A. M., STATISTICHESKAYA GIDROMEKHANIKA (Statistical Hydromechanics), Part I, Moscow, Nauka, 1965.

12. Resnyanskiy, Yu. D., "Parameterization of Integral Dissipation of Turbulent Energy in the Upper Quasihomogeneous Layer of the Ocean," IZV. AN SSSR: FIZIKA ATMOSFERY I OKEANA, Vol 11, No 7, 1975.

13. FIZIKA OKEANA. T 1. GIDROFIZIKA OKEANA (Oceanic Physics. Vol 1. Oceanic Hydrophysics), Moscow, Nauka, 1978.

14. Csanady, G. T. and Shaw, P. T., "The Evolution of a Turbulent Ekman Layer," J. GEOPHYS. RES., Vol 85, No C3, 1980.

15. Denman, K. L., "A Time-Dependent Model of the Upper Ocean," J. PHYS. OCEANOGR., Vol 3, No 2, 1973.

16. Denman, K. L. and Miyake, M., "Upper Layer Modification at Ocean Station Papa: Observations and Simulation," J. PHYS. OCEANOGR., Vol 3, No 2, 1973.

17. Fedorov, K. N., "On the Summer Daily Heating and Diurnal Heat Budget of the Upper Ocean Layer," STUDI IN ONORE DI GIUSEPPINA ALIVERTI, Napoli, 1972.

18. Gallacher, P. C., "A Description of the Oceanic Mixed Layer at Ocean Station P During August and September," EOS, TRANS. AMER. GEOPHYS. UNION, Vol 59, No 12, 1978.

19. Garwood, R. W., Jr., "An Oceanic Mixed Layer Model Capable of Simulating Cyclic States," J. PHYS. OCEANOGR., Vol 7, No 3, 1977.

20. Garwood, R. W., Jr., "Evidence of Planetary Scale Dissipation in the Summertime Oceanic Boundary Layer," EOS, TRANS. AMER. GEOPHYS. UNION, Vol 59, No 12, 1978.

21. Kato, H. and Phillips, O. M., "On the Penetration of a Turbulent Layer Into Stratified Fluid," J. FLUID MECH., Vol 37, Pt 4, 1969.

22. Kraus, E. B. and Turner, J. S., "A One-Dimensional Model of the Seasonal Thermocline. II. The General Theory and Its Consequences," TELLUS, Vol 19, No 1, 1967.

23. Lundgren, T. S. and Wang, F. C., "Eddy Viscosity Models for Free Turbulent Flows," PHYS. FLUIDS, Vol 16, No 2, 1973.

24. Rossby, C. G. and Montgomery, B. R., "The Layer of Frictional Influence in Wind and Ocean Currents," PAPS. PHYS. OCEANOGR., Vol 3, No 3, 1935.

25. Tabata, S., Boston, N. E. J. and Boyce, F. M., "The Relation Between Wind Speed and Summer Isothermal Surface Layer of Water at Ocean Station P in the Eastern Subarctic Pacific Ocean," J. GEOPHYS. RES., Vol 70, No 16, 1965.

26. Tennekes, H., "A Model for the Dynamics of the Inversion Above a Convective Boundary Layer," J. ATMOS. SCI., Vol 30, 1973.

27. Tennekes, H., "Reply," J. ATMOS. SCI., Vol 32, 1975.

UDC 556.535.5:556.06

DERIVATION OF EXPRESSIONS FOR PREDICTING MAXIMUM ICE JAM (ICE RUN) WATER LEVELS IN THE BREAKUP OF SIBERIAN RIVERS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 2 Mar 81) pp 83-87

[Article by I. Ya. Liser, candidate of geographical sciences, West Siberian Regional Scientific Research Institute]

[Abstract] On the basis of a generalization of long-term hydrological observations it has been possible to determine the sites of the most frequent formation of ice jams, estimate the frequency of recurrence and severity of ice jams and other characteristics. All these data have been included in a published catalogue. However, it is most important to predict the maximum ice jam level ($H_{max\ ij}$). For many years this problem has remained unsolved due to the complexity of the phenomenon, its poor study and the diversity of natural conditions. The increasing use of rivers and the needs of the national economy make it essential to provide such forecasts. During recent years much has been done along these lines by R. A. Nezhikhovskiy (METEOROLOGIYA I GIDROLOGIYA, No 5, 1977; TRUDY IV VSESOYUZNOGO GIDROLOGICHESKOGO S"YEZDA, Vol 7, 1977). He demonstrated the decisive importance of the volume of water discharge during the breaking-up period on height ($H_{max\ ij}$). Nezhikhovskiy in a number of examples gave a dependence in the form

$$H_{max\ ij} = f(Q_{breakup}). \quad (1)$$

The forecast of $H_{max\ ij}$ in no way takes into account such ice characteristics as strength of the ice cover (φh) during the breakup period, the height of levels during the winter period, etc. Nezhikhovskiy cites the existence of a correlation between $Q_{breakup}$ and φh during the breakup, as a result of which allowance for φh is superfluous. Use of his expression has yielded positive results, but it seems clear that it is necessary to consider still another important factor: the level of the preceding freezing (H_{fr}) or the maximum level at the beginning of winter ($H_{max\ win}$). H_{fr} or $H_{max\ win}$ are directly related to the volume of ice material accumulated in the channel by the time of the breakup and this naturally exerts a direct influence on the character of the ice jam. H_{fr} (or $H_{max\ win}$) governs the level height at which the ice begins to go out in the coming spring. The freezing level also characterizes the degree of compaction of the ice masses during freezing, which exerts an influence on the intensity of ice growth in winter. H_{fr} or $H_{max\ win}$) is an integral characteristic which includes the influence of a number of factors. The following expressions are therefore more valid:

$$H_{max\ ij} = f(Q_{breakup}, H_{fr}) \quad (2)$$

$$H_{max\ ij} = f(Q_{breakup}, H_{max\ win}. \quad (3)$$

Figures 2; references: 10 Russian.

UDC 551.50:633.11

RATE OF GROWTH AND DEVELOPMENT OF WINTER WHEAT DURING WINTER THAWS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 6 Apr 81) pp 88-92

[Article by I. V. Svisyuk, candidate of geographical sciences, Northern Caucasus Territorial Administration of Hydrometeorology and Environmental Monitoring]

[Text]

Abstract: A study was made of the problem of the rate of development of winter wheat during the period of winter thaws and a method is proposed for predicting the appearance of sprouts, the third leaf and tillering of this crop in dependence on the nature of the thaws.

It is well known that in the southern part of the European USSR due to the instabilities of winters in periods of thaws winter crops frequently renew their growing, forming new leaves and stems, and in individual years experience entire interphase periods.

Already the first investigations of this problem indicated that the occurrence of interphase periods during the time of winter thaws does not conform to the regularities observed during the regular growing season.

What is the process of growth and development of winter wheat during the period of winter thaws? There is no clear answer to this question. The fact is that the study of the winter period in the life of winter crops has proceeded in virtually only one direction, that is, in the direction of a study of the influence of low temperatures on the course of wintering of plants and the role of thaws in this process has been investigated only indirectly [2, 3, 5]. In this same connection there has been some discussion of the problem of change in bushiness against a background of reduced positive temperatures during the period from the cessation of the autumn to the renewal of the spring growing season of winter crops [1, 3].

Some discussion of the problem of change in the state of fields of winter wheat during the period of winter thaws was presented in our studies [6, 7] in connection with the development of a method for predicting the optimum times for the sowing of this crop. But in these studies as well it was examined indirectly.

We began direct observations and study of the influence of winter thaws on the growth and development of winter wheat with an investigation of the influence of a reduced background of positive temperatures on the course of germination of seeds

Table 1

Influence of Winter Thaws (2-5°C) Alternating With Cold Periods on Duration of "Sowing-Sprouting" Period

Meteorological station	Winter	$\sum t > 0°C$	Number of days with $t < 0°C$ between thaws	Level of mean daily temperature in period of thaws, °C	Duration of "sowing-sprouting" period--days
Armavir	1971/72	120	70	2.5	48
Armavir	1972/73	205	49	4.6	44
Slavyansk-na-Kubani	1972/73	207	45	5.0	41
Ust'-Labinsk	1971/72	135	54	3.1	43
Ust'-Labinsk	1972/73	200	42	5.3	38
Novo-Aleksandrovskoye	1971/72	170	54	3.8	44
Novo-Aleksandrovskoye	1972/73	160	46	4.5	38
Izobil'nyy	1971/72	72	31	1.8	40
Izobil'nyy	1972/73	147	14	3.4	43
Labinsk	1971/72	142	45	3.3	43
Labinsk	1972/73	167	45	3.9	43
Krymsk	1971/72	126	55	3.5	36
Krymsk	1972/73	157	26	4.1	38
Kanevskaya	1971/72	140	28	3.9	36
Kushchevskaya	1971/72	133	22	3.7	36
Cherkessk	1971/72	130	38	3.5	37

and the appearance of sprouts, and also on the degree of activity of the growing season for winter crops during the time of thaws [8, 9]. As a result of the investigations it was found that at the beginning of almost every thaw with an increase in air temperature the renewal and intensity of the growing season of winter crops are dependent not only on the positive air temperature value, but also on the state of the soil during the period preceding the thaw, its depth of freezing and moistening. Interesting biological characteristics of winter wheat plants, whose growth transpired with a positive mean daily air temperature from 2 to 5° during the time of thaws, alternating with periods of freezing temperatures, were revealed. Under such temperature conditions the rate of development of the plants remains approximately identical, regardless of the air temperature level. For example, the period from the sowing to the sprouting of winter wheat plants always transpires in a close number of days (36-44 days, on the average 41.5 days), regardless if whether the mean daily temperature is close to 2°C and the accumulated temperature sum during this period is 75-80°C or whether it is close to 5°C and during this period the accumulation is 200-205°C (Table 1).

Table 2

Increase in Sums of Positive Temperatures During "Sowing-Sprouting" Period During Thaws in Dependence on Intensity of Frosts ($\sum t < 0°C$) Preceding Thaws

Observation point or source of collected data	Winter	$\sum t > 0°C$	$\sum t < 0°C$
[4]	Growing season	120	0
Novoaleksandrovskaya	1971/1972	152	-577
Ust'-Labinsk	1971/1972	154	-457
Kanevskaya	1972/1973	138	-34
Ust'-Labinsk	1972/1973	132	-32
Zernograd	1972/1973	123	-20
Cherkesek	1972/1973	125	-27

The development of winter wheat at reduced mean daily positive temperatures from 2 to 5°C during winter thaws, alternating with coolings, is always delayed. For example, the "sowing-sprouting" period on the average lasts 41-42 days, even at temperatures close to 5°C, whereas in autumn, with a mean daily temperature 5°C, but without alternation of days with positive and negative air temperatures, it only continues for 24 days [4].

With a mean daily air temperature above 5°C during thaws the growth and development of winter wheat conform to known patterns, when with an increase in air temperature there is a shortening of the interphase period, but the sum of temperatures necessary for the transpiring of this period remains constant, provided there are no temperature decreases to negative values.

During coolings between thaws there is an increase in the sum of positive temperatures for the transpiring of the interphase period. The more intense the cooling, the greater is the sum of positive temperatures necessary for transpiring of the interphase period. During coolings of an identical intensity, all other conditions being equal, the sum of positive mean daily temperatures necessary for the transpiring of the interphase period is approximately identical, but always is greater than during the growing season (Table 2).

Table 3

Influence of Intensity of Frosts ($\sum t < 0°C$) Preceding Thaws on Duration of the "Sowing-Sprouting," "Sprouting-Third Leaf" and "Third Leaf-Tillering" Periods During Winter Thaws

Meteorological station	Winter	$\sum t < 0°C$	Number of days with temperature from 0 to 5°C	$\sum t > 0°C$	Duration of interphase period, days
"Sowing - Sprouting"					
Armavir	1972/73	-265	26	173	43
Kanevskaya	1972/73	-47	25	155	38
Zernograd	1972/73	-20	25	123	34
Kanevskaya	1971/72	-296	19	138	32
Slavyansk-na-Kubani	1972/73	-32	18	132	28
"Sprouting-Third Leaf"					
Otradnaya	1976/77	-325	53	+389	85
Korenovsk	1973/74	-213	55	+148	70
Otradnaya	1972/73	-336	36	+206	54
Taman'	1970/71	-67	36	+133	45
Labinsk	1972/73	-268	26	+254	42
Armavir	1969/70	-89	25	+123	35
"Third Leaf-Tillering"					
Divnoye	1969/70	-324	46	215	66
Zelenokumsk	1969/70	-162	44	139	51
Novoaleksandrovskaya	1976/77	-308	30	177	44
Budennovsk	1969/70	-2	29	169	36

In the investigation of cases of repeated cessation and renewal of the growing season of winter wheat during the time of winter thaws it was found that the influence of the intensity of negative temperatures on the rate of development of winter wheat is retained in any phase of crop development. The stronger the freezing before the thaws, the greater is the sum of positive temperatures required for passage of any interphase period and the longer will this period be (see Table 3). The lengthening of the interphase period after stronger frosts is attributable to two factors: first, the stronger frosts cause deeper freezing and cooling of the soil, its stronger cementation, and therefore more heat is expended for thawing of the soil and this lengthens the interphase period; second, the stronger cooling causes a more intense restructuring of the organism of the wintering plant, and it is natural that with the onset of thawing the plant requires more time to undergo the transition from a state of forced rest to renewal of the growing season.

Taking into account all the above-mentioned peculiarities in the development of winter wheat during the period of winter thaws, it can be concluded that in the development of a method for predicting the onset of the phases of development during the period of winter thaws in addition to the sums of positive mean daily temperatures it is also necessary to take into account the intensity of the frosts.

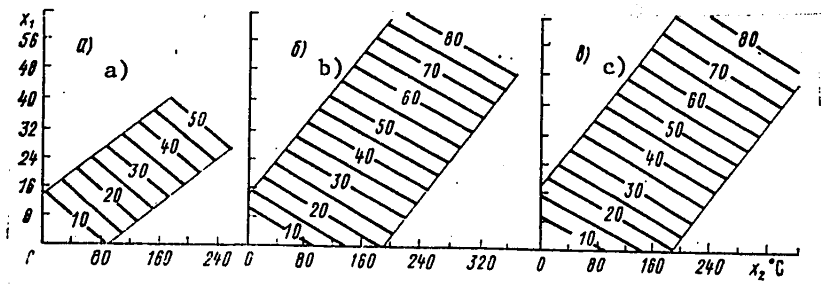


Fig. 1. Dependence of duration of interphase periods (y) on the number of days with a mean daily temperature from 0 to 5°C (x_1) and sum of positive mean daily temperatures (x_2). a) "sowing-sprouting" interphase period; b) "sprouting-third leaf" interphase period; c) "third leaf-tillering" interphase period.

We investigated two variants of the relationship between the duration of the interphase periods with the number of days with a positive mean daily air temperature in winter. One variant takes into account all days when in a period without snow the mean daily air is above 2°C; in the other variant all days are taken into account when in the absence of snow the mean daily air temperature is above 0°C.

In the two variants the correlation was linear, but it was closer in the second variant when allowance was made for all days with a mean daily temperature above 0°C. This variant was adopted for further investigations.

The correlation between the duration of the "sowing-sprouting," "sprouting-third leaf" and "third leaf-tillering" periods with $\sum t > 0$°C and the number of days with an air temperature from 0 to +5°C was quite close: the multiple correlation coefficient (R) with different combinations of the predictors varies from 0.78 to 0.98.*

As a result of a regression analysis it was possible to establish a quantitative dependence of the duration of the interphase periods for winter wheat growing in winter on the number of days with a positive air temperature and the sum of positive air temperatures during these periods (see Fig. 1).

The correlation equations have the following form:

$$y = 0{,}79\,x_1 + 0{,}12\,x_2 - 0{,}47;$$
$$R = 0{,}98 \pm 0{,}001;\ n = 50;\ S_y = \pm 1{,}5 \text{ days} \qquad (1)$$

---

* The introduction of the intermediate third leaf phase was associated with the need for computing the areas which were in this phase during the wintering period.

For the "sprouting-third leaf" period

$$y=0,86\,x_1+0,10\,x_2+0,99;$$
$$R=0,99\pm0,001;\ n=46;\ S_y=\pm1,57 \text{ days} \quad (2)$$

For the "third leaf-tillering" period

$$y=0,86\,x_1+0,10\,x_2+0,76;$$
$$R=0,98\pm0,001;\ n=136;\ S_y=\pm2,3 \text{ days} \quad (3)$$

In the indicated equations y is the duration of the interphase period ["sowing-sprouting" (1), "sprouting-third leaf" (2), "third leaf-tillering" (3)]. The dates of mass onset of the phases are used for the beginning and end of the interphase period; x_1 is the number of days with a mean daily temperature from 0 to 5°C during the interphase period; x_2 is the sum of positive mean daily air temperatures during the interphase period.

BIBLIOGRAPHY

1. Grudeva, A. Ya., "On the Problem of Tillering of Winter Crops at Reduced Temperatures," TRUDY IEM (Transactions of the Institute of Experimental Meteorology), No 13, 1970.

2. Lichikaki, V. M., "Method for Predicting the Critical Temperature of Winter Wheat," METEOROLOGIYA I GIDROLOGIYA (Meteorology and Hydrology), No 6, 1955.

3. Monseychik, V. A., AGROMETEOROLOGICHESKIYE USLOVIYA I PEREZIMOVKA OZIMYKH KUL'TUR (Agrometeorological Conditions and Wintering of Winter Crops), Leningrad, Gidrometeoizdat, 1975.

4. Nosatovskiy, A. I., PSHENITSA (Wheat), Moscow, Kolos, 1965.

5. Petunin, I. M., "Method for Preparing a Forecast of Conditions for the Wintering of Winter Wheat and Rye," SBORNIK METODICHESKIKH UKAZANIY PO ANALIZU I OTSENKE SLOZHIVSHIKHSYA I OZHIDAYEMYKH AGROMETEOROLOGICHESKIKH USLOVIY (Collection of Methodological Instructions on Analysis and Evaluation of Prevailing and Anticipated Agrometeorological Conditions), Leningrad, Gidrometeoizdat, 1957.

6. Svisyuk, I. V., "Determination of the Duration of Autumn Tillering of Winter Wheat," SBORNIK RABOT ROSTOVSKOY GMO (Collection of Papers of the Rostov Hydrometeorological Observatory), No 5, 1967.

7. Svisyuk, I. V., POGODA I SROKI SEVA OZIMOY PSHENITSY (Weather and Times of Sowing of Winter Wheat), Rostov-na-Donu, Rostizdat, 1969.

8. Svisyuk, I. V., "Degree of Activity of Growing of Winter Wheat During Winter Thaws," METEOROLOGIYA I GIDROLOGIYA, No 11, 1979.

9. Svisyuk, I. V., POGODA I UROZHAYNOST' OZIMOY PSHENITSY NA SEVERNOM KAVKAZE I V NIZHNEM POVOLZH'YE (Weather and Yield of Winter Wheat in the Northern Caucasus and in the Lower Volga Region), Leningrad, Gidrometeoizdat, 1980.

UDC 551.509.322+551.515.8

COMPUTING WIND VELOCITY DURING GUSTS IN NARROW COLD FRONT ZONES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 23 Jan 81) pp 93-94

[Article by M. A. Masterskikh, candidate of geographical sciences, USSR Hydrometeorological Scientific Research Center]

[Abstract] In many studies attempts have been made to find a statistical dependence between wind velocity and different thermodynamic parameters of the atmosphere in frontal zones. But no close correlation has been established between these values. Few data are available on the actual distribution of temperature, humidity and other meteorological elements in narrow zones of cold or warm fronts. The best formula for computing wind velocities on cold fronts is

$$V_{surf} = \sqrt{V_x^2 + V_z^2}, \quad (1)$$

where V_{surf} is the maximum wind velocity at the surface, V_x is the horizontal component of wind velocity at some altitude governed by the pressure gradient, V_z is the vertical component of the air flow arising under the influence of Archimedes force. However, it is difficult to compute V_{surf} in this way. Therefore, the author proposes that $\overline{V}_{surf}$ be computed from expression (1) with allowance for the pressure gradients and mean $\overline{V}_{surf}$ values in narrow (up to 50 km) cold front zones. Substituting into (1), with allowance for the friction coefficient K = 0.7

$$V_{surf} = 0.7 \sqrt{\left(\frac{4.8}{\sin\varphi} \Delta p_{eff}\right)^2 + \overline{V}_z^2}, \quad (2)$$

where φ is latitude, Δp_{eff} is the pressure gradient in a narrow (up to 50 km) cold front zone (in mb/111 km), $\overline{V}_z$ is the mean value of the vertical wind component. The vertical component (V_z) can be determined using the formula

$$V_z = \sqrt{2gh \frac{T_1 - T_2}{T_1}} \quad (3)$$

where g is the acceleration of free falling, T_2 and T_1 is the temperature of the subsiding air volume in the surrounding medium. However, computation of V_z in each specific case is difficult and therefore it is proposed that $\overline{V}_z \approx 8$ m/sec be used. A working equation is derived for computing wind velocity in gusts in narrow cold front zones

$$V_{surf} \simeq 0.7 \times \sqrt{\left(\frac{4.8}{\sin\varphi}\right)^2 (\Delta p_{fl}^2 + \alpha^2 \Delta t_{fz}^2) + 64.} \quad (4)$$

[fl = frontal line; fz = frontal zone]

Figures 1; references: 9 Russian.

UDC 551.466.3

INTERACTION OF SWELL WAVES WITH HEAD WIND

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 4 Feb 81) pp 95-97

[Article by V. K. Makin, candidate of physical and mathematical sciences, Leningrad Division, Institute of Oceanology]

[Abstract] On the basis of a numerical model of wind-wave interaction the author investigates the influence of a head wind on a swell wave with the length L = 50-200 m propagating in deep water. (A similar investigation of the head wind and a wave was made by P. R. Gent in J. FLUID. MECH., Vol 82, 1977, but for shorter waves with a length of 3 and 18 m.) Here a formula is derived for computing the parameter of interaction between the waves and wind β. A procedure is given for determining the attenuation time t_{att} during which the wave amplitude decreases by a factor of $e^{-\pi}$. It is shown that the interaction parameter β is a function only of the time of wave development v_*/c. In the case of a strong wind the interaction between the wind and swell is determined by different mechanisms (such as overturning of the short waves forming on the crest of the swell) and the dependence of β on the wind disappears, that is, β = const. Data from numerical computations confirm the existence of a self-similar dependence of β on v_*/c. The β parameter increases from 10^{-5} in the case of a weak wind to $2.5\cdot10^{-5}$ in the case of a moderate wind. (Gent, extrapolating the results obtained for short waves, obtained a value $3.5\cdot10^{-5}$, which agrees with the results obtained here by direct numerical computations.) The attenuation of swell is essentially dependent on frequency. Short waves lose their energy several times more rapidly than long waves. With a wind U_5 = 780 cm/sec (U_5 = 780 cm/sec is wind velocity at a height of 5 m) short swell almost completely loses its energy after 2 days. For swell with a length 300 m the attenuation time is 18 days. The results of this investigation show that for short swell it is necessary to take into account its interaction with a head wind. A table gives the results of numerical computations for swell waves with a length of 100 m when the direction of the wind and the propagation of swell coincide. In the case of low friction velocities the waves impart energy to the wind. The energy flux changes sign with a value U_5/c = 0.9. Figures 1, tables 2; references 7: 3 Russian, 4 Western.

UDC 556.048

JOINT EVALUATION OF INTRAANNUAL AND LONG-TERM PROBABILITY OF EXCEEDING OF MEAN DAILY WATER DISCHARGES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 11 Dec 80) pp 97-100

[Article by A. M. Komlev, professor, Perm' State University]

[Abstract] So-called duration curves are in common use in hydrological and water-management computations. They are of equal importance in evaluating the duration of water levels and a number of other elements of the hydrological and meteorological regimes. In hydrological and water management computations it is most common to use curves averaged over a long-term period in the form of an absolute or generalized curve of the duration of discharges, and also in the form of a mean curve. However, averaged duration curves do not reflect the nature of the distribution of discharges in many specific years, especially those which are anomalous in one respect or another. For this reason it is extremely desirable that in addition to an averaged curve the discharges of different guaranteed probability be used for the required duration value. Accordingly, the author has developed a method for solving this problem. The method is illustrated in the example of data for the Kama River at Bondyug village. The water discharges with durations of 30, 90, 180, 270 and 355 days are taken from hydrological yearbooks. Adding to these data the annual values of the maximum and minimum water discharges, seven statistical series are obtained which are used in constructing empirical guaranteed probability curves. By taking from these curves the discharges for stipulated guaranteed probability values, it is possible to construct curves of the duration of equally guaranteed discharges. A nomogram is given which makes it possible to carry out a joint evaluation of the features of the intraannual distribution of runoff and the long-term variability of discharges with equal probability in the course of the year. The method makes it possible to estimate discharges of any guaranteed probability for any particular duration. Figures 2; references: 11 Russian.

UDC 551.521.3

SOME PROBLEMS OF VISIBILITY THROUGH CLOUDS AND FOGS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 31 Mar 81) pp 101-109

[Article by A. S. Drofa and I. L. Katsev, candidates of physical and mathematical sciences, Institute of Experimental Meteorology and Physics Institute, Belorussian Academy of Sciences]

[Abstract] This is a review of theoretical and experimental investigations for study of the visibility of objects through clouds and fogs (the authors draw upon 38 published sources). Expressions are derived for evaluating the optical transfer function of the cloud medium and the signal-to-noise ratio in the image of the object observed through the medium. A detailed examination is made of the influence exerted on these characteristics by the light-scattering properties of the cloud medium and their distribution along the visibility path. The conclusion is drawn that there is now an adequately well-developed theoretical approach which makes it possible to make evaluations of the quality of transmission of an optical image in the atmosphere, taking into account the broad range of changes in its optical properties. However, there are a number of problems which require priority solution. For example, for an analysis of the possible variations in visibility conditions there is still an extreme inadequacy of experimental data, especially data obtained in the atmosphere with monitoring of its principal optical and microphysical characteristics. There is a need for simple formulas describing visibility characteristics in different wavelength regions. There are no simple expressions for computing the scattering function, which is necessary for evaluations of the background level of scattered light and contrast when making observations of small self-luminescent objects. There is need for detailed work on the nature of image transfer through a scattering medium with a randomly inhomogeneous distribution of light-scattering characteristics. Figures 2; references 38: 36 Russian, 2 Western.

UDC 551.5

EXPERIMENTAL AND SYNOPTIC STUDIES OF ATMOSPHERE IN PUBLICATIONS OF O. G. KRICHAK (ON THE SEVENTIETH ANNIVERSARY OF HIS BIRTH)

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 (manuscript received 9 Apr 81) pp 110-113

[Article by S. O. Krichak, candidate of physical and mathematical sciences, and N. Z. Pinus, professor, USSR Hydrometeorological Scientific Research Center, and Central Aerological Observatory]

[Abstract] Oskar Grigor'yevich was a member of the first graduating class from the Moscow Hydrometeorological Institute (1935). Upon graduating from the meteorology department there he began work at the Ukrainian Administration of Hydrometeorology as a specialist in the aerology section and at the same time headed the weather bureau at Kiev. In 1936 he became affiliated with the Central Weather Institute in Moscow. At this time he became interested in polar research. He was particularly interested in the use of balloons for atmospheric research. In 1940 he was responsible for establishing an aerological observatory at the Central Institute of Forecasts. He became head of this observatory, which from its beginning made extensive use of balloons, aircraft and radiosondes. In 1940 he defined a new classification of synoptic processes over Europe, the first significant proposal along these lines since 1916. For the first time these processes were broken down into groups for the cold and warm half-years. He served as a meteorologist in the ranks of the Red Army and this classification proved to be highly valuable in predicting weather conditions affecting military operations. After receiving the degree of Candidate of Geographical Sciences in 1945, from 1946 to 1950 he headed the Aviation-Aerological Administration of the Main Administration of Hydrometeorology. O. G. Krichak did much work in developing and strengthening the material-technical base of the aerological network of the Soviet Union and also in the development of a network for routine aircraft sounding of the atmosphere, playing a major role in study of the fine structure of the troposphere and cloud structure. In 1952 he published a new genetic classification of clouds, followed in 1956 by a textbook on synoptic meteorology. The latter gave the paths of migration of cyclones and anticyclones in Europe on the basis of data for 1930-1954. In 1956 he participated in the Second Soviet Antarctic Expedition, on which he headed the aerometeorological detachment at Mirnyy. He later generalized the results of this work in various publications, such as "Some Characteristics of Atmospheric Circulation Over Antarctica" (1958) and the fundamental study OSOBENNOSTI ATMOSFERNOY TSIRKULYATSII NAD ANTARKTIDOY I YEYE SVYAZ' S OBSHCHEY TSIRKULYATSIYEY YUZHNOGO POLUSHARIYA (Features of Atmospheric Circulation Over Antarctica and Its Relationship to General Circulation in the Southern Hemisphere) (1960). In 1959 he again headed the aerometeorological detachment of the Fifth Soviet Antarctic Expedition. On the night of 3 August 1960 he died in a fire which swept the building of the aerometeorological detachment. Figures 1.

REVIEW OF MONOGRAPH 'EARTH'S ATMOSPHERE FROM THE 'SALYUT-6'' (ATMOSFERA ZEMLI S 'SALYUTA-6'), BY A. I. LAZAREV, V. V. KOVALENOK, A. S. IVANCHENKOV AND S. V. AVAKYAN, LENINGRAD, GIDROMETEOIZDAT, 1981

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 114-115

[Review by A. G. Nikolayev, candidate of technical sciences, USSR flier-cosmonaut]

[Text] The authors of this book, two of whom are USSR flier-cosmonauts, have presented, systematized, analyzed and generalized the results of optical investigations of the earth's atmosphere carried out by the main crew of the second expedition of the "Salyut-6" orbital scientific station. During the prolonged 140-day flight the USSR flier-cosmonauts V. V. Kovalenok and A. S. Ivanchenkov carried out systematic investigations of the atmosphere and atmospheric-optical phenomena making it possible to detect some new patterns observable in the earth's atmosphere. Substantial advantages of a prolonged space flight for systematic investigations of the phenomena visually observable from space are emphasized. During the prolonged flight the cosmonauts, with the assistance of consultations of specialists carried out during the course of communication sessions, begin to systematize and analyze the registered phenomena and independently carry out individual experiments for investigating the environment. This enabled V. V. Kovalenok and A. S. Ivanchenkov to obtain extensive material on many atmospheric-optical phenomena.

The book begins with a chapter devoted to the peculiarities of optical investigations from space. It examines the principal parameters and criteria of optical instruments and systems necessary for observing and registering extended and point sources of radiation under real flight conditions. Extensive use is made of the tool of frequency-contrast characteristics of the visual system and the transfer functions for the earth's atmosphere and spaceship windows. The reliability of visual observations of cosmonauts is essentially dependent on the state of the visual system under conditions of a prolonged space flight. For that reason it is entirely legitimate to include in the book a section on the principal parameters of vision in space. Emphasis is on the contrast characteristics of the visual system under the real conditions for carrying out visual observations. The authors emphasize the appreciable deterioration of contrast characteristics when there are low levels of brightness and illumination characteristic for the conditions of observation on the nighttime side and in the twilight zone. The patterns of behavior of the visual system were taken into account in the processing and interpretation of the results of visual observations under the corresponding experimental conditions.

In the book a considerable place is devoted to investigation of emissions of the earth's nighttime and twilight atmosphere. A detailed examination is made of the emission of the earth's upper atmosphere on the nighttime side and in the twilight zone. Much attention is devoted to an analysis of the spatial-temporal distribution of emission of the upper atmosphere under different geo-heliophysical conditions, including during solar flares and during magnetic storms. Separate consideration is given to the spatial-temporal variations of intensity of radiation of the first and second emission layers of the nighttime atmosphere. There is a detailed exposition of the results of observations of global bursts of the second emission layer from space by V. V. Kovalenok and A. S. Ivanchenko.

The third chapter is one of the most important in the book and is devoted to auroras. The authors give a detailed description of the history of observations and the spatial-temporal distribution of regions of appearance of auroras. In an analysis of the results of visual observations of auroras in the course of flight it was confirmed that auroras in the auroral zone exist at all times. Cases of the observation of auroras at a global scale up to latitudes ±25° are described.

There is a very detailed presentation of the results of visual registry of the color and spatial characteristics of the powerful aurora of 29 September 1978 when rayed forms were observed at the orbital altitude of the "Salyut-6" and above. All the cases of observations of strong auroras are compared with data from surface observations of auroras over the territory of the USSR and geomagnetic investigations at different world observatories. Also examined are the prospects for visual and instrumental optical investigations of auroras from manned space vehicles and orbital scientific stations.

The book gives the results of observations and registry of cloud formations in the troposphere, stratosphere and mesopause. There is a detailed description of the pattern of generation and development of cyclonic disturbances observed from space and an attempt is made to investigate the interaction of tropospheric clouds and powerful oceanic currents. V. V. Kovalenok and A. S. Ivanchenkov for the first time observed from space, in the direction of the shadow from the station, a sort of "rainbow spot" moving along the surface of the cloud cover, which is attributable to the interference pattern arising in water droplets, known under the name gloria. In late August 1978 the cosmonauts for the first time observed "rainbow" clouds from space. These were of mustard and violet colors.

Particularly interesting results were obtained in the observation of noctilucent clouds and aerosol layers in the mesopause during flight of the "Salyut-6" orbital station on the sunny side of the orbit in late June-early July 1978. These observations of V. V. Kovalenok and A. S. Ivanchenkov were made together with members of the international visiting crew -- P. I. Klimuk, USSR flier-cosmonaut and M. Hermaszewski, flier-cosmonaut of the Polish People's Republic. The cosmonauts discovered noctilucent clouds or aerosol formations in the mesopause in the region of the low and equatorial latitudes. The results of these observations after a year were confirmed by the crew members of the third expedition on the "Salyut-6" orbital station, V. A. Lyakhov and V. V. Ryumin.

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500020056-3

Original results were obtained in observation of the phenomenon of "hanging" of the twilight radiation of the upper atmosphere over the earth's horizon, which was given the name "whiskers" effect; this was observed for the first time by V. I. Sevast'yanov and the author of this review from the spaceship "Soyuz-9" in June 1970.

The authors carefully analyze the results of systematic investigations of zodiacal light. It was possible to trace the relationship between the rayed structure of the zodiacal light and meteor streams and associations. The materials cited in the book on the investigation of luminescent dust particles, arising during operation of the spaceship engines, are of definite scientific and practical importance.

The book is written well, in literary language, and will be useful to specialists in the field of geophysics and space optics. It will be used extensively in the training of cosmonauts for carrying out optical investigations from space.

SEVENTIETH BIRTHDAY OF BORIS GRIGOR'YEVICH ROZHDESTVENSKIY

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 p 116

[Article by personnel of the Scientific Research Institute of Instrument Making]

[Abstract] Boris Grigor'yevich Rozhdestvenskiy, a well-known designer of meteorological radar sets, has marked his 70th birthday. The many-sided activity of Boris Grigor'yevich is associated with the development of machine building, aviation and radioelectronics. In 1939 he began his work at the Central Aerohydrodynamic Institute, but beginning in 1948 became affiliated with the All-Union Scientific Research Institute of Electromechanics, where he directed a major section and was chief designer of meteorological stations. He not only created new instrumentation, but took an active part in implementing a program of scientific research in collaboration with the Central Aerological Observatory. In 1964 B. G. Rozhdestvenskiy became head of the Technical Administration and was named a board member of the Main Administration of the Hydrometeorological Service. The talents of Boris Grigor'yevich Rozhdestvenskiy as an engineer, inventor and scientist are well known abroad, where he has worthily represented the USSR Hydrometeorological Service. Rozhdestvenskiy has headed expeditionary groups for implementing scientific research programs on scientific ships during Antarctic expeditions. Since late 1978 he has been a senior scientific specialist at the Scientific Research Institute of Instrument Making. At present he is busily engaged in exploring the possibilities of various technical means for the collection of hydrometeorological information for studying processes transpiring in the atmospheric surface layer.

ACTIVITIES AT THE USSR STATE COMMITTEE ON HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 116-118

[Article by G. K. Veselova]

[Text] On 15 June the Central Methodological Commission on Hydrometeorological Forecasts (CMCHMF), under the direction of Ye. I. Tolstikov, heard reports of representatives of the USSR Hydrometeorological Center, All-Union Scientific Research Institute of Agricultural Meteorology and Arctic and Antarctic Scientific Research Institute on the results of tests and introduction of new methods for forecasting and adopted the following decisions concerning them.

A comparative evaluation of the accuracy of objective analysis of the pressure field, based on the optimum interpolation method (A. N. Bagrov scheme) and spectral objective analysis (D. M. Sonechkin) was given. An analysis of the pressure field made by the weatherman in the Division of Analysis of World Weather at the USSR Hydrometeorological Center was adopted as a standard in the comparison. This comparison revealed that objective analysis using the A. N. Bagrov scheme corresponds better to the analysis made by the weatherman. For example, according to the Bagrov scheme the differences in the position of the pressure centers at the earth's surface were about 280 km and at the 500 gPa level about 270 km. The pressure (geopotential) values at the centers of the pressure formations at the earth's surface and at the 500 gPa level differed by 1.8 gPa (dam). The spectral analysis had differences exceeding those indicated by a factor of 1.5-2.

The CMCHMF approved the work on carrying out operational testing of objective analysis methods and recommended the A. N. Bagrov objective analysis scheme used in the operational practice of the USSR Hydrometeorological Center for the purposes of automated compilation of an archives of hemispherical data in the Data Support Laboratory. At the same time the USSR Hydrometeorological Center proposed an examination of the problem of the use of automated objective analysis of the northern hemisphere instead of an analysis prepared manually.

A description of the recommended objective analysis scheme was given in the TRUDY GIDROMETTSENTRA SSSR, No 196, 1978.

The CMCHMF agreed with the decision of the USSR Hydrometeorological Center that until 1983 work be continued on testing of the method for predicting major weather anomalies over the pastures of the northwestern Caspian area, developed by T. N. Bochkova, taking into account the inadequate number of cases with dangerous weather phenomena. This method is based on parametric linear discriminant analysis and multiple regression equations. For all months of the year it makes it possible to predict the mean monthly air temperature, and for December, January and February predict glaze and blizzards in stochastic form.

The tests were carried out from December 1979 through February 1981. The success of forecasts of mean monthly temperature in the considered period was characterized by $\rho = 0.42$ and $Q = 0.66$. The guaranteed success of forecasts of glaze in different months was only 43-71% and for blizzards was 50-60%, although the prevention of these phenomena was rather high, 67-100%.

The method was published in METEOROLOGIYA I GIDROLOGIYA, No 1, 1978, and TRUDY VNIIGMI-MTsD, No 36, 1977.

The CMCHMF granted permission to the USSR Hydrometeorological Center for using in its operational practice a method for predicting temperature for natural synoptic seasons (spring and the first half of summer) (author Kh. Kh. Rafailov) as an auxiliary to the fundamental seasonal forecasting method. This method is based on allowance for the patterns of general circulation of the atmosphere. The forecasting computation scheme takes into account the following principal factors: state of the phases of the quasi-two-year cycle of the prevailing flow in the equatorial zone of the middle stratosphere and its influence on the change in the pressure field of the stratosphere and troposphere in the intratropical latitudes, stability of long waves for the hemisphere in time and space, characteristics of the thermal regime of the oceans and the peculiarities of circulation during natural synoptic seasons. The forecast is computed on an electronic computer. Operational tests of the computation scheme were made from 1976 through 1981. The guaranteed probability of forecasts of the air temperature anomaly with respect to ρ for the natural season of spring was 0.32 and for the first half of summer was 0.24 with a guaranteed probability $\rho > 0$ equal to 80%.

The principles of the method were published in TRUDY GIDROMETTSENTRA SSSR, No 198, 1978, and No 150, 1974, and in METEOROLOGIYA I GIDROLOGIYA, No 1, 1973.

The method for predicting the air temperature anomaly for natural synoptic seasons in the warm part of the year in the eastern part of Siberia and in the Far East was developed by N. M. Zakharova (USSR Hydrometeorological Center) and tested at the Far Eastern Scientific Research Institute in 1978-1980. The method is based on regularities in change of macroprocesses from season to season and is formulated with allowance for the precursors of natural synoptic seasons and interseasonal changes in H^{500}_{1000}. As additional indications use is made of the gradients of H_{10}, T_{100}, the ozone distribution in the northern hemisphere and in the second natural synoptic region, as well as changes in the thermal state of the northeastern part of the Pacific Ocean.

Taking into account that when carrying out operational tests of this forecasting method at the Far Eastern Scientific Research Institute there were deviations from the program, the CMCHMF considers it desirable to continue its testing in 1981-1982 in accordance with the program. The content of the method was published in TRUDY GIDROMETTSENTRA SSSR, No 213, 1979.

The method for agrometeorological forecasting of the gross yield of winter wheat and rye for the principal economic regions of the USSR (author A. N. Derevyanko, USSR Hydrometeorological Center) is based on allowance for the tendency in the gross yield which is attained by improvement in the level of agricultural techniques and also an allowance for deviations from the trend caused by variations in weather conditions. The principal points in the method were published in TRUDY GIDROMETTSENTRA SSSR, No 253, 1981.

The testing of the method was carried out during 1978-1980. The mean guaranteed success of the forecasts for all economic regions in 1978 and 1979 was 75%, in 1980 -- 80%.

The commission recommended for practical use at the USSR Hydrometeorological Center a method for predicting the gross yield of winter wheat and rye over the entire winter-sowing zone of the Soviet Union: Donets-Dnepr, Southwestern, Southern, Northern Caucasus, Volga, Ural, Central Chernozem, Central, Volga-Vyatka, Northwestern, Baltic, West Siberian and also Central Asian regions, and also over the Moldavian, Belorussian and Kazakh SSRs.

The CMCMHF summarized the results of testing and introduction of new methods for hydrometeorological forecasts for the period from July 1980 through June 1981. During this time the commission examined 46 forecasting methods, of which the following were recommended for adoption: 7 short-range forecasting methods, 4 long-range weather forecasting methods, 16 agrometeorological and 2 marine weather forecasting methods--63% of the total. Despite the high percentage of introductions, as basic methods the commission recommended only objective analysis of the pressure field (author A. N. Bagrov, USSR Hydrometeorological Center) and methods for predicting the anomaly of five-day air temperature over the territory of Kazakhstan and on the Kola Peninsula (authors G. K. Turulina, Kazakh Scientific Research Institute and N. N. Bezukh, Murmansk Affiliate of the Arctic and Antarctic Scientific Research Institute). The remaining methods have an auxiliary character.

The most significant work on testing of the methods and introducing new and improved forecasting methods during the report period was carried out by the USSR Hydrometeorological Center, Central Asian Scientific Research Institute, Arctic and Antarctic Scientific Research Institute, Far Eastern Scientific Research Institute, West Siberian, Ukrainian, Upper Volga, Belorussian, Northwestern, Northern Caucasus, Central Chernozem Oblasts, Volga, Kazakh, Latvian, Estonian and Far Eastern Administrations of the Hydrometeorological Service.

CONFERENCES, MEETINGS, SEMINARS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 118-125

[Article by V. G. Glazunov and L. I. Petrova]

[Text] During the period 21-22 April at the USSR Hydrometeorological Center there was a conference-seminar of scientific workers of the scientific research institutes of the State Committee on Hydrometeorology and Environmental Monitoring on the theme "Status and Prospects for the Development of Measurement Instruments and Methods for Predicting Wind Shear in the Lower Layers of the Atmosphere." The conference was attended by more than 100 specialists of the State Committee on Hydrometeorology and Environmental Monitoring, USSR Hydrometeorological Center, Central Aerological Observatory, Main Geophysical Observatory, Institute of Experimental Meteorology, Central Volga Hydrometeorological Observatory, Scientific Research Institute of Instrument Making, All-Union Scientific Research Institute of Hydrometeorological Information-World Data Center, Ukrainian Scientific Research Institute, West Siberian Scientific Research Institute, Central Asian Scientific Research Institute, Main Aerometeorological Center, Kazakh Scientific Research Institute, Arctic and Antarctic Scientific Research Institute, Far Eastern Scientific Research Institute, and also a number of scientific research institutes of other departments.

The conference examined the interdepartmental (State Committee on Hydrometeorology and Environmental Monitoring, USSR Ministry of Civil Aviation and USSR Ministry of the Aviation Industry) complex plan on the wind shear problem, heard and discussed 20 reports and communications of representatives of 14 scientific research institutes.

In his opening remarks the chairman of the organizing committee for the conference-seminar, V. A. Ivanov, head of the Administration of Meteorological Support of Aviation of the State Committee on Hydrometeorology and Environmental Monitoring, noted the great timeliness and importance of the problem of supplying aviation with information on wind shears in the lower layers of the atmosphere for increasing the safety of takeoffs and landings of aircraft.

A. A. Vasil'yev (USSR Hydrometeorological Center), in a review report entitled "Requirements on Information on Wind Shear and the Possibility of Such Support," reported that the ICAO has indicated the need for furnishing pilots with data on wind velocity and direction at the beginning of the airstrip, at the landing point and on considerable changes in the wind along the strip and on the takeoff path, as well as at the point of aircraft landing. Since for the time being there are no instruments which could directly satisfy these requirements, for a long time there will be a need for developing methods for the qualitative determination of the wind shear on the basis of the nature of the synoptic situation and the search for quantitative criteria for specific conditions.

A group of reports devoted to the means and methods for measuring the wind parameters in the lower layers of the atmosphere applicable to the problems involved in meteorological support of aviation was presented at the conference.

M. Yu. Yurchak and B. S. Orlov (Institute of Experimental Meteorology), in a report entitled "Possibility of Measurement of Wind Shear by the Radioacoustic Method," demonstrated that on the basis of measurement of the speed of sound in the lower layer of the atmosphere by means of a Doppler radar it is possible, with an accuracy and routineness adequate for practical purposes, to obtain the wind shear values in the lower layers of the atmosphere.

In a report by O. A. Volkovitskiy, Ye. K. Garger, A. V. Naydenov and D. B. Uvarov (Institute of Experimental Meteorology) entitled "Determination of Wind Velocity Shear and Turbulence Using Vertical Smoke Plumes" it was demonstrated that this method makes possible a routine determination of the wind profile and shear by means of stereophotography and an evaluation of turbulence in the lower 300-m layer of the atmosphere during daytime.

G. B. Avrushchenko, G. S. Gershenzon and S. V. Lebedeva (Scientific Research Institute of Instrument Making), in a report entitled "Technical Characteristics of Foreign Anemometric Instruments," pointed out that there are great possibilities for creating improved wind detectors and systems for the processing, registry and display of the corresponding information.

Above and beyond the program for the sessions of the conference-seminar a number of brief communications were presented: G. A. Smirnova (Central Aerological Observatory) -- "Possibilities of Using Meteorological Radar Data for Detecting Zones of Intensification of Wind Shear"; Yu. P. Baykov, V. M. Zakharov and G. M. Kruchel'nitskiy (Central Aerological Observatory) -- "Correlation Anemometric Lidar"; and a paper by N. P. Krasnenko (Institute of Atmospheric Optics, Siberian Department, USSR Academy of Sciences) and V. I. Sid'ko (Khar'kov Institute of Radioelectronics) entitled "Acoustic Sounder as a Means for Measuring Turbulence and Wind Velocity." These communications and the planned reports demonstrated that the corresponding developments, successfully continuing at a number of scientific research institutes, can give meteorologists servicing aviation new and more effective remote means and methods for measuring the wind field at low altitudes in the airport zone.

A second group of reports was devoted to the problems involved in creating methods for predicting wind shears in the lower layers of the atmosphere in the airport zone and study of the meteorological conditions for their intensification.

A report by L. R. Orlenko (Main Geophysical Observatory), entitled "Status and Prospects for Developing a Method for Computing Vertical Wind Shears in the Surface Layer of the Atmosphere on the Basis of the Synoptic Situation," proposed that computation methods developed by the author for determining wind shears in the lower layers of the atmosphere based on use of some common parameters (velocity of the gradient wind, etc.) be used for airports situated in the open in the absence of orographic effects and a well-expressed nonstationary character of the processes (especially excluding zones of passage of fronts).

N. L. Byzova, Z. I. Volkovitskaya and N. F. Mazurin (Institute of Experimental Meteorology), in a report entitled "Turbulence and Wind Shears in the Lower Layer of the Atmosphere," on the basis of computations of the statistical characteristics of the instantaneous wind shear values, proposed a method for evaluating the fluctuation component of vertical wind shear, tested on the basis of initial material, which can be used in practical work.

A report by V. G. Glazunov (USSR Hydrometeorological Center), entitled "Recommendations on the Prediction of Wind Shear in the Lower Layers of the Atmosphere in an Airport Zone and Prospects for Creating a Forecasting Zone," evaluates the possibilities of determining wind shear on the basis of parameters of the synoptic situation. Parameters are discriminated which can be used in evaluating the wind shear under different conditions and some prognostic recommendations are formulated which can be used in the practice of meteorological support of flights in the airport zone.

V. A. Shnaydman and S. V. Pavlenko (Odessa Hydrometeorological Institute) presented a report entitled "Theoretical Model for Computing the Vertical Wind Velocity Shears Using Standard Aerosynoptic Data" in which on the basis of a three-parameter model of the planetary boundary layer the authors proposed a method (in two variants -- "manual" and using an electronic computer) for computing vertical wind shears and some examples of computations are given.

In a report by R. S. Golubov (Kazakh Scientific Research Institute) entitled "Determination of Zones of Intensive Turbulence on Cold and Warm Fronts" it was indicated that there is a relationship between the intensity of turbulence in the frontal zone and the computed slope of the frontal surface; an empirical graph with the discrimination of zones of increased turbulence was constructed. R. S. Golubov also presented a report entitled "Vertical Wind Shears in the Neighborhood of the Alma-Ata Airport" in which, on the basis of data from pilot-balloon measurements, information was given on the frequency of recurrence of wind shears to an altitude of 500 m under different conditions (wind direction, character of meteorological conditions, etc.).

Kh. L. Lutfiyev (Central Asian Scientific Research Institute), in a report entitled "Wind Shears in the Atmospheric Surface Layer According to Data From Balloon Sounding and Base Pilot Balloon Observations," examines the frequency of recurrence of wind shears at the principal stations of Soviet Central Asia and discriminates the regions in which strong shears are encountered more frequently; he demonstrated that the strongest shears are discovered most frequently in the zones of storm winds in mountain valleys.

A report by O. A. Lyapina and Ye. I. Sofiyev (Central Asian Scientific Research Institute) entitl "Some Results of Experimental Investigations of Wind Shears at Krasnovodsk Airport" gave an analysis of the results of measurements of wind shear which indicated a dependence of wind shear intensity on the thickness of the layer at whose boundaries the wind was measured and also the relationship between shears and aircraft accelerations in a zone of orographic turbulence. It has been established that single-point pilot-balloon observations do not suffice in determining wind shears.

I. I. Tsigel'nitskiy (Arctic and Antarctic Scientific Research Institute) presented a report entitled "Vertical Wind Shears in the Atmospheric Boundary Layer Over the Arctic Ocean" in which, on the basis of numerous aerological data for the first time it was possible to examine the conditions of formation, annual variation and altitudinal change of wind shears in the lower layers over the Arctic Ocean. The dependence of shear on velocity of the gradient wind and stratification was demonstrated.

V. N. Barakhtin and E. A. Morozova (West Siberian Scientific Research Institute), in a report entitled "Methods for the Diagnosis and Prediction of Turbulence in the Lower 500-m Layer of the Atmosphere," proposed a method based on use of the equations of linear multiple regression relating the turbulence value and a number of predictors. The method makes it possible to evaluate the background level of turbulence and the probability of a maximum vertical gust in the selected layer.

A report by V. A. Shnaydman and S. A. Stepanenko (Odessa Hydrometeorological Institute) entitled "Theoretical Model of Computation of Turbulence Parameters in the Surface Layer of the Atmosphere" proposed a method for computing the mean square wind fluctuations near the earth's surface using standard aerosynoptic information on the basis of a three-parameter turbulence model. The authors demonstrated the probability of routine use of the method.

V. N. Barakhtin (West Siberian Scientific Research Institute), in a report entitled "Results of Investigation of Turbulence in the Lower Layer of the Atmosphere on the Basis of Materials From Flight Experiments in the Territory of Siberia and Kazakhstan in 1973-1978," gave information on the statistics of the standard deviation of the vertical wind velocity component at altitudes up to 500 m under different conditions and on the relationships of this parameter and weather conditions; these data served as a basis for the method of diagnosis and prediction of turbulence exerting an influence on aircraft flight developed by the author.

It is noted in the resolution of the conference-seminar that at the scientific research institutes of the State Committee on Hydrometeorology and Environmental Monitoring specialists have carried out a number of investigations for developing measurement apparatus and a method for predicting wind shear in the lower layers of the atmosphere; some of the results can be recommended for practical use in the meteorological support of civil aviation.

The discussion of the prospects of investigations indicated that in general the subject matter of the work which has been carried out and which is planned corresponds to the problems of meteorological support of aviation with data on wind shears and turbulence in the lower layers of the atmosphere and corresponds to implementation of the tasks of the Interdepartmental Complex Plan on the Wind Shear Problem. At the same time, the conference noted that it is necessary to expand and intensify work in the following principal directions:

-- development of technical apparatus and methods for remote measurement of wind and turbulence parameters in the lower layers of the atmosphere in the airport area (radioacoustic, acoustic, laser, etc.);

-- implementation of experimental investigations of wind shear and turbulence in zones of takeoff and landing of aircraft, especially at the time of passage of atmospheric fronts, under conditions of temperature inversion and active convection;
-- theoretical modeling of the characteristics of the wind profile and turbulence, exerting an influence on the takeoff and landing of aircraft for the conditions of advection, strong nonstationarity of processes, convection and complex orography;
-- continuation of investigations for developing methods and prognostic recommendations for determining wind shears and turbulence in the lower layers of the atmosphere in the airport zone on the basis of the synoptic situation;
-- study of meteorological conditions causing a strong wind shear and turbulence in the zone of takeoff and landing of aircraft at airports with complex local relief;
-- creation and adjustment of standard-produced industrial production of improved mechanical wind-measuring apparatus and wind detectors (including three-component apparatus) and recorders for them for the purpose of their mass use for the outfitting of meteorological masts, towers and beacons, and also for installation at airports;
-- investigation of the possibility of using data from measurements of meteorological parameters on masts, towers and beacons for operational meteorological support of the nearest airports;
-- investigation of the possibility of use of meteorological radars for routine determination of zones of turbulence and wind shears in the airport region.

The conference proposed the preparation of methodological recommendations for analysis of data on the wind shear in the lower layers of the atmosphere.

It was noted in the resolution that the implementation of work under the Interdepartmental Complex Plan is one of the principal tasks of the scientific research institutes of the State Committee on Hydrometeorology and Environmental Monitoring. In this connection the conference called upon the key and regional scientific research institutes of the State Committee on Hydrometeorology and Environmental Monitoring to take an active part in the broadening of studies of the wind shear problem.

V. G. Glazunov

During the period 15-21 June 1981 a Soviet-American conference was held in Leningrad for studying the influence of an increase in the quantity of carbon dioxide in the atmosphere on climate. Below we give a summary of this conference, whose compilers were: from the USSR -- M. I. Budyko, V. N. Adamenko, E. K. Byutner, K. Ya. Vinnikov, G. S. Golitsyn, G. V. Gruza, V. P. Dymnikov, I. L. Karol', S. S. Khmelevtsov; from the United States -- W. A. Gates, J. Angell, M. McCracken, F. MacKenzie, W. Ramanathan, M. Steiver, E. T. Sundquist.

Introduction

Since the signing of the bilateral Soviet-American agreement on preservation of the environment, within the framework of Working Group VIII under this agreement there has been discussion of the problems of carbon dioxide, changes in its atmospheric concentration, its effects on climate and the possible influence on man. Initially there was discussion of problems related to study of the air temperature trends, the used observational data and the interpretation of the results of model computations. In order to comprehend better the scientific points of view of the different parties a number of symposia were held: at Tashkent (1976), Leningrad (1977), Dushanbe (1978) and Tbilisi (1979). The results of the symposia were of considerable scientific interest. They enabled scientists of each country to exchange information on the results of their studies. Unfortunately, the principal unclear aspects of the CO_2 problem were not entirely solved.

In October 1979 a protocol was signed at Tbilisi containing a recommendation on creation of a group of scientists for discussing important problems relating to the influence of the increase in CO_2 content on climate. The idea of such a conference was raised again at a symposium in Leningrad in 1977. It was understood that the existing differences in opinion can be eliminated only when specialists from both countries meet and in a working session discuss the prevailing disagreements. The conference, held in June 1981 at Leningrad, attained this purpose: eight American and nine Soviet scientists, representing a wide range of disciplines, in the course of a week discussed in detail the problem of change in CO_2 atmospheric content in the past, present and future, and also possible consequences of these changes.

The summary of the conference contains a detailed exposition of the results attained. The principal conclusions were compiled so that the interested parties could, in general, become familiar with the results of the conference and evaluate their importance and significance for future economic activity in both countries.

Principal Scientific Conclusions

1. Change in the concentration of atmospheric carbon dioxide. From the beginning of the organization of monitoring of atmospheric carbon dioxide (1958) to 1980 its concentration increased by 22 $mill^{-1}$. During this same time interval the industrial discharge of carbon was 39 $mill^{-1}$ (which corresponds to 82 Gtons). The data obtained at Mauna Loa station during the entire observation period agree well with the values for the industrial discharge of CO_2, multiplied by the coefficient 22/39. The observations and computations made using different models of the carbon cycle show that the remaining part of the anthropogenic carbon dioxide is absorbed by the ocean. The role of the biota for this time interval was not significant. The influence of changes in the biota on the concentration of CO_2 in the atmosphere is small, at least for this time interval.

An analysis of the results of direct measurements of the CO_2 content carried out in the 19th century reveals a preindustrial concentration of about 290 $mill^{-1}$. In order to refine this quantity computations were made of changes in the content of radiocarbon in the atmosphere arising due to the industrial discharge of CO_2 from 1860 to 1950. These take into account the natural variability of the content of ^{14}C during this period of time as a result of variations of the geomagnetic field and the intensity of the solar wind. A good agreement of the results of computations and the experimental data is obtained with values of the preindustrial concentration of CO_2 of 280-297 $mill^{-1}$ if it is assumed that the changes in biomass are also insignificant for this time interval.

If the rates of development of world energy during the course of the next 20 years remain the same as they were in the preceding 20 years, the concentration in 1990 will be 360±6 $mill^{-1}$, and in the year 2000 -- 394±9 $mill^{-1}$.

Computations of the distribution of anthropogenic carbon dioxide between the atmosphere, ocean and continental biomass for the time interval up to the year 2050, carried out for different scenarios of development of power production in the future, show that independently of the choice of scenario not less than 60% of the industrial effluent of CO_2 will remain in the atmosphere. According to most scenarios of development of electric power, a doubling of CO_2 should set in during the 21st century, in all probability in the interval between 2030 and 2060.

2. Paleoclimatic analogues of modern changes in climate. One of the possible ways to evaluate the consequences of global warming is related to study of the climates of the past. Particularly important is a clarification of the effects of the anticipated warming on other climatic variables, such as precipitation, on the natural and agricultural ecosystems, the stability and distribution of glaciers, sea ice and the level of the seas and oceans.

An example of such an approach can be the study of the climatic optimum of the Pliocene (3-5 million years ago). A paleogeographic reconstruction indicates that at this time in the extratropical part of the northern hemisphere there was a considerable difference in the distribution of temperature and precipitation in comparison with modern conditions. The permanent sea and continental glaciers in the northern hemisphere were probably nonexistent at that time.

These data can be useful for an understanding of the regularities of the anticipated climatic warming.

It is postulated that the warmer climate of the past could be associated with a higher CO_2 concentration. It is therefore necessary to continue further the investigations of climatic changes in the past, the global cycle of carbon and their relationships to the atmospheric CO_2 content.

3. Empirical investigations of modern climatic changes. There is an excellent agreement between the estimates of change in surface air temperature in the northern hemisphere obtained by the scientists of the USSR and the United States. The considerable warming observed from the late 19th century approximately to 1940 was replaced by a cooling continuing to the mid-1960's, which was followed by a warming which has continued to the present time (1981). Thus, the surface air temperature of the northern hemisphere has increased during the last hundred years; more than 30% of the dispersion of the series is related to a linear trend. The warming between the end of the 19th century and approximately the 1940's to a considerable degree determined this linear trend. The modern warming at the earth's surface was evidently more sharply expressed in the southern hemisphere than in the northern hemisphere.

This modern warming is manifested in data on the mean temperature of the troposphere in both hemispheres. There is reliable evidence that the warming of the troposphere was accompanied by a cooling of the stratosphere. Evaluations of the climatic trends cannot be used in the prediction of climate of the future by extrapolation, but can be useful in understanding the observed temperature changes.

Using a statistical analysis of data from meteorological measurements in the past it was possible to obtain estimates of the change in local climatic conditions in the processes of global warming and cooling of the northern hemisphere. These estimates can be used for the range of changes in mean annual air surface temperature of the northern hemisphere ±0.5°C.

Attempts have been undertaken to interpret the observed changes in surface air temperature of the northern hemisphere for the purpose of detecting changes caused by the influence of CO_2 on climate. The analysis made on the assumption that the changes in atmospheric transparency and CO_2 concentration are the basic reasons for the modern changes in mean temperature indicated that during the period 1883-1977 the northern hemisphere warmed by 0.4-0.6°C as a result of the influence of CO_2. This increase in temperature, caused by the observed increase in CO_2 content by 15%, corresponds to the estimates obtained from models of climate. In some investigations for an explanation of the changes in temperature in addition to atmospheric turbidity it was necessary to take into account some other factors. There are some empirical investigations in which it was not possible to detect the influence of CO_2 on temperature.

A spectral analysis of the observed changes in air surface temperature in the zone 50-70°N indicated that the temperature signal caused by the influence of CO_2 is more easily detected in summer because the noise level in summer is lower than in the remaining seasons. Such statistically significant temperature changes were not discovered for the time up to 1977 either due to the thermal inertia of the climatic system or as a result of the compensatory cooling caused by the influence of other factors. The mentioned investigation does not preclude the possibility of a warming due to the influence of CO_2.

At the present time it does not seem possible to conclude with absolute assurance that warming due to CO_2 has been discovered, although there are definite indications confirming this fact. Progress in modeling, together with an increase in the volume of measurement data in time and in space, in the near future should provide an adequately clear answer to this important question.

4. Model investigations of climatic changes caused by carbon dioxide. Different types of model investigations show that an increase in the CO_2 concentration in the atmosphere leads to a general warming of the troposphere and a cooling of the stratosphere. The mean annual global warming at the earth's surface is from 2 to 3° with a doubling of the CO_2 concentration. In this process the intensity of the hydrological cycle increases by several percent. The warming in the high latitudes should be several times greater than in the low latitudes. These effects can be increased as a result of the influence of small admixtures of anthropogenic origin by a value of approximately 50%.

The principal knowledge concerning these effects is obtained from three-dimensional dynamic models of climate which reproduce modern climate well. More realistic experiments with these models can give the geographical and seasonal distributions of a number of climatological elements important for many practical investigations.

But in order to obtain more precise knowledge, and for a comprehension of the reasons for the differences between individual models there must be additional research. Numerical experiments must be carried out with allowance for a gradual increase in the CO_2 concentration. The models must include allowance for the ocean, interacting with the atmosphere, real topography, seasonal and diurnal variations of insolation, the complete hydrological cycle, variations in the quantity of clouds and changes in the concentrations of small components. Such computations require an enormous amount of computation time but they are necessary in order to obtain statistically significant realistic results. These investigations are also necessary for the earliest possible detection of climatic changes caused by the influence of CO_2.

Simplified models of climate were necessary for understanding different physical mechanisms operative in the climatic system. They are also capable of giving realistic values of the global and zonally averaged distributions of changes in the climatic elements. Studies with such models should be continued, especially for investigating such problems as the influence of small components on climatic change.

5. Summary. The anthropogenic effects on the atmosphere are increasing at such a rate that their influence on global climate is becoming inevitable. This especially applies to an increase in the atmospheric content of CO_2 as a result of the combustion of fossil fuel. The influence of this increase in CO_2 on climate will evidently lead before the end of the 21st century to a general global warming with an increase in mean air temperature by several degrees. Such a warming may occur between 2030 and 2060. Using the best available estimates from model and empirical investigations it can be concluded that the greatest warming will evidently occur in the high latitudes.

Such a warming and the changes in the precipitation regime and other climatic elements associated with it will have important consequences for the biosphere, for agriculture and other types of economic activity. In order to foresee these consequences with adequate completeness it is necessary to continue investigations which must be well coordinated with the work being done in the shortest possible time. In this connection the continuation and strengthening of Soviet-American cooperation in this field of climatic research will be especially important.

***

An international symposium on tropical meteorology was held at Nal'chik during the period 9-13 March. It was attended by scientists of the USSR, Cuba and Vietnam.

Forty-eight reports on the following subjects were presented and discussed: numerical and laboratory modeling of tropical cyclones (TC); experimental investigations of the conditions for the development of a TC and its structure; convection, cloud cover, precipitation; boundary layer; predicting TC trajectories; interaction between the atmosphere and ocean at different scales; tropical zone; measurement instruments and methods.

Two reports were discussed at the plenary session. The review report of V. N. Ivanov (Institute of Experimental Meteorology) contained a generalization of experimental investigations carried out during recent years both in the USSR (expeditions

"Tayfun-75," "Tayfun-78" and others) and abroad relating to the conditions for the generation of TC, their structure in different stages of development. It was emphasized in the report that the dynamic characteristics of the troposphere play a decisive role in the tropical cyclogenesis process. In particular, it was noted that the following spatial distribution of the vertical wind shear is favorable (together with a number of other conditions) for the intensification of a disturbance: a small shear in the central zone of the disturbance and a considerable vertical shear of opposite signs on the periphery. The speaker emphasized the importance of further investigations of the central part of a TC, especially its mesoscale structure.

In a report by Ye. M. Dobryshman (Institute of Physics of the Atmosphere), devoted to nonlinear problems of dynamics of the atmosphere in the low latitudes, there was emphasis on the need for creating and studying simple models of circulation of the equatorial atmosphere. Such models can be useful not only for study of processes in the tropical zone, but also in formulation of models of general circulation of the atmosphere. The subject of atmospheric circulation in the low latitudes (especially gyroscopic movements of the atmosphere) was also the content of a report by Nguen Suan Sui (Vietnam). An interesting approach to the problem made it possible to obtain some analytical results. Despite an inevitable schematization, a comparison of the theoretically determined trajectories of air particles with the results of field experiments with neutral buoyancy spheres indicated their qualitative agreement.

Numerical modeling of tropical cyclones was discussed in a paper by A. P. Khain (USSR Hydrometeorological Center) and an investigation by V. Ye. Zakharov and Yu. T. Sapronov (Institute of Experimental Meteorology). Both models are axially symmetric. The author of the first of these endeavored to describe a number of physical processes transpiring in TC and in particular modeled the mutual influence of a moving cyclone and the ocean and the penetration of a cyclone onto the land. The second model had a more methodological character and was characterized by the use of a numerical method of an increased order of accuracy, which, in the opinion of the authors made it possible to a considerable degree to avoid the effects of computed viscosity and study the influence of different methods for stipulating the turbulence coefficient on the evolution of a model cyclone.

Laboratory modeling served as a basis for a report by a group of authors (O. G. Martynenko, V. I. Kalilets and A. V. Solodukhin, Institute of Theoretical Meteorology, Belorussian Academy of Sciences, E. Perez, Cuba) entitled "One Variant of a Laboratory Model of Eddy Formations." The authors told about an eddy created in a special apparatus by means of a multiblade fan. The velocity field characteristic for a TC was obtained.

Eleven reports were devoted to experimental investigations of the conditions of development of a TC, its structure and energetics, and also the structure of the troposphere in the zones of generation of a TC. These included three joint reports (USSR and Cuba). These studies were based on field data from Soviet expeditions to the tropical zone, and also on the results of observations of hurricanes occurring in regions surrounding Cuba. In all the reports in this group there is emphasis on the considerable spatial and temporal variability of different characteristics in a TC. Expeditionary investigations also made it possible to detect a number of new peculiarities of TC structure. In particular, it is demonstrated in a report by L. I. Petrova (Institute of Experimental Meteorology) that the thick inflow layer, up to the level 200 mb (with discrimination of two maxima: in the boundary layer and in the middle troposphere) is a characteristic feature of TC circulation.

An interesting fact was noted in a study by L. S. Minina and Ye. N. Arabey (USSR Hydrometeorological Center) and R. Parrado (Cuba): in typhoon Carmen (1978) there was a lower tropospheric warm nucleus. It is necessary to emphasize the work of A. Pene (Cuba), devoted to the synoptic conditions for the development of TC, in which it was demonstrated that about 30% of the total number of hurricanes originating in the North Atlantic develop on cold fronts.

The influence of centers of action of the atmosphere on the generation and intensity of typhoons was examined in a report by N. I. Pavlov (Far Eastern Scientific Research Institute). The possibility of the formation of a cyclonic eddy in the zone of interaction of three anticyclones was examined in a report by M. Portela (Cuba) entitled "A Tropical Cyclone From the Point of View of Thermodynamics As a System of Eddies." Also examined was the influence of the wind field in anticyclones on the movement of a TC.

The problems involved in parameterization of convection were examined in reports by A. P. Khain and M. G. Yarmolinskaya (USSR Hydrometeorological Center) and A. I. Fal'kovich (USSR Hydrometeorological Center). The first of these studies discussed two schemes for parameterization based on the representation of a cloud in the form of a central nucleus and a shell of mixed air entrained from the sides. In the first scheme convective heating is determined on the basis of computations of precipitation in the nucleus and shell and in the second the distribution of heating is proportional to the temperature difference between the cloud and the ambient atmosphere. A report by A. I. Fal'kovich dealt with a new principle for the parameterization of moist convection based on the idea of expansion of the solution in a small parameter. The author also investigates the problem of allowance for radiation cooling in the parameterization of moist convection in the model of a tropical cyclone.

A study by A. P. Khain and Ye. A. Agrenich (USSR Hydrometeorological Center) entitled "Characteristics of the Surface and Boundary Layers in a Tropical Cyclone" examined a model of the layer under the clouds with allowance for interaction with the free atmosphere.

A major group of reports was devoted to study of the interaction between a tropical cyclone and the ocean. Theoretical and experimental (based on data from the expeditions "Tayfun-75" and "Tayfun-78") studies in this direction dealt with the reaction of the ocean to the passage of a TC and also the problems involved in the exchange of energy and moisture between the ocean and the atmosphere. Among the theoretical studies we should mention a report by I. D. Ginis and Kh. Zh. Dikinov (Kabardino-Balkarian State University), giving the results of numerical modeling of the nonlinear reaction of a stratified ocean to a TC. Allowance for the nonlinear terms in the equations of motion made it possible to investigate the problem of relaxation of the thermodynamic disturbance in the ocean, caused by the wind stress characteristic for a TC, after cessation of the wind effect. The detailed thermal structure of the track of typhoon Virginia (1978) was examined in a report by V. N. Ivanov, V. D. Pudov and S. A. Petrichenko (Institute of Experimental Meteorology). The authors for the first time on the basis of field data demonstrated the possibility of initiation of an eddy of a synoptic scale in the ocean by a tropical cyclone.

In a report by R. S. Bortkovskiy and B. G. Vager (Main Geophysical Observatory) entitled "Structure of the Boundary Layer" it was demonstrated that the change in conditions for turbulent and radiation exchange of energy between the ocean and the atmosphere in the region of the track of a TC has a stable character. The variability of the flows of heat and moisture entering from the ocean in the tropical zone, including during the passage of a TC, is illustrated in the reports of A. Rodriguez and R. Parrado (Cuba), R. S. Bortkovskiy (Main Geophysical Observatory) and A. Rodriguez and O. Padilla (Cuba), as well as A. N. Nadgurnyy (Arctic and Antarctic Scientific Research Institute). The numerical experiments on interaction between the atmosphere and ocean under stormy conditions, set forth in a report by Ye. N. Borisenkov and M. A. Kuznetsov (Main Geophysical Observatory), indicate the considerable contribution of spray in moisture exchange of the ocean-atmosphere system in a tropical storm.

The "prognostic direction" in investigations of tropical cyclones was represented by three studies of Cuban specialists. A report by R. Parrado, entitled "Method for Predicting the Maximum Level Rise Due to a Tropical Cyclone," was of great interest. He proposed a statistical method for predicting the maximum level rise in dependence on the maximum pressure at the center of a TC. A checking of the equation on the basis of an independent sample gives an 80% guaranteed probability. A refinement of the prognostic equation was achieved by taking into account the angle between the TC trajectory and the shoreline. A report by M. Bal'ester and O. Garsin dealt with prediction of the intensification of tropical disturbances. They proposed a method for predicting the intensification of tropical waves and depressions with the use of cloud cover photographs taken from meteorological satellites and also a number of computed parameters. The method gave satisfactory results in 76% of the cases when it was checked in practical work. The second report of the mentioned authors, devoted to application of the method for predicting the direction of movement of a TC developed by Fett and Brand, demonstrated the possibility of using this method for 12 hours, as well as 24 hours.

Two studies were devoted to the modeling of movement of a tropical cyclone: B. Ya. Shmerlin (Institute of Experimental Meteorology) and A. V. Nesterova (Institute of Experimental Meteorology), as well as A. V. Nesterov (Moscow State University). The two models are based on the replacement of a TC by a solid rotating cylinder and investigation of the motion of this cylinder in a stipulated flow. In the first of these studies, on the basis of an analytical solution, obtained for a simple case, a study is made of the stability of trajectories of TC in a zonal flow. The second model is more complete (includes nonstationarity, variability of the Coriolis parameter, etc.) and is solved numerically.

Among the studies of instruments and measurement methods presented at the symposium mention should be made of two reports from the Pacific Ocean Institute, Far Eastern Scientific Center, USSR Academy of Sciences, the authors of which were L. M. Mitnik, M. L. Mitnik and I. A. Alekseyeva, Ye. P. Dombkovskaya and L. M. Mitnik.

These reports were devoted to an evaluation of the parameters of the tropical atmosphere on the basis of the spectrum of ascending SHF radiation. It was demonstrated that the present-day status of satellite SHF radiometry makes it possible to investigate the humidity field, cloud cover and pressure fields in such zones as zones of tropical cyclones inaccessible for experimental study.

A report by O. N. Bukina, U. Kh. Kopvill' and S. Yu. Stolyarchuk (Pacific Ocean Institute, Far Eastern Scientific Center, USSR Academy of Sciences) dealt with the use of picosecond lidars for selective resonance sounding of aerosols in the atmosphere in tropical cyclones at a distance up to 90 km. V. S. Korolev (Institute of Experimental Meteorology) and A. A. Barannikov (Khar'kov Aviation Institute) presented a report on the the use of radio-controlled small flightcraft for studying the boundary layer of the atmosphere. The developed measurement complex can find extensive use in different investigations, especially in the study of clouds.

The report of V. F. Grakovich, Ye. A. Kopot' and Yu. V. Kopylov (Central Aerological Observatory) gives some idea concerning the possibility and prospects of use of microcomputers aboard an aircraft-laboratory. An interesting approach was used in a study by U. Kh. Kopvill', G. I. Dolgyy and A. N. Pavlov (Pacific Ocean Institute, Far Eastern Scientific Center, USSR Academy of Sciences). It gave a description of a system making it possible to register the interaction between a tropical cyclone and the ocean by means of an optical deformator in combination with a seismic channel.

The reports of Ye. P. Veselov, R. Perez, Z. Gonzales, D. Arcia, I. Diaz, P. Perez and N. Hernandez (Cuba) and P. Parrado and E. Oria (Cuba) proposed methods for computing the maximum velocity V_{max} in a tropical cyclone. In the first study it was possible to derive regression equations for evaluating V_{max} on the basis of the diameter of the cloud masses, evaluated on the basis of satellite photographs. The second study proposed an expression for computing V_{max}, including a correction to the cyclostrophic wind, taking into account the frictional force and local latitude.

In conclusion special mention should be made of a report by M. T. Abshayev and M. Ch. Zalikhanov (High-Mountain Geophysical Institute) devoted to investigations of the dynamics and structure of cloud systems. These results were obtained by creating a complex measurement system, making it possible to obtain the spatial thermodynamic structure of well-developed convective cloud cover. This study is characterized by a high level of formulation of a complex experiment and interesting physical results.

L. I. Petrova

NOTES FROM ABROAD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 125-126

[Article by B. I. Silkin]

[Abstract] It has been postulated that the reason for the recurrence of glaciations at the scale of thousands to hundreds of thousands of years is changes in the earth's orbit. But a weakness in the hypothesis is the excessively sharp onset of cycles in comparison with the relatively weak astronomical effect, assuming that it is the sole factor in the onset of glaciations. However, specialists at the Lamont Geological Observatory and New York State University have proposed supplementation of this hypothesis in order to explain such a phenomenon. The greatest area of glaciation usually occurs when as a result of astronomical factors extremely cold summers and relatively warm winters occur in the northern hemisphere. A rapid retreat of glaciers occurs under conditions of a stable warm summer and a cold winter in the same hemisphere. Evidently the physical mechanism leading to this is that the greater part of the thermal energy participating in the formation of the earth's climate is stored in the world ocean and ignoring this in any model of change in climate leads to spurious results. This new research has demonstrated that the phase of a cold summer on the earth, favoring the spread of glaciers on the land surrounding the North Atlantic, coincides with a drawn-out warming of the ocean, intensifying evaporation from its surface. This saturates the atmosphere with an excess quantity of moisture. The latter falls in the form of snow which feeds the glaciers. Paradoxically, the glaciers increase more rapidly during a period when the ocean is relatively warm. During the final period in the cycle of onset of glaciers the northern part of the Atlantic Ocean is covered with ice. It is maintained by acti[illegible]ing as a result of icebergs entering the sea. With a change in the characteristics of the earth's orbit in the direction of onset of a warm summer the glaciers begin to retreat, forming a still greater number of icebergs, as a result of which the ocean temperature drops still more and evaporation from its surface becomes minimum. Despite the setting-in of cold winters, the glaciers are no longer able to restore the mass of ice which they have lost in summer due to the lack of the necessary quantity of precipitation.

***

The process of accumulation of carbon dioxide in the atmosphere in the distant past has usually been investigated by an analysis of the content of carbon isotopes in tree rings. An Australian specialist has now concluded that tree rings cannot serve as reliable indicators of CO_2 content in the atmosphere of the past. It has been assumed that the anthropogenic increase in atmospheric CO_2 is clearly manifested in the tree rings studied in the northern hemisphere. However, a study of trees on Tasmania has failed to reveal the existence of long-term deviations from the mean level during the last 200 years. This suggests that in the northern hemisphere trees growing near sources of industrial contamination have probably reacted to local effects, rather than to a real change in atmospheric composition on a global scale. Until the reasons for the discrepancy between findings for the northern and southern hemisphere have been explained this whole question must be regarded as still open. Projections for the future must take into account this unresolved problem.

OBITUARY OF YEVGENIYA SAMOYLOVNA RUBINSHTEYN (1891-1981)

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 126-127

[Article by staff of the Order of the Red Banner of Labor Main Geophysical Observatory imeni A. I. Voyeykov]

[Abstract] Professor Yevgeniya Samoylovna Rubinshteyn, an outstanding Soviet climatologist, the oldest worker of the Hydrometeorological Service, died on 6 April 1981. During the years 1914-1930 this outstanding woman worked in various subordinate posts at the Main Physical Observatory. Beginning in 1930, at the Main Geophysical Observatory, for many years she headed climatological subdivisions and during the prewar years was director of the Institute of Climatology. She was granted the title professor in 1934 and was awarded the degree of Doctor of Geographical Sciences in 1937. The sphere of her scientific activity over the course of more than a half-century was solution of major problems in climatology, fundamental climatographic generalizations, solution of such highly important problems in the activity of the Hydrometeorological Service as the rational operation of the meteorological network, the creation of a unified group of climatologists both at the Main Geophysical Observatory and at outlying institutes and administrations. A number of major climatic atlases of the USSR and the entire world were created and were published with her participation or under her direction. Her name is linked to fundamental generalizations of actual data on the climate of the USSR in the form of the series CLIMATIC HANDBOOKS. During the years of the Great Fatherland War she was engaged in meeting the needs of the Soviet Army. Her scientific publications, numbering over 100, are known both in the USSR and abroad. They include well-known texts on climatology for colleges.

MEMORIAL TO FEOFAN FARNEYEVICH DAVITAYA (1911-1979)

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 81 pp 127-128

[Article by M. I. Budyko]

[Abstract] This year marks the 70th anniversary of birth of the late Feofan Farneyevich Davitaya, outstanding Soviet agrometeorologist, climatologist and geographer. He graduated in 1932 from the Institute of Subtropical Crops in Tbilisi and in 1936 defended his candidate's dissertation. In 1950 he was awarded a doctor's degree and in 1960 was elected a full member of the Academy of Sciences Georgian SSR. During the period 1945 through 1951 F. F. Davitaya headed a laboratory at the All-Union Institute of Plant Cultivation. In the years 1951-1959 he was deputy head of the USSR Main Administration of the Hydrometeorological Service. Thereafter, to the end of his life (June 1979) F. F. Davitaya was director of the Geography Institute of the Georgian Academy of Sciences. Beginning in 1963 F. F. Davitaya headed the Division of Earth Sciences and was a member of the Presidium of the Academy of Sciences of the Georgian SSR. He was repeatedly elected to key posts of different Soviet and international scientific organizations. In 1969 he was elected President of the Georgian Geographical Society and in 1972 and 1976 was elected Vice President of the International Geographical Union. He was the author of about 300 publications, including a series of monographs on a broad range of aspects of the earth sciences. Particularly important was the work of F. F. Davitaya in the field of the agroclimatology of viticulture, which exerted a great influence on the development of grape production in the USSR. He also developed a method for predicting the thermal regime of the growing season. He was chairman of the editorial board preparing the CLIMATIC ATLAS OF THE USSR and he directed work on an extensive treatise devoted to study of the climate in the region of the virgin lands. Among other important contributions which he made was work on the ATLAS OF THE GEORGIAN SSR, the NATIONAL ATLAS OF CUBA and his investigations of the influence of economic activity on the biosphere.

5303 - END -
CSO: 1864/5