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NOTICE

The contents of this report will change with the next issue. Instead of cover-to-cover translation, it will contain either translations or abstracts of all articles from the Soviet journal METEOROLOGY AND HYDROLOGY. The Table of Contents will list each article in that issue of the journal and will note those articles which have been abstracted.

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USSR REPORT

METEOROLOGY AND HYDROLOGY

No. 6, June 1981

Translation of the Russian-language monthly journal METEOROLOGIYA I GIDROLOGIYA published in Moscow by Gidrometeoizdat.

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PRINCIPAL RESULTS AND PROSPECTS FOR DEVELOPMENT OF HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 (manuscript received 16 Apr 81) pp 5-18

[Article by Yu. A. Izrael, corresponding member USSR Academy of Sciences, chairman of the USSR State Committee on Hydrometeorology and Environmental Monitoring]

[Text]

Abstract: The results of the work of the USSR State Committee on Hydrometeorology and Environmental Monitoring during the Tenth Five-Year Plan and the basic tasks facing the Committee and the prospects of its development are examined.

During the past Tenth Five-Year Plan the broad use of hydrometeorological data and information on the state of the environment assumed ever-greater importance.

The principal directions in the activity of the State Committee on Hydrometeorology, including a number of new directions, follow from the most important state documents, documents of the 26th CPSU Congress.

It must be emphasized that at the 26th CPSU Congress, among the most important tasks in the field of the natural and technical sciences, a variety of problems were defined such as further study and exploitation of space in the interests of development of science, technology and the national economy; problems in study of the world ocean, including the shelf, for the purpose of rational use of its resources; problems in improving methods for prediction of weather and other natural phenomena, an increase in the effectiveness of measures in the field of preservation of nature; development of work in the field of ecology.

The congress defined major tasks in the field of preservation of nature.

The problem is defined of implementing a series of measures for the purpose of reducing the discharge of harmful substances into the environment, improvement in state control and intensifying of monitoring in the field of use of nature and preservation of the environment.

The tasks defined at the congress in the report of Comrade L. I. Brezhnev are tasks which are directly related to the personnel of the State Committee on Hydrometeorology which must be solved during the Eleventh Five-Year Plan. The results of the work of the Committee during the Tenth Five-Year Plan should be evaluated in the light of these problems.

During the past Five-Year Plan the Main Administration of the Hydrometeorological Service was transformed into the USSR State Committee on Hydrometeorology and Environmental Monitoring; the local administrations of the Hydrometeorological Service were transformed into republic and territorial administrations of hydrometeorology and environmental monitoring; centers were established for study and monitoring of contamination of the environment, the strengthening of network and scientific institutes. The state observation system is developing at a new technical level.

Hydrometeorological Support of the USSR National Economy

During the Tenth Five-Year Plan the hydrometeorological conditions were unfavorable for many branches of the national economy. For example, for agricultural work the weather conditions were unfavorable in three of the five years. This resulted in an increased demand for the supplying of Party and soviet agencies and national economic organizations with information on current and anticipated hydrometeorological conditions.

The principal task in the field of meteorological support, which was faced in the Tenth Five-Year Plan and a problem which must still be solved is an increase in the effectiveness of servicing of all branches of the national economy.

During the Tenth Five-Year Plan the guaranteed probability of short-range predictions and warnings of the occurrence of dangerous phenomena, even according to a new, more rigorous evaluation, increased by 1-3%. The mean guaranteed probability of diurnal (24-hour) predictions for a region for 1980 was 89%. The broad use of these predictions in the national economy will give an appreciable economic effect.

During the Tenth Five-Year Plan much work was done on improving the system for disseminating warnings of the occurrence of especially dangerous weather phenomena to the leaders of Party and soviet agencies and interested organizations.

For the purpose of a further increase in the quality of hydrometeorological support of the developing branches of the national economy over the course of the Tenth Five-Year Plan the operational-prognostic agencies were strengthened at 21 administrative centers of the autonomous republics and oblasts and seven new specialized hydrometeorological observatories and three hydrometeorological bureaus were organized.

During the Tenth Five-Year Plan the institutes of the State Committee on Hydrometeorology under complex hydrometeorological conditions for the most part in a timely manner and properly supplied key agencies and interested organizations with information on heat and moisture supply of sown crops, their state, anticipated conditions for yield formation and warnings on the occurrence of weather phenomena dangerous for agriculture.

Each year surface and aerial investigations of sown crops and pasture vegetation are carried out in a large volume.

During the Eleventh Five-Year Plan it is necessary to ensure a more routine and complete receipt of information on the condition and moisture supply of agricultural crops and pasture vegetation, increasing the areas of investigations of agricultural crops to 55 million hectares and gamma suveys of soil moisture content to 15 million hectares.

There was a considerable expansion in the collection of information on the conditions for yield formation on drainable soils. Three new agrometeorological stations were opened, as well as 80 agrometeorological posts on improvable lands and 390 agrometeorological posts at collective and state farms.

The annual predictions of crop yield and gross harvest of grain, prepared by the USSR Hydrometeorological Center and the administrations of hydrometeorology and environmental monitoring, were extremely successful.

The tasks of developing the agroindustrial complex in our country, decreed by the 26th CPSU Congress, require a substantial improvement in the hydrometeorological support of agriculture.

During the current Five-Year Plan the institutes of the State Committee on Hydrometeorology are faced with the task of developing new or improving existing methods for agrometeorological predictions, making it possible to predict the gross harvest of grain crops with an error not exceeding 5-10%. The solution of this problem is provided for within the framework of a special purposeful program.

The institutes of the State Committee on Hydrometeorology and the administrations of hydrometeorology and environmental monitoring, jointly with the All-Union Academy of Agricultural Sciences and the scientific research institutes of the USSR Agriculture Ministry, must generalize the experience in use of hydrometeorological information in the distribution of agricultural crops and the planning of agroengineering measures.

During the Tenth Five-Year Plan there was further development of the modification of hail processes for the purpose of protecting valuable agricultural crops against hailfalls. The area of the protected crops was increased during the period of the five-year plan by 2 million hectares and in 1980 reached 6.4 million hectares. Eleven new antihail detachments were formed, the technical outfitting of the antihail service was improved and new modification apparatus is being introduced. This will give an economic effect of about 100 million rubles each year.

Long-range predictions of water inflow into the reservoirs of the Volga-Kama Hydroelectric Power Station, Angara-Yenisey stages and other major hydroelectric stations had a high guaranteed probability during the Tenth Five-Year Plan. At the present time such predictions are prepared for 110 reservoirs.

Predictions of the water volume in the rivers of Central Asia and Kazakhstan had great importance for the planning of sown areas and the distribution of water among the republics at the time of low water in 1976 and 1977. The water volume of rivers in irrigable regions of Central Asia during the growing season and in 1980 was also ably predicted.

The institutes of the State Committee on Hydrometeorology carried out a considerable volume of work for studying mudflow and avalanche danger.

Despite the frequent recurrence of unfavorable weather conditions on the seas during the five-year period, there were no mishaps or disasters there due to incorrect forecasts and storm warnings. The guaranteed probability of the warnings of dangerous phenomena was from 96 to 100%.

There was further development of servicing of ships of the Ministry of the Maritime Fleet and the Ministry of the Fish Industry with recommendations on the most advantageous and safe navigation routes in the oceans. Each year from 2,500 to 3,000 ships received such recommendations.

During recent years support has been given to the work of the fishing and krill expeditions of the USSR Ministry of the Fish Industry in new, poorly studied regions of the Antarctic Ocean.

Work has successfully developed on study and exploitation of Antarctica. The 25th Soviet Antarctic Expedition opened the new Soviet station "Russkaya" in one of the inaccessible regions of Western Antarctica.

A snow-ice airdrome was constructed in 1980 at Molodezhnaya station and the first test flight of an Il-18D aircraft was made along the Moscow-Antarctica route.

In the central polar basin of the Arctic five high-latitude aerial expeditions were carried out in the last five years and the "Severnyy Polyus" drifting stations continued to operate. The new "Severnyy Polyus-25" station began to operate this year.

The total economic effect from the use of hydrometeorological information and predictions in the national economy during the five-year period in those branches where this effect can be taken into account was more than 4 billion rubles.

The task in the field of hydrometeorological servicing of the national economy is to increase the economic effect from the use of hydrometeorological information in the national economy by 10-15% in comparison with the Tenth Five-Year Plan.

Despite the definite successes attained in the Tenth Five-Year Plan, there are unsolved problems which lower the quality and effectiveness of hydrometeorological support of the national economy. For example, the guaranteed probability of the monthly predictions does not meet the needs of the national economy; the flexibility of the system for the registry and collection of information is inadequate, especially outside the standard observation times under anomalous conditions and at the time of weather phenomena; the interaction between the directors of a number of republic and territorial administrations of hydrometeorology and environmental monitoring and Party and soviet agencies and national economic organizations is inadequate.

Special attention must be given to the need for clarity and routineness in the collection and dissemination of information.

In the Eleventh Five-Year Plan it is proposed that one of the first steps be the development of an automated system for the dissemination of information from the Computation Center of the USSR Hydrometeorological Center to the computation centers of the Ministry of Power and Electrification, Ministry of the Gas Industry and Ministry of Land Reclamation and Water Resources (USSR) and the Ministry of Agriculture (RSFSR).

During the Tenth Five-Year Plan particular attention was devoted to the meteorological support of civil aviation. Aviation is developing at an exceptionally vigorous rate and is very sensitive to weather; the requirements on meteorological support here are exceptionally high.

During the Tenth Five-Year Plan 6 new aviation meteorological centers, 51 aviation meteorological stations, 47 operations groups and 80 meteorological aviation posts were organized. The plan for development of the operational network was completely implemented.

Individual methods for aviation predictions (thunderstorms, hail, icing) were developed and improved; methodological recommendations on determination of the wind shear and turbulence in the lower layer of the atmosphere, etc. were published.

An improvement was achieved in the meteorological support of civil aviation as a result of implementation of the above-mentioned measures. As an average for the five-year period there was only one interrupted flight due to incorrect predictions per 7,070 aircraft departures.

During the Eleventh Five-Year Plan in order to improve the meteorological support of civil aviation plans call for:
-- development of the operational network of aviation meteorological centers and aviation meteorological stations at civil aviation airports for the most part in the Siberia and Far East regions, including the organization of 142 new aviation meteorological stations, groups and posts;
-- introduction of 120 automatic stations into operation at airports, as well as 6,000 different meteorological instruments, introduction of an automated measurement-information system and other measures at airdromes.

Work on Study and Monitoring Environmental Contamination

During the Tenth Five-Year Plan work in the field of study and monitoring of the environment was greatly advanced. The plan for organizing new network subdivisions was completely implemented.

Fifty-one laboratories for monitoring the contamination of atmospheric air, 19 laboratories for monitoring the contamination of surface waters and 17 hydrobiological laboratories were organized. At virtually all the republic (territorial) administrations of hydrometeorology and environmental monitoring centers were established for studying and monitoring environmental contamination.

As of 1 January 1981 the monitoring of the contamination of atmospheric air by the agencies of the State Committee on Hydrometeorology was being carried out at 273 cities and industrial centers of the country; monitoring of the quality of surface waters was being carried out at 3,150 points and monitoring of the quality of sea water at 1,500 stations.

Work was further developed on the prediction of the levels of contamination of atmospheric air. Predictions are now being prepared for 122 cities.

The monitoring of transboundary transport of contaminants over great distances was organized.

At the present time the State Committee on Hydrometeorology has been assigned the responsibility for carrying out the functions of an interbranch administration for monitoring environmental contamination. The Committee has actively participated in drawing up the "Law on Preservation of Atmospheric Air," adopted by the USSR Supreme Soviet in June 1980.

Since 1976 the State Committee on Hydrometeorology has formulated and at fixed times has sent to the USSR State Planning Committee the drafts of national plans for the economic and social development of the USSR with relevance to the "Preservation of Nature and the Rational Use of Natural Resources."

The State Committee on Hydrometeorology has organized an inventorying of the sources of discharge of harmful substances into the atmosphere.

During the Tenth Five-Year Plan specialists developed a number of new technical means for monitoring contamination of the environment, a high percentage of which have been put into standard production.

Work has developed on the setting of norms for the discharge of harmful substances from stationary sources of contamination. In the cities the key organizations for the setting of norms have been determined. Drafts of "Regulations on the Sequence for Approval and Introduction of Maximum Admissible Concentrations" and "Systematic Instructions on the Setting of Norms for Discharges Into the Atmosphere" have been drawn up. Appropriate sections and groups have been established in 55 cities in the country.

The institutes of the State Committee on Hydrometeorology have initiated work on the expert evaluation of projects with respect to prevention of the contamination of atmospheric air; this will make it possible, already in the planning stage, to make provision for the necessary environmental protection measures.

During the last two years the agencies of the State Committee on Hydrometeorology have carried out expert evaluations of about 2,000 major planning decisions.

The specialists of the State Committee on Hydrometeorology have checked the status of work on preservation of the air basin and have drawn up proposals for its sanitization in many cities.

In 1980 the State Committee on Hydrometeorology raised a number of questions concerning the improvement of environmental protection work at the enterprises of several ministries and departments.

During the Eleventh Five-Year Plan plans call for the implementation of the following measures in the field of regulation of the use and preservation of the air basin:

-- creation of a State Inspectorate for Protecting Atmospheric Air Against Contaminants and by the end of the five-year period the organization of all links in the State Inspectorate for the most part will be completed;
-- development of norms for the maximum admissible discharge of harmful substances into the atmosphere and interim approved discharges of harmful substances for enterprises situated in 250 cities;
-- organization of regular taking and analysis of samples of discharges into the atmosphere at 1,700 major enterprises (in 110 cities).

It is desirable that major regional subdivisions for expert evaluations be established.

During the Eleventh Five-Year Plan subdivisions will be established for the setting of norms for discharges of harmful substances and plans will be developed for preservation of the air basin in another 104 cities, which will make it possible to monitor enterprises located in 159 cities, that is, in virtually all oblast centers of the country.

Since 1974 the Committee has had the responsibility for an ionospheric-magnetic service and a service for monitoring radiation conditions in circumterrestrial space. For all practical purposes these services were organized and fully developed in the course of the Tenth Five-Year Plan.

A system for the collection and processing of heliogeophysical information and services for predicting the state of the ionosphere, the earth's magnetic field and radiation conditions were created, as well as regional centers for these services.

During recent years there has been an increase in the number of organizations serviced with information and predictions by the geophysical services. Since 1979 the Committee has successfully ensured the servicing of distant flights of crews of the "Soyuz"-"Salyut" space complexes with predictions of radiation conditions in circumterrestrial space.

Development of the State System for Observing and Monitoring the State of the Environment and Climate

At the present time one of the principal sources of information on the state of the environment is the surface subsystem. It is made up of 3,100 hydrometeorological stations, 8,000 hydrometeorological posts, 134 hydrometeorological observatories, several thousand stations for the monitoring of contaminants, more than 300 laboratories for monitoring contaminations and more than 70 major expeditionary and scientific research ships.

Observations and primary processing are carried out in these network agencies.

The surface network is enormous in its structure, but it has not yet reached its optimum size.

During the Tenth Five-Year Plan the surface network continued to develop. The tasks of opening and rationalizing stations and posts were carried out. A total of 116 hydrometeorological stations were opened and 1,160 posts were organized.

During the years of the five-year plan there was an increase in the quality of observations and work at the majority of the administrations. More than 95% of the stations and posts provided excellent and good work quality.

During the five years in the network new service, residential and work structures were constructed at more than 300 stations at a cost of more than 10 million rubles.

A broad range of technical instrumentation and equipment for the collection of hydrometeorological information was furnished to the organizations of the State Committee on Hydrometeorology during the Tenth Five-Year Plan either for the first time or to replace worn-out or outmoded equipment. The plans for accomplishing such work during the five-year period and in 1980 were met.

Work was completed on the development of a number of new types of technical equipment (Scientific Research Institute of Instrument Making, Central Design Bureau, etc.). Much work was carried out for creating and putting into operation the "Pogoda" automated weather system.

Thirty-one computation centers are operating in the data processing system of the State Committee on Hydrometeorology. Among the electronic computers put into operation most are computers of the YeS series.

The space subsystem for hydrometeorological observations and the study of natural resources occupies a special place in the state observation system.

During the Tenth Five-Year Plan there was a considerable expansion in the use of space vehicles and facilities for the collection of hydrometeorological information and for the purpose of monitoring the environment.

Work was completed on tests of the meteorological space system with the second-generation satellites "Meteor-2," considerably surpassing first-generation satellites in their technical specifications.

At the administrations of hydrometeorology and environmental monitoring the network of autonomous surface points for the reception of satellite information was considerably expanded and by the end of the five-year period had attained 60 points.

On the basis of the "Meteor" experimental satellites it was possible to put the experimental "Meteor-Priroda" space system into operation. Satellites of this system ensure the collection of information needed by many ministries and departments for the study of natural resources in the solution of branch problems.

During recent years the surface complex for the reception and processing of satellite data has been considerably upgraded with new and superior equipment.

Work is being done on the creation of a geostationary meteorological satellite.

The purposeful program for the development of the State System for Observations and Monitoring of the Environment during the Eleventh Five-Year Plan and in the period ending in 1990 provided for measures directed to its further development (second stage). The Central Design Bureau of the State Committee on Hydrometeorology has prepared the sound basis for such development.

In the development of the subsystem for the collection of information plans call for the development of several modifications of automatic and semiautomatic stations (semiautomatic station for the large-scale network, making it possible to exclude the need for nighttime personnel) and other technical apparatus on the basis of integrated meteorological equipment systems (ASMT -- agregatirovannyye sredstv meteorologicheskoy tekhniki).

During the Eleventh Five-Year Plan it is proposed that 300 new points for meteorological observations be established, as well as 250 points for hydrological observations, 60 points for agrometeorological observations, approximately up to 60 points for radar observations of clouds and precipitation, 70-75 points for operational meteorological support of civil aviation airports, more than 500 points for monitoring air contamination and 1,000 for monitoring water contamination.

Since existing network observation facilities will long retain their importance in the surface subsystem for a long time, plans call for a substantial increase in the volume of construction and repair of work and residential buildings and structures of hydrometeorological organizations, especially inaccessible stations, and also carrying out other measures for improving the working conditions and work environment of workers.

In this five-year plan it is proposed that the network for radiosonde observations of the atmosphere be reoutfitted with a new complex: the small MARZ radiosonde - the "Titan" radar - a mini-computer. However, the "Meteor" and "Malakhit" aerological stations will still be in use for a number of years.

During the course of the five-year plan the first clusters of observation facilities outfitted with a new generation of unserviced stations will be created.

Shipboard hydrometeorological stations will be outfitted with remote measurement instruments and shipboard automatic stations.

Beginning in 1982 the MRL-2 will be outfitted with special instrumentation for the automatic processing of meteorological data, the "Tsiklon" outfit. Plans call for the annual installation of up to 10 outfits over the course of the five-year period.

During the Eleventh Five-Year Plan it is proposed that the MRL system be introduced not only in zones of airline routes, but also for radar determination of precipitation in regions with a danger of floods.

Provision is made for a considerable increase in the degree of automation in the making of observations and the processing of primary data.

In the Far East provision is made for the creation of an automated system of observations of the development and propagation of tsunamis and the issuance of tsunami warnings from the main center for the collection and processing of data at Yuzhno-Sakhalinsk.

In the Eleventh Five-Year Plan the complex program provides for a further improvement of the Committee's communication system. The following should be accomplished:
-- development of the new "Priroda" automated communication system, ensuring an increase in the rate of transmission through communication channels up to 9600 bits per second;
-- development and testing of an apparatus complex for the high-rate facsimile transmission of data, making it possible to reduce the time required for transmission and reception of a standard synoptic chart to 1-2 minutes. By 1985 plans call for the outfitting of all regional centers with this outfit;
-- development of a system for the collection of data from automatic observation facilities using geostationary artificial earth satellites.

By 1985 there will be considerable development of the "Priroda" automated data transmission system.

Plans call for the reoutfitting of presently operating and organization of new communication points at the largest prognostic facilities.

In the data processing system the complex program provides for the following objectives:
-- the possibility of operational processing of global meteorological information;
-- the possibility of mutual backing-up of the data processing centers and their integration into a unified computation center network;
-- creation of an environmental data bank.

At the higher data processing level plans call for the creation and operation of the Main Computation (Prognostic) Center and a considerable development of the All-Union Scientific Research Institute of Hydrometeorological Information.

In order to improve existing and create new data banks plans provide for the further outfitting of the All-Union Scientific Research Institute of Meteorological Information, being a world data center (WDC), with modern high-output electronic computers, bearing in mind that it will serve as a general informational data base and will ensure the creation of an upper-level environmental data bank.

The plan for 1981-1985 provided for the creation of the following specialized banks and their preparation for experimental use: "Surface Meteorology and Climate," "Synoptic Forecasting," "Aerology," "Oceanography" and a bank for a new type of data given the name "Profiles" ("Razrezy"); at the State Hydrological Institute -- "State Water Inventory Bank"; at the Main Geophysical Observatory -- "Actinometry" and "Atmospheric Contamination"; at the Institute of Applied Geophysics -- "Heliogeophysics"; at the All-Union Scientific Research Institute of Agricultural Meteorology -- "Agrometeorology."

At the regional data processing level plans call for the development of the computation capabilities of four regional centers: at Moscow, Novosibirsk, Tashkent and Khabarovsk.

With respect to the system for data reduction the complex program provides for the following during the period 1981-1985:

-- development of proposals, testing and experimental operation of an automated system for the reduction of data on the environment ensuring compatability with republic automated control systems (based at the Belorussian Administration of Hydrometeorology and Environmental Monitoring);
-- expansion of the information base and improvement in the technical outfitting of the "Sigma" system for the purpose of routine support of directive and planning agencies with information;
-- development of a system for the continuous radio transmission of current and urgent information on the environment to users.

Scientific Research

The scientific investigations of the Committee during the Tenth Five-Year Plan were carried out at 21 scientific research institutes where about 19,000 specialists work.

A new independent Laboratory for Monitoring the Environment and Climate (LAM -- Laboratoriya monitoringa prirodnoy sredy i klimata) of the State Committee on Hydrometeorology and Environmental Monitoring and the USSR Academy of Sciences was organized.

The five-year plan for scientific research and experimental design work of the Committee for 1976-1980 for the most part has been successfully implemented. Important scientific and practical results have been obtained in many directions and these are used extensively in the country's national economy.

In the field of weather forecasting the institutes of the Committee (USSR Hydrometeorological Center, West Siberian Scientific Research Institute and others) have worked on creation of computation methods for the prediction of meteorological elements on the basis of numerical solutions of the full equations of atmospheric hydrothermodynamics.

As a result of work in the field of mesometeorology, carried out during recent years at the institutes of the Committee (Central Aerological Observatory, Main Geophysical Observatory, West Siberian Scientific Research Institute) for the first time it became possible to approach the creation of a model for local numerical prediction of meteorological elements, that is, prediction for a territory comparable to the extent of Moskovskaya Oblast, for a time period of about 24 hours but with a greater resolution (about 10 km horizontally).

During the Tenth Five-Year Plan it was possible to achieve new results in the improvement of methods for short- and intermediate-range weather prediction. In particular, a method was introduced into operational practice for prediction with a regional prognostic model on the basis of solution of a system of full equations in hydrodynamics. The guaranteed success of short-range predictions for Moscow in 1980 was 86.5%, for Moskovskaya Oblast -- 89%, and in the period of the summer Olympic Games the guaranteed success of short-range 24-hour predictions was 93.8%.

All this indicates the availability of quite good methods for making short-range weather predictions.

An automated intermediate-range weather prediction system was put into operation. A system for the objective interpretation of hydrodynamic predictions was created for obtaining a prediction of weather elements. A result of this, in particular, is the prediction of minimum and maximum air temperature for a five-day period. Detailed methods for predicting air temperature for 5-10 days for individual regions of the country have been developed and are being successfully used in practical work.

A model of general circulation of the atmosphere has been developed for the purpose of development of prognostic schemes for study of planetary atmospheric processes by the USSR Hydrometeorological Center. Using this model the USSR Hydrometeorological Center has carried out investigations in the field of planetary dynamics and on their basis has developed a method for predicting meteorological elements for 10 days.

In the field of development of methods for long-range weather prediction definite work has been carried out by the USSR Hydrometeorological Center, West Siberian Scientific Research Institute, Main Geophysical Observatory and other institutes. In particular, the USSR Hydrometeorological Center has formulated the theoretical principles for including nonadiabatic factors in a highly simple thermodynamic model of the atmosphere and ocean.

The West Siberian Scientific Research Institute, in collaboration with the Computation Center of the Siberian Division of the USSR Academy of Sciences, on the basis of the concept of G. I. Marchuk on the decisive role of the ocean in the formation of long-term weather anomalies, carried out numerical experiments within the framework of a general model of circulation of the atmosphere and ocean. The results indicate the possibility of practical application of the proposed approaches.

In order to solve the problem of long-range weather prediction it is necessary to obtain detailed information on atmospheric processes, especially concerning atmospheric circulation, at a global scale. Work carried out under the Program for Investigation of Global Atmospheric Processes (GARP) was directed precisely to these ends. The scientific institutes of the State Committee on Hydrometeorology took an active part in this work. As a result of this work we now have sets of data on the state of the atmosphere and ocean for the observational phase of GARP which are unique with respect to quality and completeness. Work has been initiated on the processing and use of the accumulated data.

As before, one of the central problems in the improvement of weather predictions is the task of supporting the mentioned studies with high-output electronic computers. Such equipment is planned for the Main Computation (Prognostic) Center which is to be established in this five-year period in Moscow.

Long-range prediction imposes special requirements on information on the state of the atmosphere, ocean and surface of the land. Precisely from this point of view it is necessary to emphasize the importance of the observations organized in the last five-year period on a permanent basis in the Atlantic Ocean within the framework of the "Razrezy" program. The very same can be said with respect to the creation of a cloud cover service organized on the basis of use of information obtained from meteorological artificial earth satellites.

Much work was done during the Tenth Five-Year Plan by the scientific research institutes of the Committee in the field of development of methods for making agrometeorological predictions (USSR Hydrometeorological Center, All-Union Scientific Research Institute of Agricultural Meteorology).

The scientific research institutes of the Committee have formulated special recommendations on the agrometeorological validation of individual agroengineering procedures for the cultivation of agricultural crops and meliorative measures in the nonchernozem zone of the RSFSR and other regions of the country.

During the past five-year period the USSR Hydrometeorological Center and other institutes (Central Asian Scientific Research Institute, Ukrainian Scientific Research Institute) developed methods for long-range predictions of water inflow into the reservoirs of major hydroelectric power stations and methods for the rational use of water resources (State Hydrological Institute). Investigations and predictions of possible hydrological, climatic and ecological changes over the territory of the USSR were used in preparing the technical-economic basis for the shifting of part of the runoff of northern and Siberian rivers into the southern regions of the country (State Hydrological Institute, Arctic and Antarctic Scientific Research Institute, and others).

Studies in the field of creation of a theory of climate and the development of methods for predicting climate, carried out at the Main Geophysical Observatory, State Hydrological Institute and other institutes, made it possible to draw conclusions concerning the influence of economic activity on possible climatic changes.

Work was carried out for improving methods for warning of and contending with avalanches and mudflows (Central Asian Scientific Research Institute, Transcaucasian Scientific Research Institute, High-Mountain Geophysical Institute, Kazakh Scientific Research Institute).

The institutes of the State Committee on Hydrometeorology, headed by the Institute of Applied Geophysics (jointly with the institutes of the USSR Academy of Sciences and other departments) have developed complex predictions of the state of the environment and have given evaluations of man's influence on nature. It is important to note that during the Tenth Five-Year Plan a number of institutes of the State Committee on Hydrometeorology began extensive ecological investigations. The scientific principles for a many-sided analysis of the state of the environment were formulated (LAM).

The Institute of Applied Geophysics formulated scientific approaches to evaluation and analysis of the propagation of contaminating substances over great distances. These served as the basis for Soviet proposals for the drawing-up of an international convention on the transboundary propagation of contaminations over great distances.

The Institute of Applied Geophysics, Hydrochemical Institute, Main Geophysical Observatory, Laboratory for Monitoring the Environment and Climate and other institutes of the Committee have done much work on the scientific validation of an optimum system for observations and monitoring of the level of environmental contamination, including at the background level.

The Main Geophysical Observatory has prepared systematic instructions on the inventorying of the discharges of harmful substances into the atmosphere of cities and industrial centers and a method for setting norms for discharges of harmful substances into the atmosphere for industrial enterprises.

Investigations in the field of preservation of the marine environment were further developed during the Tenth Five-Year Plan (State Oceanographic Institute, Far Eastern Scientific Research Institute, Arctic and Antarctic Scientific Research Institute).

In the field of development of methods for computing hydrometeorological characteristics the institutes of the Committee have obtained a number of significant results. In particular, climatic indices were generalized for setting norms for glaze and glaze-wind loads.

A manual on the study of microclimate for the purposes of agricultural production, a map of agroclimatic resources of the nonchernozem zone of the RSFSR, a climatic map of the Baykal-Amur Railroad zone and a map of the heat supplies for the growing season in the zone of the Baykal-Amur Railroad were prepared and published for meeting the needs of agriculture.

The State Oceanographic Institute, in collaboration with the Arctic and Antarctic Scientific Research Institute, Main Geophysical Observatory, Far Eastern Scientific Research Institute and other institutes and territorial administrations of the State Committee on Hydrometeorology, developed the scientific principles for the supplying of the hydroengineering construction industry with regime hydrometeorological data, including studies for the finding and production of petroleum and gas in the shelf zone of USSR seas.

Scientific investigations directed to the development of new and improvement of existing methods for the artificial modification of meteorological processes have been extensively developed. Methods have been developed for the artificial regulation of precipitation, methods and apparatus for the modification of hail, thunderstorms, fog and low clouds (Institute of Experimental Meteorology, Central Aerological Observatory, High-Mountain Geophysical Institute, Transcaucasian Scientific Research Institute).

Major investigations of the world ocean were carried out during 1976-1980. As a result of these studies new and important information was obtained concerning thermodynamic processes in the ocean and on the interaction between the ocean and the atmosphere at different scales. Investigations were made of sea waves, currents, tides, the ice cover of the oceans and seas.

Long-range predictions of hydrological and hydrochemical conditions in the White Sea, Sea of Azov, Black Sea, Caspian Sea and Aral Sea were formulated.

Extensive investigations carried out during 1976-1980 in the Arctic and in Antarctica made possible considerable progress in the practical exploitation of these regions (Arctic and Antarctic Scientific Research Institute).

In the field of satellite meteorology a method for remote determination of water surface temperature and the altitude of the upper cloud boundary was introduced into operational practice on the basis of data from satellite spectral measurements of outgoing thermal radiation. The basic principles for active and passive SHF equipment for determining the characteristics of the underlying surface were formulated and validated.

Despite the achieved results, in the activity of a number of scientific research institutes of the State Committee on Hydrometeorology there are serious shortcomings lessening the effectiveness and quality of their work. Not in all cases was there assurance that the work would be carried out on the basis of through planning of the scientific theme from theoretical investigations to practical application of the results. At some institutes inadequate attention is being devoted to the problems involved in the introduction of the final results of scientific research and experimental design work. It is necessary to strengthen monitoring of the implementation of scientific investigations on the part of the administrations and divisions of the central headquarters of the State Committee on Hydrometeorology and Environmental Monitoring.

Tasks of Scientific Research Institutes and Purposeful Programs of the State Committee on Hydrometeorology and Environmental Monitoring During the Eleventh Five-Year Plan

For the purpose of a many-sided and complete implementation of the tasks following from the resolutions of the 26th CPSU Congress, the decrees of the directive agencies in the field of hydrometeorology and environmental monitoring, as well as assurance of a tie-in of specialized plans with material-technical and financial support, multisided purposeful programs have been developed along the principal directions of Committee activity (a total of eight programs) in which there is a reflection of both the scientific and productive aspects of our activity, the problems involved in the application of the results in the national economy.

During the Eleventh Five-Year Plan the scientific investigations carried out by the institutes of the State Committee on Hydrometeorology were directed to the implementation of studies included in the program for the solution of the most important scientific and technical problems approved by the joint decrees of the State Committee on Science and Technology, the USSR State Planning Commission and the USSR Academy of Sciences. These are programs relating to the development of new and improvement of existing methods for long- and short-range hydrometeorological predictions and predictions of heliogeophysical processes and the development of methods and equipment for artificial modification of meteorological processes and their introduction into the national economy, as well as methods for evaluating possible changes in climate and the influence of these changes on the national economy, for the creation and introduction of effective methods and equipment for monitoring environmental contamination, the development and introduction of a system for monitoring the background state of the environment and climate, and also the carrying out of multisided investigations of hydrophysical processes in the world ocean, the development of scientific and technical principles and measures for improving the use and preservation of water resources, and the development of scientific and technical principles for the territorial redistribution of water resources.

Work on these programs, carried out in collaboration with other ministries and departments, will make it possible to concentrate the scientific potential of different institutes on the solution of major problems which are of great scientific and national economic importance.

As already noted, the purposeful programs of the State Committee on Hydrometeorology, directed to the solution of national economic problems, are organically related to the scientific plans and programs. In particular, work has developed extensively on the purposeful multisided program "Weather Prediction," since precisely weather prediction lies at the basis of all hydrometeorological predictions.

Thus, on the basis of the use of models of general circulation of the atmosphere, with allowance for the properties of the underlying surface, the task is set of improving the hydrodynamic-synoptic method for prediction of the principal meteorological elements by regions of the country for 5-7 days in advance with a guaranteed probability of 80-90%.

The task is set of developing methods for predicting mean monthly air temperatures and the sum of precipitation for the purpose of increasing their accuracy by 10-15% and bringing the guaranteed probability of these predictions to 70-75%.

Through the joint efforts of specialists of the State Committee on Hydrometeorology and the USSR Academy of Sciences plans call for improvement in methods for long-range weather prediction with use of the theory of conjugate equations in hydrodynamics and on the basis of a broadening of the volume of information on the state of the ocean and atmosphere so as to bring the guaranteed probability of these predictions to 60-65%.

A special purposeful program provides for improvement in the system for the hydrometeorological support of the principal branches of the national economy of the country for the purpose of a more complete and operational support of these branches with hydrometeorological information.

The purposeful multisided program "Artificial Modification" is directed to an increase in the reliability of protection of agricultural plantings against hailfalls and bringing the protected areas up to 11 million hectares with a total saving of not less than 100-150 million rubles annually, as well as ensuring work on the artificial increase in precipitation by 1985 over an area of 1.3 million hectares and by 1990 over a still greater area; in addition, it is directed to an implementation of a search for ways to modify warm fogs, thunderstorms and frosts.

A special purposeful multisided program is directed to a solution of scientific, operational, organizational and other problems in the field of development of a national service of observations and monitoring of environmental contamination. As a result of implementation of this program scientific research will be carried out, new scientific laboratories will be established and existing ones will be strengthened, centers working on this problem will be created and enlarged, network organizations will be developed and norm-setting and juridical documentation will be worked out. All this will make it possible to ensure better-defined functioning of the national service of observations and monitoring of environmental contamination.

Investigations in the Arctic and Antarctic are making it possible to obtain new and check existing concepts concerning the patterns of meteorological and hydrological processes, including the properties of the ice cover, for the purpose of ensuring a changeover to year-round navigation in the Arctic, the mastery of the continental shelf and preservation of the environment in the Arctic region. This program is concentrating the efforts of Soviet Antarctic investigations on a determination of the possibility of exploiting the natural resources of Antarctica and the Antarctic Ocean.

At the present time contamination of the environment has attained such an intensity that it has become appreciable everywhere even at the background level. In this connection, in this five-year plan the formulation and introduction of a national system for background monitoring and the implementation of prediction of the state of the environment at the background level as well is becoming extremely timely. Such a prediction is acutely necessary in the planning of the development of the national economy over the long term. This work will be carried out within the framework of a new scientific and technical program of the State Committee on Science and Technology. The State Committee on Hydrometeorology is the key department for this program. These tasks should be carried out in the course of the five-year period.

Work in the field of space meteorology and development of a general system of observations and monitoring of the state of the environment will also be developed in accordance with a special multisided program of the State Committee on Hydrometeorology and Environmental Monitoring.

Finally, it is necessary to discuss the development of international scientific and technical cooperation of the State Committee on Hydrometeorology.

International cooperation is an indispensable part of the activity of the State Committee on Hydrometeorology and is directed first of all to obtaining hydrometeorological information from the entire earth, to solving complex scientific problems.

The active participation of the Soviet Union in a number of major international projects, such as the World Weather Watch, Program for Investigation of Global Atmospheric Processes, Joint Global System of Oceanic Stations, etc., made possible a considerable increase in the volume of data arriving at the world (Moscow) and regional (Tashkent, Novosibirsk, Khabarovsk) meteorological centers.

Scientific and technical cooperation in the field of hydrometeorology, space meteorology, preservation of the environment and rational use of the earth's natural resources developed and improved during the Tenth Five-Year Plan. Cooperation with the socialist countries within the framework of multilateral and bilateral agreements developed particularly broadly and productively. International scientific and technical cooperation of the State Committee on Hydrometeorology also also took place with many developing countries (Afghanistan, India, Angola, Mozambique, and others) and with the capitalist countries (United States, France, England, Sweden, Finland, Denmark and others).

The General High-Level European Conference on the Environment, held in 1979 on the initiative of the USSR, was of exceptional importance. This led to the signing by 32 countries of Europe, the United States and Canada of an international convention on transboundary contamination of the atmosphere over great distances and a declaration on technology with little or no waste products, which was a significant contribution to realization of the official final act of the general European conference at Helsinki on safety and cooperation in Europe. The Committee made a major contribution to preparations for this conference and actively participates in the realization of this convention.

The participation of the Soviet Union in the international meteorological experiments FGGE, MONEX, POLEX and a number of others had a major effect. As a result of these experiments new data were obtained on global circulation of atmospheric processes, on interaction between the atmosphere and ocean, so necessary for the solution of the problem of long-range weather predictions; the analysis of the results of the Atlantic Tropical Experiment (GATE) has been virtually completed.

As already noted, work is successfully developing under the "Razrezy" ("Profiles") program on a national and international basis. This program is specially directed to a quantitative determination of the role of interaction between the atmosphere and ocean, the role of special energy-active zones in the ocean in the formation of weather on the continents.

The effective development of the mentioned work in the field of international cooperation will help in the successful solving of highly complex problems in the field of long-range weather prediction, evaluation of possible changes in the earth's climate, ozone layer, anthropogenic changes in the state of the biosphere and other particularly acute geophysical and ecological problems.

In conclusion it must be noted that the development of work in the field of hydrometeorology and environmental monitoring in the Eleventh Five-Year Plan and in the more distant future should make a substantial contribution to the development of the national economy of our country and should also favor the preservation and improvement of a high quality of the environment, being a highly important element in the well-being of the Soviet people.

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WEATHER FORECASTING: STATUS AND IMMEDIATE TASKS*

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[Article by M. A. Petrosyants, professor, Hydrometeorological Scientific Research Center]

[Text]

Abstract: The article summarizes the results of work of the USSR Hydrometeorological Center on the method for forecasting weather for different times in advance during the Tenth Five-Year Plan and problems for the future are outlined.

As a result of the ever-increasing needs of man's economic activity for precise weather forecasts for different times in advance the number of studies devoted to this problem, both in the Soviet Union, and especially abroad, is increasing like an avalanche. A review of investigations in this field is a timely but an independent task. In addition, routine practical work in the preparation of forecasts at the present time is extremely dependent on the technical means for collecting and processing information. The standardization of these means for the time being is a matter of the future. Accordingly, in this article we will examine exclusively the studies of the USSR Hydrometeorological Center directed to the improvement of weather forecasts for different times in advance.

Short-Range Weather Forecasts (Forecasts for One-Three Days in Advance)

The working method for preparing short-range weather forecasts is the synoptic method, that is, the frontological analysis method, which now relies not on the extrapolation method, but on the numerical hydrodynamic prediction of the synoptic situation (fields of the principal isobaric surfaces).

A highly important element of the analysis is determination of the position and character of the fronts and is now accomplished with additional use of satellite cloud cover photographs. The quality of short-range weather forecasts is

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dependent on the volume of meteorological information used and the quality of the hydrodynamic forecasting methods. The theoretical principles of these forecasting methods have been well developed [20, 24, 45]. However, their practical application is dependent on many factors, the most important of which are the productivity and memory of available electronic computers and data support.

At the present time the USSR Hydrometeorological Center has the following numerical short-range forecasting schemes in practical use:

A quasigeostrophic scheme for predicting the surface pressure field and the geopotential of the isobaric surfaces 850, 700, 500, 400, 300 and 200 gPa for the territory of the Moscow Regional Center for times up to 72 hours. With the use of this scheme there is simultaneous diagnosis and prediction of vertical air velocities at the surfaces 850, 700 and 500 gPa, prediction of the trajectories for stipulated points for times up to 42 hours [5] and prediction of some other parameters. The scheme has been combined with a synoptic-hydrodynamic scheme for predicting surface pressure for 24 hours and prediction of precipitation for a period up to 36 hours [29, 43]. A total of 40 maps per day is computed using these schemes.

The "Sintez" hemispherical six-level adiabatic scheme with the use of a system of full equations in hydrodynamics. A difference analogue was constructed for the isobaric surfaces 1000, 850, 700, 500, 300 and 100 gPa and 1,625 "checkerboard" points, formed by two square grids measuring 29 x 29 and 28 x 28 points and with an interval of 600 km and with an integration time interval of 12 minutes, meshed in one another. The grid region is a square inscribed in the circle of the equator on a map of the northern hemisphere. Computations of a 24-hour forecast require 14 minutes. A forecast is given for a time up to 84 hours. Each day this scheme is used in computing 20 24-hour maps [4].

The "Region" regional six-level scheme with the use of a system of full equations in hydrodynamics is telescoped in the "Sintez" hemispherical scheme for the same isobaric surfaces as in the "Sintez" scheme. The region of telescoping is a rectangle on the map of the Moscow region, which contains 1,193 points, formed by two mutually embedded grids measuring 27 x 23 and 26 x 22 points, each with an interval of 300 km, with the integration time interval being 6 minutes. Forecasting for 24 hours requires 25 minutes with a BESM-6 computer and the forecast is computed for times up to 48 hours [5, 22].

At the edges the regional scheme uses values of the variables computed in the hemispherical model at the time of the preceding computation session. It is also combined with a synoptic-hydrodynamic scheme. The latter uses the forecast of the geopotential fields obtained in a "Region" scheme and an objective analysis of the pressure tendency at the earth for the 0300 hours observation time and a forecast of surface pressure is given for 24 hours and a forecast of precipitation is given for 36 hours. At the present time the "Region" scheme is used in computing five maps each day. However, the "Region" scheme can give the entire volume of production provided by a quasigeostrophic scheme.

For the needs of aviation a wind forecast is computed at the isobaric surfaces 400 and 300 gPa for 12 and 24 hours on the basis of data for 0300 hours by means of solution of a system of full equations in hydrodynamics [9]. Data for 0300 and 1500 hours are used for these same surfaces in issuing 24-hour forecasts of zones of strong clear-air turbulence twice a day [11]. A total of six maps is issued each day.

Table 1 gives the relative errors of operational forecasts for 1979 for two regions: the region best covered with observational data (A -- European USSR and Western Europe) and the entire Moscow region (B). The data in the table reveal a definite advantage of a hemispherical scheme.

Table 2 gives the relative errors of regional AT_{500} forecasts using the "Region" and quasigeostrophic schemes. The figures in Table 2 indicate the advantage of the "Region" scheme, especially in 24-hour forecasts.

An analysis of the history of development of short-range weather forecasts shows that a substantial increase in guaranteed probability of success in forecasts in every case was associated with major technical innovations in the weather service: with the creation of the aerological sounding network, with the introduction of electronic computers and numerical methods for forecasting pressure fields, with the use of satellite information for an analysis of atmospheric processes [10].

It is natural to expect that a further improvement in the quality of short-range weather forecasts can be achieved only with a substantial technical reoutfitting of the weather service. This reoutfitting should lead, first of all, to a broadening of the volume of meteorological information used in forecasting and an increase in the productivity of electronic computers.

First of all there should be a broadening of the data base on the state of the atmosphere, ocean and land surface. At the present time synoptic (SYNOP, SYNOP SHIP) and aerological (TEMP and TEMP SHIP) data are used in analysis and forecasting, as well as a number of fictitious (prepared by the weatherman) data in the form of TEMP telegrams from regions where few actual observations are made. In the synoptic analysis use is also made of radar and satellite observations.

Over the course of the last few years a mathematical support has been created which makes it possible to interpret virtually all types of communications on synchronous and asynchronous observations now being transmitted through communication channels (PILOT, SATEM, SATOB, AIREP, DRIBU, COLBA, BATHY, TESAC and GRID [37, 44]). The next task is the use of this mathematical support in preparing diagnostic charts and in objective analysis.

The objective analysis used in the technological process of short-range forecasting is based on the optimum interpolation method. Its use gives surface pressure and geopotential of nine surfaces (850, 700, 500, 400, 300, 250, 200, 150, 100 gPa), the surface three-hour pressure tendency, temperature and humidity, and also the field of water temperature of the ocean surface in the North Atlantic, interpolated in a regular grid of points [2]. The development of the objective analysis subsystem in the immediate future can be seen from the diagram in Fig. 1. A series of problems must be solved:

-- development of effective methods for checking operational data on the wind received from the aerological network, aircraft and satellites, and also satellite data on temperature profiles;

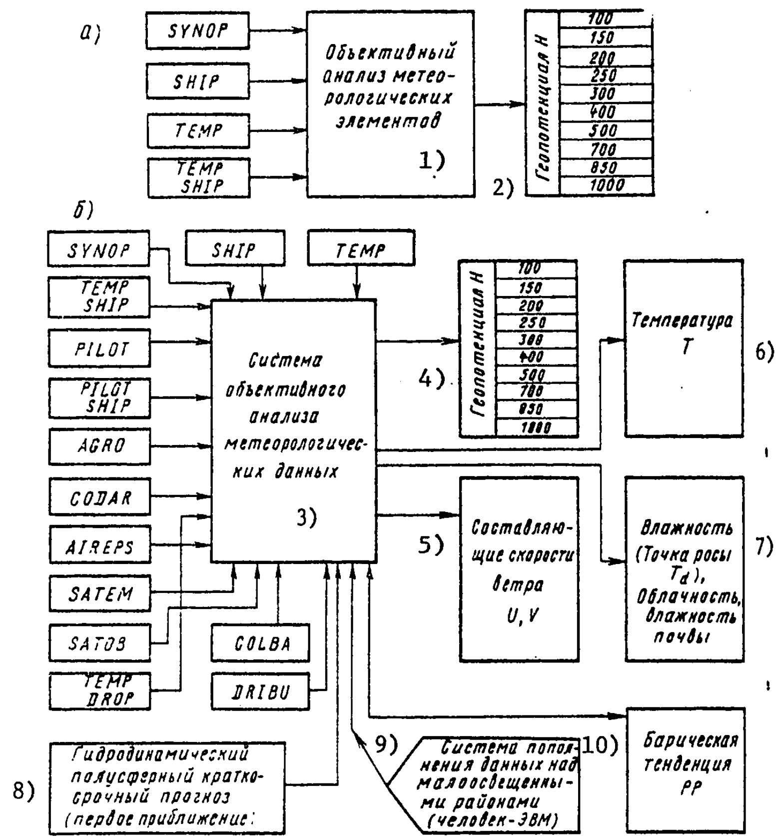

Fig. 1. Diagram of development of objective analysis subsystem. a) 1980; b) long-range development.

KEY:
1) Objective analysis of meteorological elements
2) Geopotential N
3) System for objective analysis of meteorological data
4) Geopotential N
5) Wind velocity components u, v
6) Temperature T
7) Humidity (dew point T_d, cloud cover, soil moisture content)
8) Hydrodynamic hemispherical short-range forecast (first approximation)
9) System for supplementing data on poorly covered regions (man-computer)
10) Pressure trend PP

-- development of a method for objective analysis of the wind field and matching of the wind and geopotential fields;
-- coverage of all poorly reported regions for which the weatherman prepares fictitious aerological data;

-- development of objective analysis methods for the tropical zone and the southern hemisphere and some others.

The general approach for the development of short-range weather forecasts, in addition to expansion of the data base, is improvement of numerical schemes for the hydrodynamic forecasting of meteorological fields. In particular, this involves realization, in an operational regime, of the hemispherical and regional nonadiabatic models already developed at the USSR Hydrometeorological Center. In a hemispherical nonadiabatic model with full equations there is an allowance for the heat from condensation, radiation, turbulent thermal conductivity and influence of the boundary layer [6]. In a regional nonadiabatic model with full equations an allowance is made for surface friction, orography, radiation heat influxes and heat fluxes from the underlying surfaces, macroscale and convective precipitation-forming processes [22]. The introduction of these models into operational practice will make it possible to reduce the relative error by 5-15% in forecasts of the synoptic situation up to 72 hours. In the future, as the USSR Hydrometeorological Center acquires more modern computers, a decrease in the relative error of numerical forecasts will occur as a result of a decrease in the spatial grid interval and a more precise description of physical processes on a subgrid scale.

Table 1

Relative Errors of Operational Forecasts (1979)

Forecast time, hours	Hemispherical scheme				Quasigeostropic plus synoptic-hydrodynamic schemes			
	A		B		C			
	surface	500 gPa	surface	500 gPa	surface	850 gPa	500 gPa	300 gPa
24	0.73	0.68	0.83	0.79	0.75	0.81	0.73	0.69
48	0.83	0.77	0.92	0.86			0.79	
72	0.93	0.85	1.02	0.94			0.92	

Table 2

Relative Errors of Regional Forecasts of AT_{500} Using "Region" Scheme and a Quasi-geostrophic Scheme (1979-1980)

Scheme	Forecasting time, hours	
	24	36
"Region"	0.64	0.71
Quasigeostrophic	0.73	0.74

The minimum spatial resolution of the grids used in numerical schemes for hydrodynamic forecasting at the Hydrometeorological Center at the present time is 150 km. Taking into account the prospects for outfitting the Hydrometeorological Center with new electronic computers, the grid interval probably cannot be significantly decreased. Accordingly, a numerical hydrodynamic forecast, as before, will give a large-scale forecast of the future synoptic situation for one, two and three days.

Thus, the interpretation of the synoptic process and the formulation of a forecast in weather terms for a specific point or region remains the task of a weatherman. In making a 24-hour forecast the weatherman has at his disposal different methods for forecasting the weather elements and the results of computations of temperature and precipitation using synoptic-hydrodynamic schemes. However, the situation with the prediction of weather for the second and third day is considerably more complex. In order to objectivize weather forecasting for these times as well, it is necessary to develop synoptic-statistical relationships between the elements predictable in numerical schemes (predictors) and the weather phenomena of interest to us (so-called "MOS concept"). Such studies have already been initiated [41] and they must be developed further in the future. We feel that it is especially promising to make use of the MOS concept in application to the forecasting of local weather phenomena, such as local winds, orographic precipitation, fogs, etc. A necessary condition for the development of this direction is the creation of an archives of the results of prognostic computations using hydrodynamic models.

It is also necessary to intensify investigation of fronts and their mesostructure on the basis of satellite and radar information and also investigation of mesoscale phenomena leading to dangerous weather phenomena.

Determination of the course of weather by hours within the limits of a 24-hour period is becoming possible with the creation of methods of local hydrodynamic forecasting (with departure from the quasigeostrophicity hypothesis), which would make it possible to model mesoscale atmospheric processes.

The hydrodynamic modeling of individual mesoscale atmospheric processes (orographic disturbances, breeze and mountain-valley circulation, convective movements, etc.) has a rather long history. However, for the time being sufficiently complete mesoscale nonhydrostatic models have not been created which could be routinely used in forecasting. At the USSR Hydrometeorological Center studies for the creation of a prognostic scheme of a local forecast were initiated in 1979. A model has now been created which is based on the equations of intense convection, ensuring a description of mesoscale processes. The temporal change of macroscale currents is taken into account by the formulation of boundary conditions at the lateral boundaries of the computation region. It is assumed that by the use of this model it will be possible to give a forecast of temperature, pressure, the three components of wind velocity, humidity, cloud cover and precipitation for Moscow and Moscow Oblast for a time up to 36 hours. The immediate tasks are perfecting this model and computing experimental forecasts [14, 21, 47].

Intermediate-Range Weather Forecasts (Forecasts for 4-10 Days)

Since 1973 the USSR Hydrometeorological Center has routinely three times a week prepared forecasts of the mean five-day temperature and quantity of precipitation, mean five-day temperature anomaly and once in five days -- forecasts of the mean ten-day temperature [18, 19]. The probable success of these forecasts is quite high and they have a substantial advantage over inertial and climatic forecasts [12]. However, practical needs and successes in the creation of short-range hydrodynamic forecasts have made the task of developing a method for the hydrodynamic forecasting of weather day-by-day for a period of up to two weeks a matter of priority. Precisely this task is one of the main goals of the Program for the

Investigation of Global Atmospheric Processes and its First Global Experiment. The difficulties standing on the path of solution of this problem are of a fundamental character: in particular, a hydrodynamic model for the prediction of meteorological elements must be nonadiabatic, with sufficiently complete allowance for the physical processes exerting an influence on the formation of atmospheric circulation; the region of solution of the equations for the prognostic model must take in the entire earth, and accordingly, hydrometeorological information on the state of the atmosphere, ocean and land must be global; resolution in the model both horizontally (with respect to spatial intervals or spectral numbers) and vertically (number of levels) should make it possible to describe sufficiently small disturbances, such as newly developed cyclones, frequently being transformed during their development in the course of the forecasting time into enormous vortices which determine the circulation for the entire period. All this indicates that the creation of an intermediate-range forecasting method is essentially impossible without using an electronic computer and that the requirements on electronic computers are extremely high [46].

For the purposes of developing intermediate-range weather forecasting the USSR Hydrometeorological Center has created an automated programming-technological "line" for the processing of meteorological information ("Liniya") [23]. It consists of the following subsystems:
-- reception, primary processing and checking of data arriving in communication channels;
-- supplementation of the data with additional meteorological information by establishing a "man-computer" relationship;
-- spectral objective analysis;
-- hydrodynamic forecasting of geopotential for the northern hemisphere for a period up to 10 days;
-- objective interpretation of hydrodynamic forecasts for the purpose of obtaining an intermediate-range forecast of weather elements;
-- interaction among the above-mentioned special-task subsystems through data banks.

The most complex task is the creation of a scheme for the forecasting of geopotential for the northern hemisphere for times up to 10 days. At the present time tests are being made of a finite-difference model of general circulation in the full equations of hydrodynamics with real initial data [42]. The model includes the parameterization of physical processes: radiation, boundary layer, macroturbulence, hydrological cycle (macroscale condensation, falling and melting of snow, moisture accumulation in the soil, evaporation). The model was constructed on the modular principle with the separation out of a programming core, which includes modules for the control, processing and exchange of information between the operational and external memories and is common for different variants.

A "Saber-172" computer was used with a four-level hemispherical scheme with a latitude-longitude grid in two variants: with 576 points (18 in latitude x 32 in longitude) and with 1152 points (18 in latitude x 64 in longitude). The latter variant requires 90 minutes computer time with the "Saber-172" for forecasting for 24 hours. A telescoping model was also employed [15]. The following information is necessary as initial data: surface pressure, temperature (or geopotential), wind, humidity, temperature of the ocean surface and soil moisture content.

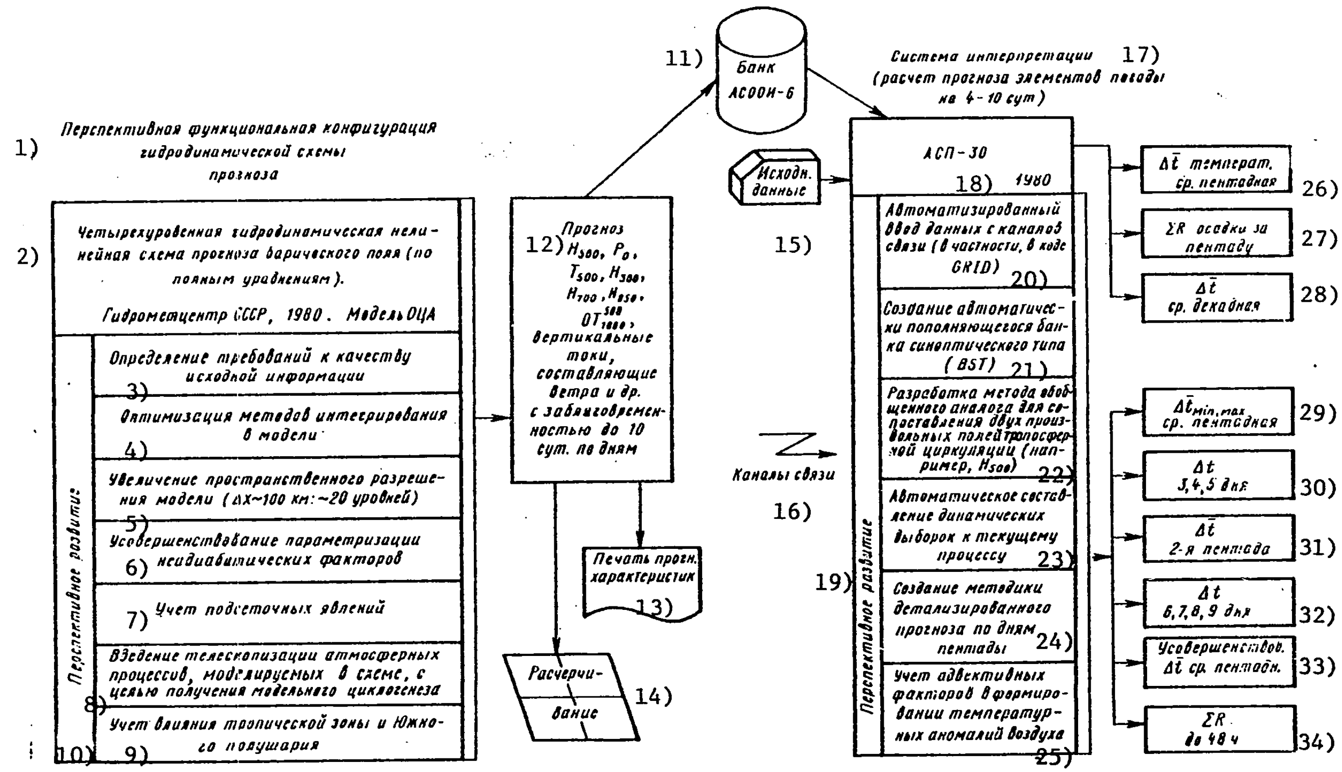

Fig. 2. Diagram of development of prognostic subsystems.

KEY TO FIG. 2

1. Prospective functional configuration of hydrodynamic forecasting scheme
2. Four-level hydrodynamic nonlinear scheme for predicting pressure field (on the basis of full equations). USSR Hydrometeorological Center, 1980. OTsA model (OTsA = general circulation of the atmosphere)
3. Determination of requirements on quality of initial information
4. Optimization of methods for integration in model
5. Increase in spatial resolution of model ($\Delta X \sim 100$ km; $\sim$ 20 levels)
6. Improvement in parameterization of nonadiabatic factors
7. Allowance for subgrid phenomena
8. Introduction of telescoping of atmospheric processes modeled in scheme for purpose of obtaining model cyclogenesis
9. Allowance for influence of tropical zone and southern hemisphere
10. Prospective development
11. ASOOI-6 bank
12. Prediction H_{500}, P_0, T_{500}, H_{300}, H_{700}, H_{850}, OT_{1000}^{500}, vertical currents, wind components, etc. with advance time up to 10 days
13. List of prognostic characteristics
14. Drafting
15. Initial data
16. Communication channels
17. Interpretation system (computation of prediction of weather elements for 4-10 days)
18. ASP-30
19. Prospective development
20. Automated input of data from communication channels (in particular, in GRID code)
21. Creation of an automatically replenishing bank of the synoptic type (BST)
22. Development of a generalized analogue method for preparing two arbitrary fields of tropospheric circulation (for example, H_{500})
23. Automatic preparation of dynamic samples for current process
24. Creation of a method for detailed prediction by days of five-day period
25. Allowance for advective factors in formation of air temperature anomalies
26. $\Delta \bar{t}$ mean five-day temperature
27. $\sum \underline{R}$ precipitation for five-day period
28. $\Delta \underline{t}$ mean ten-day temperature
29. $\Delta t_{min,\ max}$ mean five day
30. $\Delta \underline{t}$ 3, 4, 5 days
31. $\Delta \bar{t}$ second five day period
32. Δ t, 6th, 7th, 8th, 9th days
33. Improved $\Delta \bar{t}$ mean five day
34. $\sum$R up to 48 hours

A five-level global spectral model of general circulation of the atmosphere, now used for investigations [28], created at the Hydrometeorological Center, is also extremely promising. The hydrodynamic forecasting subsystem must give a forecast by days for up to 7-10 days for surface pressure, for geopotential of the isobaric surfaces 850, 700, 500 and 300 gPa, temperature, vertical movements and wind velocity components with the availability of the above-mentioned information.

With the availability of a forecast of these fields use is then made of the synoptic statistical relationships among the elements of circulation and weather elements, much as is done in the automated forecasting system [12] now in operation at the USSR Hydrometeorological Center. The operational archivization of synoptic data is an important element of this subsystem.

The development of the "Liniya" ("Line") system (Fig. 2) requires the outfitting of the USSR Hydrometeorological Center with considerably more productive electronic computers, a substantial improvement in the communication system for the collection of hydrometeorological information and the creation of a global observation system meeting the necessary resolution and accuracy requirements [35].

Weather Forecasts for One Month

A long-range weather forecast, especially a weather forecast for a month in advance, is one of the most difficult problems in the earth sciences. The reasons for this are as follows:

-- the unusually broad spatial (1 km - $4\cdot10^4$ km) and temporal (tens of minutes - several months) spectra of atmospheric disturbances forming the weather at each point;

-- the global character of atmospheric interactions exerting an influence on the course of weather in a particular region;

-- the unusual diversity of the processes and the spatial scales of transformation of energy from one form to another;

-- the many forms of interaction between the atmosphere and the earth's complex underlying surface, etc.

The solution of the problem of reliable long-range weather forecasting is complicated by the absence of a global system of observations satisfying the necessary resolution and accuracy requirements and the lack of archives of the results of observations with an adequate duration and completeness.

Despite these difficulties, practical needs have forced and are forcing the routine preparation of forecasts for a month on the basis of already existing imperfect methods [38]. Operational forecasts of the sign of the monthly temperature anomaly, monthly anomaly and quantity of precipitation are prepared by the synoptic method a half-month in advance [13] and with a zero time in advance with the use of empirical influence functions [36]. During the past five-year plan the development of the synoptic method proceeded along the lines of a clarification of the prognostic value of such predictors as the anomaly of water temperature in the North Atlantic and its difference between successive months, the monthly sum of precipitation and the snow cover. An immediate task is a critical analysis of the points in the official synoptic method in the light of the results obtained.

The method for hydrodynamic long-range forecasting based on the well-known work of Ye. N. Blinova [7] has been further developed by a more complete allowance for climate-forming and weather factors [8]. On the basis of these investigations there is systematic preparation of a forecast of the monthly temperature anomaly, whose quality, although somewhat poorer than the quality of the forecast prepared by the synoptic method, is nevertheless continuously improving. In our opinion, the broadening of the information base in the future as a result of the employment of data on the global distribution of cloud cover, snow and ice and on air temperature at the earth's surface should lead to a further increase in the probable success of these forecasts.

The most important achievement during the elapsed period is the application of the new results obtained by G. I. Marchuk in the theory of long-range weather forecasting in the practical work of the USSR Hydrometeorological Center [25-27]. On the basis of the G. I. Marchuk solutions a method was created for diagnosis of the mean monthly anomaly OT_{1000}^{500}, averaged for six geographic regions (Fig. 3) and its testing under operational conditions was initiated [39, 40]. These computations, carried out post factum immediately at the end of the month, make it possible to comprehend what contribution was made to formation of the monthly anomaly by circulation and nonadiabatic factors. Table 3 gives an example of formation of the anomaly in August 1980. This table shows, first of all, a very good agreement of the value and sign of the computed and actual anomaly for all six regions and second, that the decisive contribution to formation of the sign in regions Nos 0, 1, 2, 3, 4 is introduced by nonadiabatic factors. In addition to diagnosis, the created method makes it possible to give an adiabatic forecast of the sign of the mean monthly anomaly OT_{1000}^{500} for the six regions indicated above. The guaranteed probability of such forecasts during the period December 1979-October 1980 with respect to sign was $\rho = 0.30$, which is considerably better than for inertial forecasts ($\rho = -0.15$). Everything stated above indicates that this work direction is extremely promising since even the simplest models give such highly encouraging results. It is therefore important to continue and broaden these studies: in addition to carrying out diagnostic computations it is necessary, using the tool of conjugate equations, to create more complex models describing the ocean - atmosphere system with the parameterization of the external heat influxes in them and to broaden the bank of hydrometeorological data for the purposes of long-range forecasting.

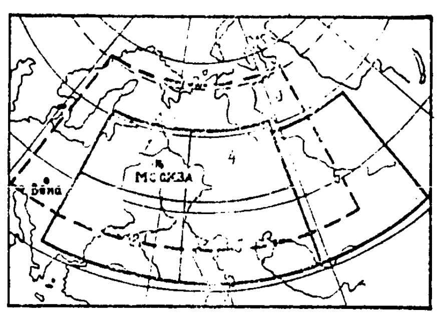

Fig. 3.

Table 3

Diagnosis of Anomalies OT_{1000}^{500}. August 1980

1) Район	2) Вклад		3) Аномалия, °C		6)	7)
	T'_0 °C	E' °C	4) расч.	5) факт.	$\Delta T_{абс}$ °C	$\Delta T_{абс}/T_{факт}$
0	1,0 1,0	−2,9 −2,9	−1,9 −1,9	−1,7	0,2 0,2	0,11 0,12
1	1,3 1,4	−3,2 −3,2	−1,9 −1,9	−1,6	0,3 0,3	0,16 0,17
2	1,1 1,1	−2,6 −2,4	−1,5 −1,4	−1,5	0,0 0,1	0,03 0,07
3	0,7 0,7	−2,1 −1,9	−1,4 −1,2	−1,4	0,0 0,2	0,00 0,18
4	0,9 1,0	−3,9 −4,0	−3,0 −3,0	−2,9	0,1 0,1	0,03 0,03
5	0,6 0,6	−0,2 −0,1	0,4 0,5	0,5	0,1 0,0	0,19 0,09

KEY:
1) Region
2) Contribution
3) Anomaly, °C
4) Computed
5) Actual
6) ΔT_{abs} °C
7) $\Delta T_{abs}/T_{act}$

Note: T'_0 is the contribution of the initial field of anomalies OT_{1000}^{500} to the computed value of the monthly anomaly OT_{1000}^{500}; E' is the contribution of external heat sources to the computed value of the monthly anomaly OT_{1000}^{500}. The upper line gives the results of computations with the use of real data on circulation of the diagnosed month; the lower line gives these same results with the use of the climatic circulation of this month.

Weather Forecasting for Seasons

Systematic forecasts (with an advance time of 1-3 months) of the anomalies of temperature and precipitation for the natural synoptic seasons of winter, spring, first and second halves of summer, autumn and prewinter have been prepared by the synoptic method since 1963. The success of a forecast of the sign of the temperature anomaly is ρ = 0.35 and for the quantity of precipitation is P = 75% [1].

A decisive contribution to the development of the modern operational method for seasonal forecasting was made by S. T. Pagava [32, 33]. An analysis of incorrect seasonal forecasts reveals that the principal failures are related to an incorrect determination of the precursor and its circulation. Accordingly, further efforts must be directed to an objectivization of determination of circulation of the precursor. Studies in this direction have already begun. A method for objective determination of the limits of the seasons, a method for computing their anticipated onset and the appearance of precursors of the future seasons have been proposed. However, these results can be considered only as a beginning.

During the elapsed period extensive investigations were made of the heat fluxes between the ocean and the atmosphere over the North Atlantic and the possibilities of their parameterization with use of the extent of cloud cover. Important negative asynchronous relationships have been established between cloud cover anomalies over the Atlantic and temperature anomalies over the European USSR [30]. On this basis a statistical method has been developed for predicting the mean two-month temperature anomaly over the European USSR with an average advance time of five months [17, 31]. Tests of this method have given encouraging results (ρ = 0.34, Q = 0.68). More detailed data are given in Table 4. Analysis of successful and unsuccessful forecasts revealed their great dependence on the character of circulation: the forecasts were successful when there was a predominance of zonal forms of circulation and unsuccessful when there was a predominance of meridional processes. The next problem which follows is a study of the possibility of combining this method with a prediction of circulation on the basis of the precursor.

Predictions of Temperature and Precipitation for One Year in Advance

The principal investigations of this problem have been concentrated at the Main Geophysical Observatory imeni A. I. Voyeykov and at the Arctic and Antarctic Scientific Research Institute. At the USSR Hydrometeorological Center investigations began relatively recently of the possibility of predicting air temperature and precipitation for the growing season by statistical methods for a long time in advance (up to 1 year) [3]. The results of the investigations show that the success of forecasting of the sign of the temperature anomaly and quantity of precipitation (with breakdown into three equally probable phases) is optimum with an advance time of about 4-6 months. However, the indices of success of forecasts are not very greatly dependent on the advance time (see Table 4). The same result is also obtained when attempting to give a forecast of the monthly anomaly for a time up to a year by the method of selection of an analogue of the temperature variation curve in a month from the entire available archives of observations [16].

Implementation of Program of the First Global Experiment GARP

The past five-year period was the period of the most intensive preparation for and implementation of the First Global Experiment (FGGE) GARP, whose field phase began on 1 December 1978 and lasted to 30 November 1979. Under the FGGE program, the Hydrometeorological Center, as one of the world meteorological centers, has been assigned definite responsibilities for the collection of level IIa data and preparation of level-IIIa operational analyses. Taking into account the diversified character of observations of special FGGE systems and the total volume of information of all observation systems, including the surface and space systems of the WWW, a special plan was developed for increasing the productivity of the computation complex at the Hydrometeorological Center. In order to achieve compatibility with the other processing centers which are on the main WWW telecommunications line, a contract was signed in 1975 with Control Data Corporation for the installation of a "Saber-18-20"-"Saber-7200"-"Saber-7600" computer complex at the Hydrometeorological Center. Unfortunately, for reasons of no fault of the Hydrometeorological Center, only "Saber-18-20" and "Saber-172" electronic computers were installed, which then were used intensively for nonoperational experimental studies with models of general circulation of the atmosphere and numerical weather forecasts.

Independently of the contract, in addition to the existing data exchange line ("M-226"-"BESM-6" communication channels) a second data exchange line was created ("Minsk-32"-"BESM-6" communication channels). "YeS-1020" and "YeS-1040" electronic computers were also installed and connected to the communication channels. These measures made it possible to register all primary FGGE information (with small interruptions) arriving in Moscow through communication channels since 15 January 1979 and also to prepare an objective analysis of geopotential for 1200 hours GMT.

Table 4

Guaranteed Probability of Forecast of Sign ρ of Air Temperature Anomaly for the European USSR

Месяц 1)		4) Заблаговременность, мес	1975	1976	1977	1978	1979	1980
исходный по облачности 2)	прогнозируемый 3)							
IV—V, VIII—IX	I—II	9 5	—0,16 —	+0,27 —	+0,45 —	0,00 —	— +0,40	— +0,24
VIII—IX	II—III	6	1,00	+0,60	+0,21	+0,38	+0,71	—0,34
IX—X	III—IV	6	+0,87	+0,92	+0,87	+0,77	+0,23	—0,18
IX—X	IV—V	7	+0,37	+0,39	+0,31	—0,70	+0,86	—0,15
II—III	V—VI	3	+0,29	+0,40	+0,41	+0,38	+0,85	—0,18
II—III	VI—VII	4	+0,04	+0,13	+0,29	+0,68	+0,07	+0,11
I—II	VII—VIII	6	+0,06	+0,26	—0,20	+0,73	—0,14	—
VI—VII	VIII—IX	2	+0,70	+0,72	+0,35	—0,14	+0,50	—
IV—V	IX—X	5	+0,85	+0,14	+0,86	+0,19	+0,53	—
VI—VII	X—XI	4	+0,48	+0,13	—0,10	+0,64	+0,07	—
V—VI	XI—XII	6	+0,47	+0,58	+0,71	—0,50	+0,85	—
VII—VIII	XII—I	5	+0,28	+0,12	—0,21	—0,26	+0,33	—
5) Среднее:		5	+0,44	+0,39	+0,32	+0,18	+0,44	—

KEY:
1. Month
2. Initial, with respect to cloud cover
3. Predicted
4. Advance time, months
5. Mean

Summary

In this brief article we have attempted to discuss only those results of investigations which have already been introduced into operational practice or have been brought to the testing stage. Many important scientific results have remained beyond the limits of our exposition, although they constitute the scientific basis which will exert an influence on weather forecasts in the future.

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STUDY OF CLIMATE AND ITS PRACTICAL ASPECTS*

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[Article by Ye. P. Borisenkov, professor, Main Geophysical Observatory]

[Text]

Abstract: The article traces the influence of climate on man's activity in the historical past. It is demonstrated what an immeasurable increase there has been in the dependence of man's activity on climate at the present time, as a result of which, in the author's opinion, optimum allowance for climatic information must be regarded as one of the ways to increase the effectiveness of social production. The problem of how man's activity can exert an influence on climate, and accordingly, also on the conditions for his life in the future, is discussed. Possible ways to further develop this problem are discussed.

This article examines one of the most important aspects of the World Climate Program (WCP) and the USSR climate research program: the influence of climate on different facets of economic activity.

As is well known, in addition to practical aspects, the WCP emphasizes study of the physical theory of the formation of climate and its dynamics, study of the changes and variability of climate on the basis of factual data and evaluation of the influence of anthropogenic factors on climate. Each of the mentioned problems merits special consideration. Information on these aspects of the work carried out in the USSR can be found in the special literature [10, 27-29].

It is not the objective of this article to give a full analysis of the investigations carried out up to the present time in the field of applied climatology in the USSR, especially at the Main Geophysical Observatory. There are also a number of extensive generalizing publications in this area [8,11,14,15,19,20,22,23,30,31].

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The principal objective of this article is an analysis of the factors (and their tendencies) leading to the sharply increasing role of climate in the life of mankind, an evaluation of the tendencies in the development of research for the study of climate and the field of applied climatology, especially in relation to implementation of the WCP. Such an analysis is extremely necessary due to the clearly noticeable tendency to the transformation of the science of climate into a real force favoring an increase in the effectiveness of social production by means of the rational use of climatic resources by society.

The mentioned tendencies make it necessary to examine the history of climate and its relationship to historical events in the past from somewhat different points of view, as is also true of the tendency in the development of climate and evaluation of its influence on the economic and social aspects of the immeasurably developed and ever-increasing activity of human society.

It is well known that climate has exerted and even now is exerting a substantial influence on man's activity during the course of the entire history of development of civilization. Nevertheless, never during the entire history of civilization has the problem of climate as a whole, including such problems as long-term tendencies in change of climate and its variability, climatic anomalies, the physical mechanisms responsible for the change in climate, the influence of climate on man's activity and the reverse effect of human activity on climate, caused such interest in the broad scientific community, among government agencies and users of climatic information as during the last decade.

This is attributable to a number of circumstances, especially the enormous increase in the scales of economic activity and the unquestionably increasing dependence of society on climate and its changes.

The rapid increase in the development of productive forces is leading and indeed has already led to the result that the dependence of a whole series of branches of economic activity and entire countries on changing climatic conditions is not decreasing in absolute terms but is instead increasing and this increase is accompanied by a growth of production. Precisely for this reason during recent years there has been a rapidly increasing comprehension of the dependence of the national economy and well-being of society on changes in climate on the part of agencies concerned with the planning of socioeconomic development and control of production [1, 3, 7, 9, 12, 18, 25, 26].

A number of major climatic anomalies of recent years which exerted a substantial effect on the economy of a number of countries and even on the conditions for the existence of some states to a considerable degree served as a stimulus for the increased interest in the problem of climate and its changes. In a number of cases the consequences of major climatic anomalies also affected the sphere of international relationships [7, 36, 47, 50, 53].

A second important circumstance favoring increased interest in the problem of the influence of climate on human activity is a clear understanding of the fact that as a result of economic activity man himself has unintentionally begun to exert an influence on climate. For the time being his influence is manifested on a limited scale and is reflected only in some features of climate for the most part of a local character. However, under the prevailing conditions of a growth in population and more intensive activity there can be an inadvertent change in climate over great areas even in the course of the life of a few generations to come [18].

A third circumstance which has increased interest in the discussed problem is the following.

It has also been found that a sufficiently reliable scientific basis making it possible to evaluate the influence of climate on the economy, the biological and social aspects of the development of society, has also not been created. There is a definite detachment between climatologists, who are inadequately aware of all the demands upon them and are not capable of evaluating the needs and requirements of numerous users, and the probable users, who do not adequately know the possibilities of climatologists and the ways to make effective use of climatic information in their field of practical activity. Due to this and a number of other factors, the already available information on climate is not used sufficiently effectively and in a number of countries or branches is not used at all [7, 53].

The principal factor in such a situation is that the climate problem was extremely complex. It is among the highly complex interdisciplinary scientific tasks and there has been no appropriate scientific and material-production base. At present it is impossible to mention any other scientific and practical problem which requires such a broad interdisciplinary approach to its solution as the problem of climate and man.

The fourth circumstance is that in addition to its interdisciplinary character, this problem is global in scope. It cannot be solved either completely or partially at national or regional levels without bringing together the efforts of countries throughout the world. Accordingly, this problem with respect to both its scientific program and with respect to the monitoring of climate and its changes, as well as with respect to the solution of practical problems, can only be regarded as an international problem.

At the present time the attitude toward the role of climate in the life of society is being considerably changed. However, many more efforts are required for this tendency to affect all the necessary aspects of human activity to an adequate degree.

Apparently it is possible to discriminate four types of knowledge concerning climate, each of which can be applied to a definite category of decisions made by man.

First of all, a knowledge is required of the general statistical characteristics of climate and its variability for different regions and for the entire earth and this requires the use of such information in working out a policy or plan for such development over a long-term period and also in the control of production.

A second type of knowledge is information concerning the influence of climatic extrema, that is, states of the climatic system atypical for the mean climate, on different aspects of economic and social life and the principles for adoption of optimum solutions with this information taken into account.

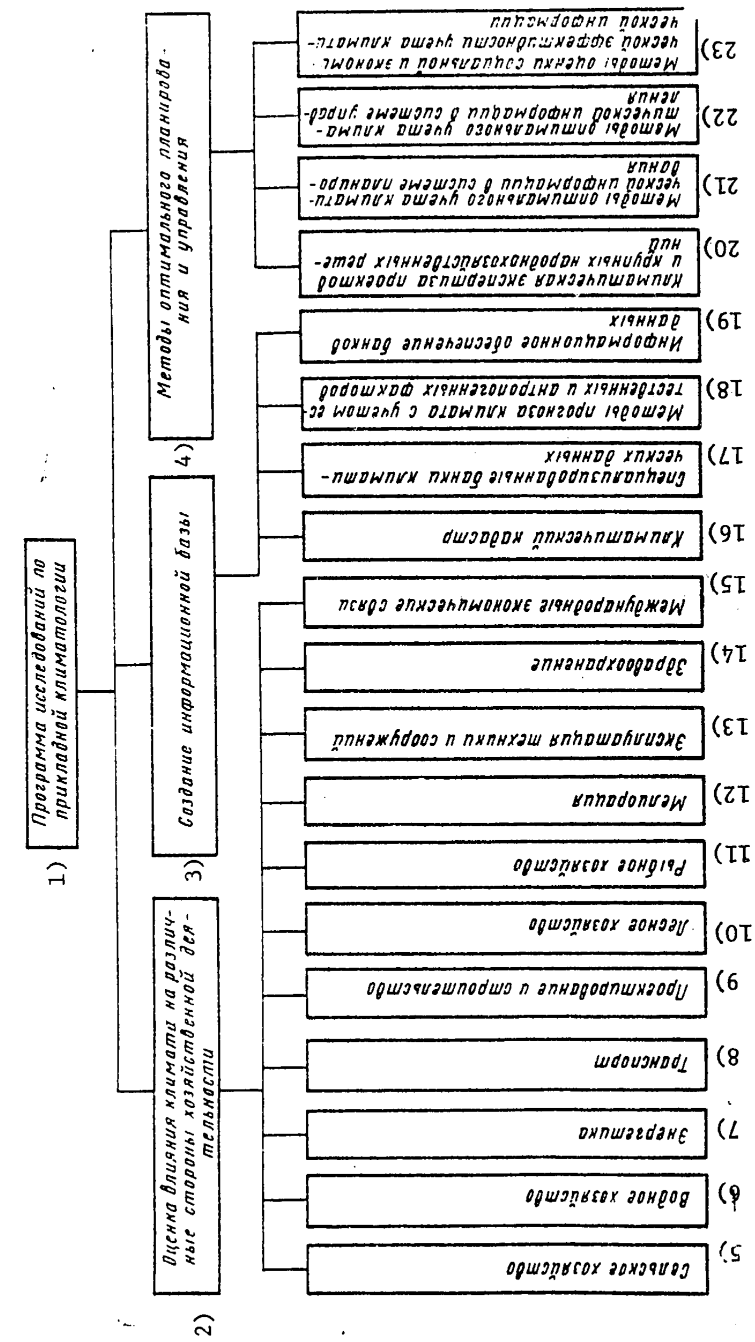

Fig. 1. Block diagram of program for research in applied climatology.

KEY TO FIGURE 1

1) Research program in applied climatology
2) Evaluation of influence of climate on different aspects of economic activity
3) Creation of information base
4) Methods for optimum planning and control
5) Agriculture
6) Water management
7) Electric power
8) Transportation
9) Planning and construction
10) Forestry
11) Fishing
12) Land improvement
13) Operation of equipment and structures
14) Public health
15) International economic relationships
16) Climatic survey
17) Specialized climatic data banks
18) Methods for predicting climate with allowance for natural and anthropogenic factors
19) Informational support of data banks
20) Climatic expert evaluation of projects and major national economic decisions
21) Methods for optimum allowance for climatic data in planning system
22) Methods for optimum allowance for climatic data in control system
23) Methods for evaluating social and economic effectiveness of allowance for climatic data

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Changes in Mean Five-Year Values of Climatic System Parameters for Period 1951-1975

Hemisphere	Climatic parameters	Region, degrees	Mean changes in decade, °C				Mean, °C
			1955—1960	1960—1965	1965—1970	1970—1975	
Northern	TMA	0—90	—	—	—0,068	—0,324	—0,196
	SAT	0—90	+0,088	—0,204	—0,068	—0,088	—0,068
	TMA	65—90	+0,556	—0,944	—0,300	—0,208	—0,224
	SAT	70—90	—0,760	—0,428	—0,184	+0,412	—0,240
	TMA	35—90	+0,328	—0,316	—0,620	—0,160	—0,192
	TMA	50—90	+0,476	—0,476	—0,584	—0,264	—0,212
	SAT	50—90	—0,156	—0,072	—0,368	+0,324	—0,018
	SST	North Pacific	+0,304	—0,492	+0,188	—0,512	—0,128
	SST	North Atlantic	—0,480	—0,200	—0,260	—	—0,313
	TMA	10—30	—	—	+0,144	—0,316	—0,086
	SAT	0—50	+0,156	—0,244	+0,028	—0,220	—0,070
Southern	TMA	0—90	—	—	+0,116	+0,068	+0.092
	TMA	60—90	—	—	+0,396	+0,468	+0,432
	TMA	30—90	—	—	—0,016	+0,180	+0.082
	TMA	10—30	—	—	+0,272	+0,104	+0,188
	SAT	0—20	+0,168	—0,508	+0,072	—0,112	—0,095

Notes. The dash denotes absence of data. TMA = temperature of middle atmosphere; SAT = surface air temperature; SST = sea surface temperature.

The third type of knowledge includes an evaluation of the influence of economic activity on climate.

The fourth type of knowledge is prediction of changes and variability of climate which is based, among other factors, on an allowance for the reverse effect of economic activity on climate.

Figure 1 is a general diagram characterizing the influence of the state of the climatic system on different aspects of economic activity.

The first block in this diagram includes a study of the influence of climate on agriculture, electric power production, water management, fishing and forestry, construction, transportation, public health, etc.

Each of the mentioned branches of economic activity to a greater or lesser degree itself influences and on an ever-increasing scale will exert an influence on local, regional or global climate. At the same time, each of these branches is complexly dependent on changing climatic conditions caused by both natural and anthropogenic processes. Accordingly, the problem of interaction between climate and economic activity and society as a whole is complex with numerous feedbacks. It therefore must be evaluated using the formula "state of the climatic system - influence on branch - new state of climatic system - influence on branch."

Practical requirements even now give rise to the question of how possible future changes of climate will exert an influence on the economy and social processes. However, at the present time we still cannot satisfactorily answer the questions: how does the existing structure of climate exert an influence on different aspects of man's activity and what is the best way to take into account the existing information on climate?

The second block of this diagram provides for creation of an information base on the state of the climatic system, including the creation of a system for access to climatic information which combines accessibility with convenience for the user.

Unfortunately, this problem is as far from a satisfactory solution as the problem of creation of data banks for research purposes, including the creation of methods for the prediction of climate, although considerable efforts have been undertaken in this direction.

The third block includes modern planning methods, taking into account climatic information on changing climatic conditions, climatic expertise on major and long-term measures and solutions in the planning and control system. This direction is in the very initial stage of its development.

In our opinion fundamental scientific investigations directed to the study of the physics of climatic changes should be oriented primarily to the creation of a scientific basis for solution of the already mentioned practical problems.

The complexity and scale of these practical problems are so great that their formulation in the first place in the WCP only intensifies and clearly orients the direction and scales of the fundamental scientific research in the field of climate.

There are several arguments in support of the reasonings cited above.

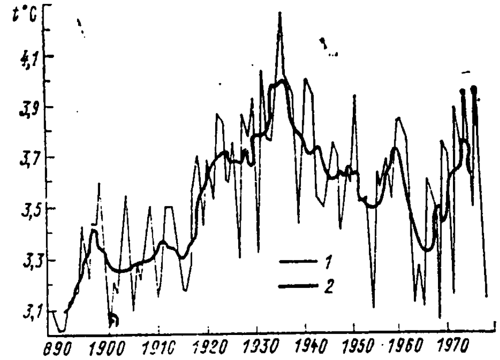

Fig. 2. Mean annual air temperature (1) and moving five-year averages (2) in the zone 40-75°N.

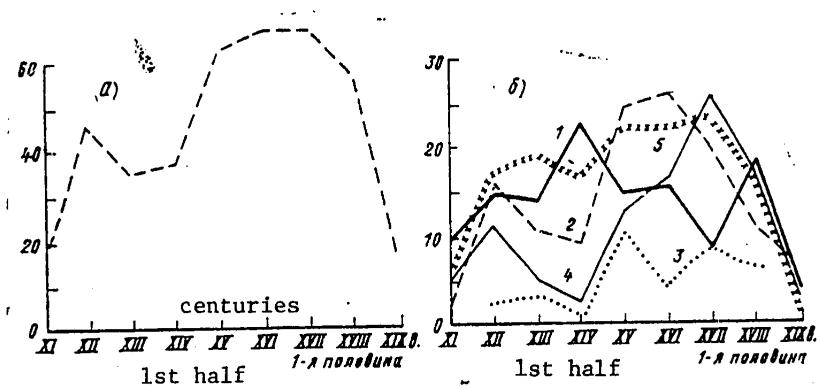

Fig. 3. Frequency of recurrence of climatic anomalies according to Russian archival sources. a) total number of climatic extrema, b) number of cases of drought (1), rainy periods (2), returns of cold (3), extremely cold winters (4), famine years (5).

First of all it makes sense to turn to the history of changes in climate and the socioeconomic processes and phenomena related to them.

We will not be concerned with ancient history. It is known from ancient history that prolonged glacial periods prevailed on the earth when there was virtually no growing season in the temperate zone [4, 7, 17, 32, 44]. The last glacial period was replaced by a rapid warming of climate and the onset of a climatic optimum approximately 8,000 years ago when civilizations developed in a number of regions in which there are now deserts (Sahara region and others).

After this, about 4,000 years ago there was a sharp cooling of climate, leading to the downfall of individual civilizations [7, 36].

Here we will not give any analysis of the factors, in many respects disputable, explaining climatic changes in the past. We will only emphasize that there have always been climatic changes. Some climatic fluctuations, even within the current interglacial period, not to mention its variations with transition from a glacial to an interglacial period and back, were so significant that they led to the fluorishing or destruction of individual civilizations [7, 36].

We have more reliable data concerning the climate of the last thousand years. During this period climatic fluctuations had lesser amplitudes in comparison with those mentioned above, but nevertheless they were extremely significant with respect to their influence on human activity.

In the climatic epochs of the last thousand years it is necessary to discriminate the "small" climatic optimum in the 8th-12th centuries, the "small" glacial period which followed it and which lasted to the middle of the 19th century, the warming of climate lasting from the middle of the 19th century to the 1930's-1940's, and the period of cooling of climate with some fluctuations beginning then and continuing even now. We will characterize the climate of the last period as modern climate.

Beginning with the "small" glacial period we have instrumental observations whose results, according to different sources, are given in Fig. 2. This figure clearly shows the period of climatic warming at the beginning of the current century, the cooling which followed and the shorter-period fluctuations registered during all periods.

We can draw conclusions concerning the climate of the period preceding the "small" glacial period for the most part on the basis of indirect data, including tree rings, historical chronicles, etc.

An analysis of these data very clearly shows that during all periods there were regional peculiarities in the changes of climate. It is apparent that never during the last thousand years have the changes in climate been identical in all regions of the earth and the regional consequences of climatic changes have not been identical.

In Europe the warming maximum was noted somewhere between the years 1200 and 1250, and in individual regions between the years 1265 and 1312.

There are indications that in the periods which followed with the onset of cooling, and especially during the period of the "small" glacial period, these changes had an unfavorable effect on economic activity. For example, according to the data in [32, 44, 45], during the years 1312-1326 in Western Europe the yield was 20% less and in the years 1326-1346 -- 6% less than during the preceding period 1265-1312. In the late 13th-early 14th centuries there was a marked increase in the intra-seasonal variability of climate.

Available data indicate that after transition to the "small" glacial period and on the "eve" of the "small" climatic optimum (between 300-1000) there was an increase in the intensity of cyclonic activity and the frequency of recurrence of climatic anomalies (droughts, return of cold periods, flooding, etc.). This was manifested particularly clearly in Europe in the years 1360-1450, in the 16th-17th centuries and during other periods. Increases in the frequency of recurrence of climatic extrema were accompanied by underharvests, years of famine and a number of social conflicts. This occurred not only in Europe, but also on other continents (America, Japan, New Zealand and elsewhere).

Without being able to cite all the available information within the framework of this article, we will limit ourselves to an illustration of extremal phenomena in old Russia according to chronicles. We made such an analysis in collaboration with V. M. Pasetskiy [35]. Some results of this analysis are given in Fig. 3. This figure shows that in Russia in the 15th, 16th and 17th centuries there was a marked increase in the frequency of recurrence of extremal phenomena. Virtually synchronously with an increase in the frequency of recurrence of climatic extrema there was an increase in the frequency of recurrence of famine years, hunger riots and some other social phenomena.

According to Lamb's data, for Great Britain the maximum duration of the growing season (the time interval when the temperature was above 5.5°C) during 1870-1895 was 255-265 days and the minimum -- 205-225 days [44]. During the period of warming during 1930-1949 these durations increased on the average by 10-15 days and became 270-275 and 237-243 days respectively. However, during the period 1950-1959 the duration of the growing season again decreased to 265 and 226 days respectively.

During the decades of the "small" glacial period the average growing season in England was 3-4 weeks shorter than during 1939-1949. Superposed on this was a great variability of climate which considerably aggravated the unfavorable effects of climate on economic activity.

The following conclusions can be drawn as a result of an analysis of the history of climate of the last thousand years:

1. Analysis of the history of climate of the past and the social phenomena associated with it is extremely important for an understanding of the effect of climate on the economy, on public and social life in the future.

2. The principal unfavorable effects of climate were related to climatic anomalies.

3. The most unfavorable climatic effects occurred during the period of cooling of climate when there was a shortening of the growing season and against this background of a shortened growing season there was an increase in the frequency of recurrence of climatic extrema, that is, an instability of climate.

The cited conclusions are extremely important for evaluating the possible influence of climate on economic activity in the future. The fact is that we are in a stage of slow cooling of climate caused by natural factors, in particular, a decrease in insolation as a result of change in the orbital parameters of our planet (eccentricity, inclination and orbital precession) [17, 42]. Because of the mentioned factors during the course of the next 8,000-10,000 years the cooling of climate will continue. In addition, an analysis of the natural factors and an analysis of the statistical patterns of shorter-period climatic changes indicate that in the course of the coming decades a general cooling of climate will continue with some fluctuations [4, 7, 17, 36, 38, 43, 47].

In [43], on the basis of a composite analysis of available data on current climate, an unambiguous conclusion was drawn: "indicators of macroscale climatic processes indicate that the oscillating cooling observed during the last 30 years in the northern hemisphere has not ended."

This conclusion is illustrated by the data in the table which give information on change in virtually all the principal and registered parameters of climate during the last 25 years taken from the cited source. This table shows that virtually everywhere there was a cooling of climate in the northern hemisphere and a warming in the southern hemisphere with a mean rate of 0.2°C per decade.

Such a tendency in natural processes should be regarded as unfavorable.

Superposed on this tendency (and this effect will increase) is the influence of anthropogenic factors (CO_2, aerosol, heat "surges," radiationally active small impurities, etc.). Taken together, the influence of anthropogenic factors should favor some warming of climate, which in principle can compensate or even somewhat overlap the natural cooling.

However, this evidently will not be a decisive factor in evaluating the influence of anthropogenic factors on climate.

Numerical experiments with models of general circulation of the atmosphere, including those which we carried out [5, 6, 26, 41], show that the regional character of anthropogenic effects should lead to a change in circulation processes, an increase in the frequency of recurrence of blocking processes, an increased frequency of recurrence of climatic extrema associated with them, and in general an instability of climate. In other words, the anthropogenic influence should be reflected to a greater degree in the climatology of the second, rather than the first moments. The latter means that both in the case of the tendency in natural cooling of climate and in the case of the tendency in anthropogenic warming of climate or an invariability of the thermal regime society in any case in the immediate future will have to contend with an increased frequency of recurrence of climatic anomalies and instability of climate.

As we have attempted to demonstrate, in the past it was specifically the instability of climate and climatic anomalies which exerted the most unfavorable effect on society. This tendency, with an increase in the scales of human activity, in all probability will be intensified.

Now we will examine the dependence of the principal branches of economic activity on climate. We will begin this examination with agriculture and the grain problem. We will analyze data on grain production for the principal grain-producing regions of the world [16]. The trend line characterizes the crop yield as a result of improvement in agricultural techniques. The variations relative to the trend line reflect the influence of climatic anomalies. These variations attain tens of millions of tons annually. Such climatic anomalies as the droughts of

1972 and 1975 in the USSR and a number of countries were reflected not only in the crop yield in the countries affected by the droughts but also in the world grain reserves. Such situations in turn immediately affected the sphere of international relationships.

The grain problem is an acute problem in the world and it can only become more acute. The world production of grain is now about 1,300 million tons annually, that is, on the average grain production is one ton per three inhabitants of the planet. In the well-developed countries (United States, USSR) this production attains one ton per capita.

The mean annual population increase is about 80 million persons [33, 51]. Thus, without taking into account the hungry, the annual increase in grain production throughout the world should be not less than 30 million tons annually, but with allowance for the consumption norms for the well-developed countries -- about 80 million tons. This means that just for supplying grain to the increased population, not to mention that there is an insufficiency of food in the world and hundreds of millions of people are hungry, the annual increase in grain production must be not less than 25-30 million tons, but with allowance for the norms for the development of countries -- about 80 million tons annually.

The annual increment of food production must be not less than 2.5% annually, or with allowance for the hungry -- not less than 5-6% annually. However, according to FAO data, for foodstuffs as a whole the annual increment was 2.7% during 1961-1970, but during 1970-1976 it fell to 0.5%. Without question, there will be an increase in crop yield as a result of improved technology. By the year 2000 experts estimate that the increase in crop yield as a result of improvement in technology will be 24% [38]. But this rate obviously does not correspond to the rates of world population growth, which by the year 2000 will double [21, 33, 51]. Variations in crop yield due to climatic trends and variability (instability) of climate can be superposed on such a generally stressed situation.

Source [16] gives data on the dependence of crop yield on climatic conditions (temperature and precipitation) for 15 "country - crop" combinations. The cited data unambiguously indicate an exceptional dependence of crop yield on temperature and precipitation anomalies. This dependence has a clearly expressed regional character [38]. In this connection many experts feel that a marked increase in crop yields in the 1950's-1960's (during the subsequent period the increase in crop yield was slowed) was caused not only by an improvement in technology, but also by more favorable climatic conditions. In evaluating the increase in crop yield as a result of improvement in technology it is impossible not to take into account the price at which this increase was achieved. During the last 100-200 years the grain yield has increased by a factor of 2-3, but the energy expenditures ensuring this increase have increased by 1-2 orders of magnitude. Accordingly, a further increase in crop yield will be associated with an increase in energy expenditures. However, the problem of climate and energy in itself is extremely complex. We will give particular attention to it.

In the analysis of the available data it is impossible not to focus attention on at least the two following circumstances:

1. Climatic anomalies can cause such variations in grain production which are completely capable of meeting the necessary increase in grain production or substantially aggravating the situation.

2. Some specialists, not without basis, feel that in the coming decade the scientific and technical "explosion" in agriculture will not occur in the field of biology and technology, but in the field of improvement in the technology of collection and effective use of information on climate, that is, in the field of improvement in crop cultivation based on the optimum use of climatic information.

In the field of agriculture alone the expenditures on practical investigations in the field of climate can give an enormous economic and social advantage from the realization of scientific results in the field of agroclimatology. The losses in agricultural production from climate as an average for the world, according to the most modest estimates, attain tens of billions of dollars annually.

The fishing problem is closely related to the food problem. More than 20% of all animal protein in the world is obtained by fishing and in some countries this percentage attains 50% or more. Practical climatology has a major debt to the fishing industry and in turn the fishing industry has many demands to place on climatologists. A whole series of dependences between fishing and climate has now been established. For example, according to data from the special Taalfe expedition, along the western shores of Greenland there were virtually no cod during the period 1908-1910. However, during the period of climatic warming toward the 1940's the cod catch in this region was increased to 70-100 thousand tons, and in the 1950's-1960's it rose to 450,000 tons. Now the exploitation of cod is virtually banned due to its virtual disappearance. This process is not unambiguously dependent on climate, but is related to it.

It has been established that the exploitation of some species of fish fluorishes and goes into a decline with a period of 80-100 years. The dependence of these periods on climate is very complex and has an obviously nonlinear form. It is characteristic that climatic variations have a relatively small amplitude, whereas the amplitude of the fluctuations in fishing associated with this is very great [13, 24].

It is easier to trace the influence of climate on the fishing industry in internal water bodies and rivers. Here climatic conditions are the decisive factor, as has been demonstrated in a special UN document on food and agriculture [7]. And although ichthyologists have not established a clear correlation between the volume of fish production and climate, such a correlation exists and must be studied further, especially in relation to the development of fishing in internal water bodies and rivers.

Now we will discuss energy and its dependence on climate. Energy is related to that branch of economic activity whose development to a greater degree determines the anthropogenic effect on climate than dependence on it. But these two problems are closely intertwined. However, the dependence of energy on climate is manifested in several directions [5-7, 18, 33, 40].

Estimates made at the Main Geophysical Observatory have shown that allowance for natural illumination, which, in contrast to temperature, for the time being is not taken into account, can give a saving of approximately the same order of magnitude. For the Lenergo system alone the potential saving can be up to 3% of the total expenditure of electric power.

However, the problem of interaction between climate and the fuel-energy complex can radically restructure the strategy for the development of this vitally necessary branch. This is associated with the general negative influence of the development of energy on climate. There is a rather extensive literature on this subject [5-7, 33, 40, 41].

As is well known, in the not too distant future the traditional types of fuel, especially petroleum and gas, will be exhausted. In addition, orientation on coal, whose reserves are also limited, is fraught with danger for the environment (an increase in the discharge of sulfur and its compounds, aerosol, carbon dioxide, etc.). In this connection the sense of duty to future generations, economic feasibility and inevitability are evidently forcing society to conserve the remaining volumes of chemical energy, especially petroleum and gas, and convert to a new form of energy. This may be a combination of nuclear and thermonuclear energy and renewable sources (wind, solar energy, geothermal heat, energy of tides and photosynthesis). One of the shortcomings of renewable sources is the low energy density. In the case of wind energy this is several watts per square meter and for solar energy it is hundreds of watts per square meter. In the well-developed countries, where 90% of the capital investments are in buildings and structures with their high concentration and poor adaptability to solar and wind energy, orientation on new types of energy causes serious objections. But in those places where there is presently no such concentration of production, development from the very beginning can be oriented on a fundamentally new strategy of development of energy. In countries or regions where the population is scattered, the development of decentralized energy is completely justified and in this case orientation on renewable energy sources is justified. Their use is also possible in combination with traditional energy sources. But the development of renewable energy sources is unthinkable without allowance for the climatic potential, the climatic regime and its changes in the operation of power systems. Unfortunately, there is an underevaluation of this fact and this can be expensive for society.

Now we will proceed to a brief analysis of the influence of climate on construction, where this influence is exceptionally great, especially in countries with extremal climatic conditions. It should be noted that in this field the most work has been done for taking climatic information into account, primarily in the planning of construction. Estimates for the United States show that a temperature decrease by only 1°C would result in additional expenditures on construction of about 10 billion dollars annually. However, the total effect of this change, taking human health into account, would be 47.7 billion dollars [1, 7]. In this branch there are several problems related to allowance for climate.

The first problem is allowance for climatic information in planning. Projects costing billions and tens of billions of rubles are now being carried out. A reduction in their cost by only 1% by means of an optimum allowance for climatic conditions would be converted into sums attaining tens and hundreds of millions of rubles, not to mention the potential effect as a result of reduced operating costs.

It is possible to define several types of problems related to planning and construction whose dependence on climate is unquestionable and requires only a quantitative evaluation.

One of the problems is the development of methods for the effective use of climatic data in such a way that there will not be an unjustifiable increase in the cost of projects and as a result, a partial nullification of capital investments, on the one hand, and on the other hand, so that there is no possibility of an inadequate strength (or heat resistance, etc.) of these objects. With errors of any sign, in addition to the mentioned losses, over the course of a long period of time there will also be an overexpenditure of operational costs.

Here it should be added that at the present time planning is being carried out for the exploitation of new regions. In these cases there is a partial lack of the necessary preproject preparations and the collection and analysis of climatic information begins simultaneously with the planning. Here there have been solutions which have inevitably been nonoptimum in climatic respects. This situation must be changed.

The second problem is related to the planning of barrier structures, heating systems, air conditioning and ventilation systems, etc., whose operation to a decisive degree is determined by climatic conditions. The effectiveness of these measures can be estimated at from hundreds of millions to tens of billions of dollars for the world as a whole.

The next problem is related to the influence of climate on the actual performance of work, especially outside work. As is well known, the duration of construction work is influenced by the duration and frequency of recurrence of extremal weather conditions during which open-air work ceases and also mean temperatures, wind velocity, precipitation, etc. Many technological construction cycles (such as concrete work, paving, operation of cranes, transportation facilities, etc.) are highly dependent on climate. There is no question but that an optimum allowance for climatic conditions will afford great possibilities for increasing the productivity of construction work solely by its more effective planning.

The fourth problem is related to the construction of electric power lines and their operation with wind, glaze and glaze-wind loads taken into account. The influence of climatic conditions here is related not so much to losses due to nonoptimum planning and increasing costs for structures and their operation. The principal material losses under unfavorable climatic and weather conditions are not governed by the cost of work on reconstruction of electric power lines, but by the losses of industry and agriculture, which are dependent on the functioning of these lines.

The fifth problem is allowance for wind, glaze and snow loads on buildings and structures of general and special types, especially on structures with a height of 40 m or more (buildings, supports, stacks, TV towers, etc.). An exaggeration of these loads leads to a marked and frequently unjustifiable increase in construction costs, whereas an underevaluation of these loads will result in a probability of damage.

We have enumerated only the principal aspects of the influence of climate on planning and construction. The listing of these problems could be made still more detailed.

In countries with a tropical climate there are special problems involved which are related to the construction of dikes, protection against tropical cyclones and hurricanes, against corrosion, etc.

It cannot be said that little is being done in this direction. But the need has now arisen for a scientifically sound allowance for climatic information and allowance for it must be optimized. This cannot be done without serious investigations.

Now a few words about the influence of climate on forestry [2]. Forests occupy an area of 50 million square kilometers or 33% of the land surface. Whereas on the average the productivity of lands on the earth is $0.31 \cdot 10^3$ tons/(km^2·year), for the forest it is $1.3 \cdot 10^3$ tons/(km^2·year), or 130 tons/(hectare·year). The total increment of wood is $65 \cdot 10^9$ tons/year. In turn the production of one ton of dry matter is equivalent to the absorption of 1.8 tons of carbon dioxide from the atmosphere and the release of 1.3 tons of oxygen into the atmosphere. Altogether, the forests absorb 119 billion tons of carbon dioxide and 86 billion tons of oxygen are released annually.

The fixation of energy in the forest biomass is about $1.2 \cdot 10^{21}$ J/year (as a comparison we point out that in 1980 the annual production of all types of energy throughout the world was about 0.3·21 J, and by the year 2025 this quantity will be $1.2 \cdot 10^{21}$ J). Thus, this problem is important both from the point of view of the influence of the forest on climate and from the point of view of the influence of climate on the forest, being an important energy and raw material resource in the world economy. It is not impossible that in the immediate future in place of the cutting of forests for agricultural and construction purposes we will be forced to pose the problem of unconditional preservation and mandatory reproduction (on a global scale) of forests as sources of energy and a regulator of gas and water exchange in the climatic system.

Available data indicate that changes in the components of the heat and water balances exert a very strong influence on the productivity of the forest and in different climatic zones this influence is different. For example, in countries with a cold climate a temperature increase favors an accelerated growth of trees, whereas an increase in evaporability does not exert a very strong influence on the growth of trees. In countries with a warm climate a temperature increase in itself does not decisively determine the growth of trees. However, in this process evaporability increases and as a result there is a decrease in tree growth.

Forests always have reacted sensitively to a change in climatic conditions and even now are excellent indicators of climate of the past, including climatic anomalies.

At the present time the problem of interaction between climate and forestry must be examined both from the point of view of the influence of climate on forests and from the point of view of the reverse effect of forests on climate.

Now we will discuss the interaction between climate and water management [7, 37, 53]. Among the three principal water balance components (precipitation, evaporation and runoff) the first two components are the most important and vary significantly in dependence on climatic conditions.

Estimates show that for a population of 8 billion people with norms of one ton of grain for each three persons it is necessary to produce not 1,300 million tons of grain, but about 2,700 million tons. If a norm of 800 kg per person is used as a point of departure, production must increase to 6,500 million tons, which is 2-5 times greater than present-day production. If 40% of this grain is produced on irrigated lands, with a crop yield of four tons per hectare and with an expenditure of 2,200 m^3 of water per ton of grain or 9,000 m^3 per hectare at the beginning of the next century it will be necessary to withdraw about 6,000 km^3 of water annually from the annual runoff, as well as 4,000 km^3 of water for industrial purposes. In other words, about 25% of the annual runoff will be withdrawn for economic purposes. About 90% of this volume will be lost in evaporation (at the present time about 73,000 km^3 is evaporated on the land).

The dependence of runoff, evaporation and precipitation on varying climatic conditions is extremely important. For example, according to data in [7, 37], for the United States the ratio of maximum runoff to mean annual runoff can vary from 3-5 to 25-30 in dependence on changing climatic conditions. The most important and primary evaluations of the influence of climate on water management will relate to the following problems:
-- planning and operation of reservoirs;
-- planning and construction of major hydroengineering complexes;
-- planning, construction and operation of irrigation structures;
-- allowance for climatic factors in regions of intensive use of ground water from boreholes and wells.

We will cite an example: in 1977, during a drought period in California, the need for water immediately increased by 53%. As a result, about 10,000 new wells were drilled in a single year. The ground water level dropped sharply and the cost of water doubled.

Nevertheless, inadequate attention is being devoted to the problem of climate and public health [7]. Here we can define several scientific directions which are in the initial stage of formation and development. Among these we feel it important to define the field of bioclimatology. Bioclimatology is a relatively new science and is concerned with study of the influence of climate on human feeling of well-being and health and also the study of the microclimate of different natural and urban landscapes and buildings and its influence on man's conditions for survival.

As is well known, the temperature zone for climatic comfort falls in the relatively narrow range 20-25°C. However, man survives in a temperature range from +55 to -60°C. Determination of the optimum climatic conditions for the organization of conditions for work, rest, survival and therapy is one of the important economic and social tasks of applied climatology in the public health field.

We still have not enumerated here a number of branches of economic activity where climate exerts an extremely significant effect. We could mention sea, air, railroad and highway transportation, exploitation of the sea shelf, etc.

As we have already emphasized, the overall problem is a serious reexamination of the role of climate in economic activity on the basis of socioeconomic evaluations and optimum solutions in the sphere of planning and control.

However, the proper evaluation of the economic and especially the social consequences of man's actions, without taking real climatic conditions into account, is an exceptionally difficult problem.

Due to the exceptional complexity, diversity and uncontrollability of climatic conditions, any economic solutions relying on climatic information involve a definite risk of reducing the effectiveness of actions and measures taken in accordance with the adopted strategy in comparison with the potential effectiveness. Here by the term "potential effectiveness" we mean the effectiveness attainable with a knowledge of reliable climatic conditions, and it goes without saying, with proper actions by the user.

In this connection the question arises of the need for finding such a strategy which under conditions of possible uncertainty in the evaluation of climatic information would reduce to a minimum the risk and loss from unfavorable climatic conditions or would yield the maximum possible effect under favorable conditions.

At the present time it must be admitted that despite the obvious influence of climatic conditions on the principal aspects of human activity the available climatic information is by no means used rationally. The most discouraging fact is that not in all branches of the economy do users understand how to make rational use of this information in the adoption of optimum solutions.

As is well known, the principal economic decisions are not made by the possessors of climate data, but by its users. They determine the strategy to be followed.

Among them there are evidently three types of users. The first type takes "willful" decisions or is guided by some norm-setting document, not taking climatic information into account and at times even completely ignoring it.

The second type uses climatic information, but very cautiously, being oriented on the "mean climate," that is, on the "norm."

Finally, a third type is trying to use more complete climatic information, including predictions, without taking their stochastic character into account. This is the most risk-taking type of user, although both the second and third types of users usually understand that the climatic information which they use contains a measure of uncertainty.

It can be said with assurance that not one of the above-mentioned three approaches to the use of climatic information is scientifically sound.

For this reason the first and foremost task must be considered the development of scientifically sound methods for the adoption of optimum socioeconomic decisions on the basis of an allowance for climatic information and its correct application to specific fields of human activity. By the term "climatologically optimum decision" (user's strategy) we mean economic decisions adopted by the user on the basis of climatological information and ensuring the maximum effect in accordance with the selected optimality criterion. As the optimality criterion it is possible to use the mean climatic losses, the minimum probability of losses, the maximum mean profit, etc. By the term "climatic losses" we mean the losses which the user of climatic information sustains due to the noncorrespondence of the adopted decision to the actual climatic conditions.

Proceeding now to an evaluation of those measures which in our opinion should stimulate development of research in this field, we will mention only a few of the most important and priority measures.

First of all there must be a marked change in the attitude toward climate in all spheres of activity and climatic resources must be regarded as one of the most important factors in increasing the effectiveness of social production.

The next stage must be the creation of a long-term program for investigations in the field of applied climatology, taking in the activity not only of scientific institutes, but also primarily organizations whose activity is dependent to the greatest degree on climate or exert an influence on climate. Such a program will require serious interdepartmental coordination and control.

The implementation of these measures should lay the groundwork for creating in the country a clearly functioning system which routinely and over a long-term basis would evaluate climatic resources, would evaluate and predict the climatic situation developing in the world, not just in the country, taking into account both natural and anthropogenic factors, and would give recommendations for optimum decisions in the planning and control sphere, taking climatic information into account.

The implementation of these measures will unquestionably favor the transformation of climatology into a real means for increasing the effectiveness of social production.

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PRESENT STATUS OF CLIMATIC RESEARCH*

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[Article by M. I. Budyko, corresponding member USSR Academy of Sciences, State Hydrological Institute]

[Text] Abstract: The article is a review of modern investigations of different problems of climatology, including studies in the theory of climate and study of its natural and anthropogenic changes.

Scientific revolution in the field of climatology. During recent years there has been such a significant restructuring of what was formerly the science of climate that in the Soviet and foreign literature there is more and more discussion of the scientific revolution in the field of climatology which is now taking place.

In the recent past climatology was for the most part an empirical discipline in which the comparative and historical research methods were used. Although with the use of these methods it was possible to establish many important patterns of the climates of the present epoch and the geological past, these methods were ill-suited for clarifying the genesis of climate, that is, for a quantitative explanation of the relationships between climate and external climate-forming factors. For this reason until recently it was extremely difficult to explain the reasons for the changes in climate and answer many other questions which are of considerable scientific and practical importance.

The principal features of the restructuring of climatology, occurring for the most part in the 1970's, are, first of all, the extensive use of modern theoretical and experimental methods of atmospheric physics, and second, determination of close relationships between earlier isolated different branches of climatic science.

The formulation of models of the theory of climate is of particular importance among the theoretical methods used in modern climatology. We should also note the rapid progress in use of detailed methods of statistical analysis of materials from

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meteorological observations in investigations of climate. The successfully developing work on the numerical modeling of the influence of climate on different natural processes, including studies of the hydrological regime, the vital functioning of plants, geographic zonality, and others also is worthy of great attention.

Whereas earlier in climatological investigations use was made almost exclusively of materials from standard surface meteorological observations, now in these investigations increasing use is being made of data from actinometric and aerological observations, materials obtained on oceanographic expeditions, and also data from satellite observations, which are especially valuable in the study of climate.

A second characteristic feature of modern investigations of climate is the organization of major multisided investigations which bring together different earlier poorly interrelated branches of climatology and in which extensive use is made of the methods and materials of many sciences bordering on climatology. The best known examples of such investigations in our country and abroad are the projects for investigating the influence of man's activity on climate.

Mention should be made of the special role of the problem of the anthropogenic change in climate in the restructuring of climatology which is now occurring. In the 1970's it was established that in the immediate future there will be a change in global climate caused by economic activity and this will exert an influence on many natural processes and on a number of such branches of economic activity as agriculture, fishing, hydroelectric power, construction, sea transport and others.

The problem of anthropogenic changes of climate has attracted the attention of governments of different countries and a number of international organizations, including the World Meteorological Organization.

It can be surmised that with continuing clarification of the scales of impending changes of natural conditions caused by anthropogenic effects on global climate measures will be taken for the further expansion of investigations of this exceptionally important problem.

In discussing the restructuring of climatology which is now taking place it must be noted that this restructuring was prepared by the studies of several generations of researchers, among whom an outstanding place was occupied by the scientists of our country.

A profound influence on the development of Soviet and world climatology was exerted by the investigations of A. I. Voyeykov in which for the first time he formulated the problem of solving a number of problems in physical climatology, including the problem of study of the earth's energy balance. In the works of A. I. Voyeykov studies were initiated for investigating the influence of general circulation of the atmosphere on climate. The successes later achieved in the development of synoptic meteorology provided a possibility for a considerable broadening of the study of circulation factors in the genesis of climate, as was done in the studies of B. L. Dzerdzeyevskiy, G. Ya. Vangengeym, S. P. Khromov, O. A. Drozdov, A. A. Girs and others. Already in the 1930's in the studies of V. V. Shuleykin, leading the way for similar foreign investigations, it was established that interaction between the ocean and the atmosphere exerts a profound influence on climate. The investigations of Ye. N. Blinova, in which she proposed a model of the theory of climate taking into account circulation processes in the atmosphere, work done in the 1940's, also considerably outpaced foreign science.

Beginning in the 1940's at the Main Geophysical Observatory, and later at the State Hydrological Institute, investigations were made of the energy balance of the earth's surface and the atmosphere, during which atlases of world maps of energy balance components were prepared. Over a period of years the world water balance was studied at the State Hydrological Institute, Institute of Geography and other institutes. The materials on the energy and water balances of the earth obtained in our country with respect to their completeness have no equal in foreign investigations.

An outstanding achievement in Soviet science, the launching of an artificial earth satellite, made possible the development of satellite climatology. The publication of materials of satellite observations of the radiation regime of the earth-atmosphere system, initiated in the late 1960's, exerted a substantial influence on the development of physical climatology.

On the basis of successes in the development of computers in the 1960's there was an appreciable acceleration in the development of climatic theories. During these years models were constructed of general circulation of the atmosphere which made it possible to compute the nonaveraged fields of meteorological elements. Then the first energy models of the atmospheric thermal regime were formulated.

Below we will discuss in greater detail three directions in modern investigations of climate: formulation of models of the theory of climate, study of natural changes of climate and investigations of the influence exerted on global climate by anthropogenic factors, which developed particularly rapidly in the 1970's. These directions, however, do not take in all the outstanding achievements of recent years in the study of climate. Worthy of mention are the investigations of the statistical patterns of the fields of meteorological elements carried out in our country by M. I. Yudin, G. V. Gruza, I. I. Polyak and others, the studies made by O. A. Drozdov, V. N. Adamenko and Yu. L. Rauner on variations in the regime of moistening and droughts, studies relating to different problems of applied climatology (including in the field of agricultural climatology), on microclimatology and many others.

Climate modeling problem. The theory of climate has the purpose of using the physical deduction method for determining the mean distributions of meteorological elements in time and space and their variability in dependence on the stipulated external factors of climate. In formulating a climate theory use is made of the methods of hydromechanics and thermodynamics, and also the regularities of radiation transfer of energy and phase transformations of water and the other relationships in modern physical meteorology.

In addition to the development of detailed models of climate, including allowance for general circulation of the atmosphere, during recent years considerable attention has been devoted to the formulation of simplified models of climate in which simultaneously with general physical laws use has been made of different empirical relationships.

Investigations devoted to the development of multiparameter models of general circulation of the atmosphere were initiated by Smagorinsky and his colleagues, Mintz and other authors.

In the investigations of Manabe and Bryan (1969) a numerical model of the theory of climate was developed, including an allowance for the influence exerted on climatic conditions by circulation of waters in the oceans. In the studies of Holloway and Manabe in 1971 maps of the principal components of the heat and water balances of the earth's surface were constructed for the first time by a theoretical method. These maps were similar to the similar maps constructed earlier by empirical methods.

Many substantial results have been obtained during recent years in studies in this direction.

In 1975 Manabe and Wetherald made computations of the influence of a change in the concentration of carbon dioxide on the mean latitudinal distribution of elements of the meteorological regime. In this same year in a study by Wetherald and Manabe an investigation was made of the influence of changes in the solar constant on climate. In 1980 Manabe and Wetherald computed changes in climate with an increase in the concentration of carbon dioxide in the atmosphere for a hemisphere part of which is occupied by a continent and part of which is occupied by an ocean. In that study conclusions were drawn concerning the change in moistening on the continents with the development of a global warming.

In a study by Manabe and Stouffer, published in 1979, computations were made of the influence of CO_2 on the thermal regime for real topography, taking into account the annual variation of meteorological elements.

Investigations in this direction are of great importance in a study of anthropogenic changes of climate.

Studies devoted to reconstruction of climates of the geological past are worth noting. In the investigations of Manabe and Hahn, Gates and other authors published in the late 1970's, on the basis of development of models of general circulation of the atmosphere it was possible to plot maps of climate for the time of the last glaciation which were very similar to the maps based on paleogeographic data.

In the development of models of general circulation of the atmosphere in the Soviet Union the most general results were obtained in the studies of G. I. Marchuk and his colleagues. We should also mention the hydrodynamic three-level model developed by V. P. Meleshko (and co-authors). The use of this model made it possible to compute the characteristics of the heat and water balances, which agree with available empirical data.

Despite the existence of many outstanding achievements attained in creating models of general circulation of the atmosphere, the difficulties standing on the path of development of these models have not yet been completely overcome. This, in particular, limits the possibilities of using these models in studying climatic changes. In addition, as pointed out by Smagorinsky, in order to compute changes in climatic conditions using models of the general theory of climate on electronic computers it is necessary to employ an enormous amount of time, frequently exceeding the capabilities of computation centers supplied with the highest-speed machines. In this connection Smagorinsky noted the need for developing methods for the parameterization of circulation processes in the atmosphere and oceans for the purpose of describing macroscale disturbances in this circulation statistically, by analogy with the usual method for investigating small-scale turbulent processes. Such an idea was used in a number of studies of the theory of climate in which the transfers of heat and moisture in the atmosphere were regarded as macroturbulent processes.

Taking into account the difficulties in using more general theories of climate in studying its changes, in a number of studies an attempt was made to use semiempirical models for this purpose in which at the price of a strong schematization of macroscale atmospheric processes, restriction of the formulated problems and use of empirical correlations it is possible to meet the following requirements: 1) the model does not include empirical data on the distribution of individual climatic elements; 2) the model realistically takes into account all types of heat influxes which exert an appreciable influence on the temperature field and in which there is satisfaction of the law of conservation of energy; 3) the model includes allowance for the feedbacks among climatic elements.

With satisfaction of these conditions the model of the theory of climate can be used for clarifying the genesis of climate and the mechanism of its changes.

In the late 1960's, first in the USSR and then in the United States, semiempirical models of the thermal regime of the atmosphere were proposed based on study of the earth's heat balance. In these models use was made of the heat balance equation for the earth-atmosphere system and empirical expressions relating the distribution of mean latitudinal air temperatures and the meridional redistribution of heat in the atmosphere and hydrosphere, determined from heat balance computations.

In the considered models an allowance was made for the principal feedbacks exerting an influence on the thermal regime, including the feedback between air temperature and the area of polar ice. Since these models in the first approximation satisfied the above-mentioned requirements, they could be used in studying climatic changes.

A number of laws of the genesis of climate were established as a result of use of these models. Among these laws, in particular, is that there is an "ambiguity" of climate (it was found that together with modern climate with the existing external climate-forming factors there can be at least one other climate variant -- a "white earth," completely covered with ice with very low temperatures at all latitudes).

A similar conclusion was later also obtained from models of general circulation of the atmosphere.

In the 1970's more than a hundred studies devoted to the development of semiempirical models of the thermal regime of the atmosphere were published. A considerable contribution to investigations in this direction, in addition to many foreign scientists, was made by G. S. Golitsyn, I. L. Karol' and their colleagues.

In addition to the development of semiempirical models, the authors of a number of studies proposed more detailed parameterized models of the theory of climate which were used in the study of the genesis of climate and in analyses of climatic changes.

In checking existing models of climate use has been made of different methods, including, for example, comparison of the computed fields of meteorological elements with the corresponding observational data.

In clarifying the possibility of using a climate model for computations of climatic conditions it is of great importance of compare the results of computations of the sensitivity of climate to changes in climate-forming factors with evaluations of this sensitivity obtained from observational data.

Table 1

Sensitivity of Thermal Regime to Changes in Heat Influx (ΔT_1)

I	II	III	IV
1.4-1.5°C	1.5°C	1.1-1.45°C	1.1-1.2°C

Table 2

Sensitivity of Thermal Regime to Changes in CO_2 Concentration in Atmosphere (ΔT_c)

I	II	III	IV
2.5-3.5°C	2.0-3.0°C	3.3°C	3.8°C

Table 1 gives the values of the ΔT_1 parameter, equal to the change in mean air temperature at the earth's surface with an increase in the heat influx toward the outer boundary of the atmosphere (solar constant) by 1%. These values were determined using a semiempirical theory of the thermal regime of the atmosphere (I), using models of general circulation of the atmosphere (II) and two empirical methods: using data from satellite observations of seasonal changes of radiation fluxes at the outer boundary of the atmosphere (taking into account data on seasonal changes in air temperature and cloud cover) (III) and using materials on the modern change in climate (IV).

The data in this table pertain to conditions of a constant or little-changing albedo of the earth's surface.

Table 2 gives data on the parameter ΔT_c which characterizes the sensitivity of the thermal regime to changes in the atmospheric concentration of carbon dioxide. This parameter is equal to the change in mean air temperature at the earth's surface with a doubling of the carbon dioxide concentration in comparison with its modern value.

Table 2 includes data on the values of the ΔT_c parameter, determined using a semiempirical model of the thermal regime (I), using models of general circulation of the atmosphere (II), and also evaluations based on materials on the modern change in climate (III) and empirical data on the climates of the past (IV).

The data in Tables 1 and 2, together with other similar materials, make it possible to draw two conclusions. First: the use for computations of sensitivity of theories of climate which take into account the most important components of the atmospheric heat balance and also the principal feedbacks between the thermal regime and different climatic factors gives results very close to empirical evaluations of sensitivity. Second: the results of use of models of general circulation of the atmosphere and schematic semiempirical models of the thermal regime for evaluating this sensitivity are rather close to one another.

It follows from these conclusions that existing theories of climate can be used successfully in solving the most important problem in modern climatology -- computations and predictions of climatic changes. For this purpose it is possible to use both schematic and the most detailed models under the condition that they satisfy the requirements mentioned above.

Natural climatic changes. Although the problem of the mechanism of natural changes of climate has been studied over the course of many decades, until recently it was considered unsolved. Such a situation created great difficulties in the investigation of the central problem in modern climatology -- the anthropogenic change of climate. It was difficult to explain the physical mechanism of this change without explaining the reasons for the natural variations of climate, which made it necessary to solve the above-mentioned problem.

In studies made in the late 1960's and in the 1970's results were obtained explaining many patterns in natural climatic changes. The successes attained in these investigations were related, first of all, to progress in the theory of climate, models of which could be used in studying climatic changes, and second, with the appearance of new empirical data considerably expanding information on the climatic conditions of the past.

Here we will give a brief review of the results of recent investigations of climatic changes relating to three time intervals: Phanerozoic (last 550-600 million years), Pleistocene (one-two million years) and modern epoch (last hundred years).

With respect to the climate of the Phanerozoic, in paleogeographic investigations it was already established long ago that during most of this period climatic conditions over the entire surface of the earth corresponded to the modern climate of the tropics or subtropics, that is, were very warm. Although glaciations appeared over part of the surface of the continents during individual relatively short time periods (for example, at the end of the Carboniferous and at the end of the Permian), nevertheless, during these epochs as well the climate over most of the earth was very warm.

Only during the course of the last 100 million years, that is, since the end of the Mesozoic, has there been a gradual change in climate in the direction of a cooling, especially conspicuous in the high latitudes.

It was difficult to explain such a change since until recently only one factor was known which exerted a significant influence on mean global air temperature in the geological past: the quantity of solar radiation, which gradually increased during the entire course of the Phanerozoic. Simple computations show that if this factor was the sole reason for change in climate during the last 500-600 million years it should have led to a considerable rise in the mean global temperature at the earth's surface, which completely contradicts empirical data.

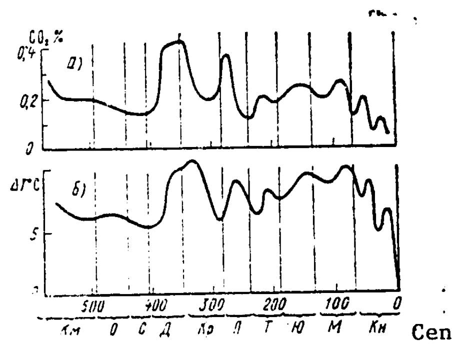

Fig. 1. Changes in the concentration of carbon dioxide (a) and mean air temperature (b) in the Phanerozoic. The letters on the horizontal axis correspond to the names of the geological periods and the Cenozoic:

Cambrian - Ordovician - Silurian - Devonian - Carboniferous - Permian - Triassic - Jurassic - Miocene

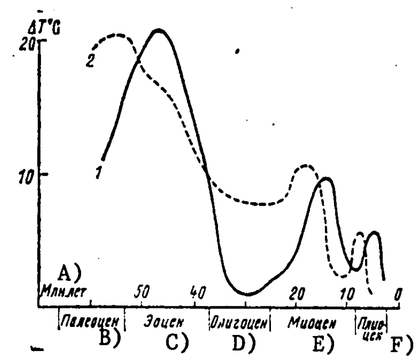

Fig. 2. Empirical data on change in air temperature in the Cenozoic.

KEY:

A) Millions of years
B) Paleocene
C) Eocene
D) Oligocene
E) Miocene
F) Pliocene

The possibility of explaining climatic conditions in the Phanerozoic appeared after investigations of the chemical composition of the atmosphere in the past were made. One of the results of this investigation is shown in Fig. 1a, where we have shown the change in the quantity of carbon dioxide in the atmosphere during the course of the Phanerozoic. The figure shows that during almost the entire Phanerozoic the quantity of CO_2 in the atmosphere exceeded its present-day concentration, equal to 0.03%, by several times, which considerably intensified the greenhouse effect in the atmosphere and increased the temperature at the earth's surface.

Over the course of the last 100 million years there was a predominance of a tendency to a decrease in the CO_2 concentration in the atmosphere, which was the reason for the Cenozoic cooling.

Figure 1b shows the results of computations of changes in mean air temperature at the earth's surface during the course of the Phanerozoic. In these computations we took into account changes in solar radiation, variations in the concentration of carbon dioxide and changes in albedo of the earth's surface caused by differences in the area of the continents and (in some epochs) the influence of polar glaciations.

The results of computations for the epoch of Cenozoic cooling can be compared with the determinations of paleotemperatures in different regions of the earth obtained during recent years. Figure 2 gives data obtained by Burckhardt on changes in the temperature of surface waters in the North Sea (curve 1) and the data obtained by Shackleton and Kennet on water temperatures in the middle latitudes of southern hemisphere oceans (curve 2).

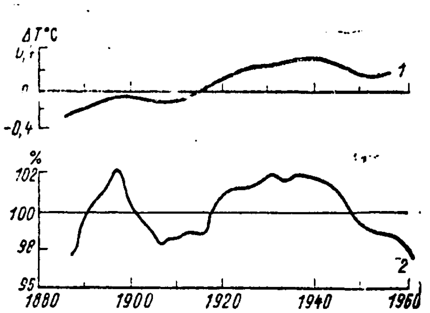

Fig. 3. Anomalies of direct radiation (2) and mean air temperature (1).

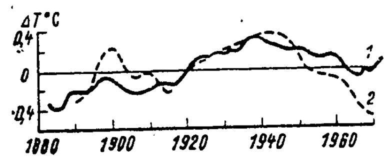

Fig. 4. Comparison of measured (1) and computed (2) air temperature anomalies.

By comparing curves 1 and 2 with the results of computations it is possible to note a good qualitative agreement of these independent materials. In particular, on all the curves one can see a warming occurring in the Eocene in comparison with the Paleocene. On all the curves there is a marked cooling in the Oligocene, a temperature increase in the Miocene and a cooling in the Pliocene. Some differences in the time of appearance of these temperature increases and decreases are related to an incomplete coincidence of the time scales used in different investigations.

The more considerable amplitude of the temperature variations on curves 1 and 2 in comparison with the curve in Fig. 1b can be attributed to the fact that the first two curves are for the middle latitudes, where, as indicated by the results of theoretical computations and empirical data, the temperature variations with changes in climate are greater than the variations in mean global temperature.

A problem of considerable interest is the reasons for the sharp climatic variations in the Pleistocene associated with the advance and retreat of continental and sea ice covers.

The use of the energy model of the theory of climate indicated that a positive feedback between the ice cover and the thermal regime is of considerable importance for these variations. Since ice increases the albedo of the earth-atmosphere system, a broadening of its area leads to a decrease in the quantity of absorbed radiation, which favors a decrease in air temperature. Thus, an increase in ice area can be both a result of climatic change in the direction of a cooling and also the reason for this change.

Allowance for this feedback in energy models of the theory of climate made possible a quantitative explanation of the development of glaciations as a result of the relatively small variations of the radiation registered in the high latitudes, caused by periodic fluctuations in the position of the earth's surface relative to the sun.

With these results taken into account, the initial reason for the Quaternary glaciations must be assumed to be the general process of cooling in the high latitudes caused by a decrease in atmospheric CO_2 concentration. Under the influence of this cooling in the polar zones of both hemispheres there was development of ice covers. When these covers attained a definite thickness the atmosphere-ocean-polar ice system was very sensitive to changes in radiation in the high latitudes which up to this time had not exerted any appreciable influence on climate. In the Pleistocene periodic variations in inclination of the earth's axis, eccentricity of the earth's orbit and the time of occurrences of the equinoxes were adequate for the development of glacial epochs. Such a conclusion, drawn for the first time in investigations of the theory of climate, was later confirmed by materials from paleogeographic studies in which a close relationship was established between the time intervals between glaciations and the periods of variation of the position of the earth's surface relative to the sun.

In order to study the anthropogenic changes in climate a factor of special importance is a clarification of the reasons for the modern variations in climate discovered during the period of existence of the world network of meteorological stations, that is, during the last hundred years.

In the late 1960's a comparison was made of the secular variation of anomalies of mean air temperature in the northern hemisphere and anomalies of direct radiation. The first of these parameters is represented in Fig. 3 by curve 1 and the second by curve 2. The presence of a definite correspondence between these curves was the point of departure for quantitative computations of the influence of variations of the meteorological solar constant (that is, the quantity of short-wave radiation entering the troposphere) on the seasonal temperature of the lower air layer.

The results of such computations are given in Fig. 4, where curve 1 characterizes anomalies of mean air temperature in the northern hemisphere, determined on the basis of observational data, whereas curve 2 shows these same anomalies, computed on the basis of variations of the meteorological solar constant, taking into account the thermal inertia of the earth-atmosphere system. The similarity of these two curves indicates a decisive role of changes in the influx of radiation into the troposphere for modern changes in climate.

Since the changes in the meteorological solar constant for the most part are determined by variations in the aerosol concentration in the lower layers of the stratosphere, which in turn are dependent on volcanic activity, the principal reason for the modern changes in climate is volcanic eruptions of an explosive character. In epochs of lessened volcanism there are global warmings, whereas with an intensification of volcanic activity there is a cooling.

This concept was confirmed in the 1970's in many studies carried out both in our country and abroad.

All the reasons for changes in climate enumerated above were known as hypotheses over the course of a number of decades. Since there were many other contradictory hypotheses not one of them was regarded as demonstrated.

The principal achievement of investigations of natural changes of climate during recent years was the collection of far more detailed empirical data concerning the studied changes in climate and the use of models of the theory of climate for the analysis of this information. The agreement of the results of generalization of empirical data with the conclusions drawn from theoretical computations made possible an approach to understanding the reasons for climatic changes.

Anthropogenic change of climate. In the early 1960's Soviet scientists concluded that with the continuation of modern tendencies in the development of energy production there would inevitably be a major change in global climate in the direction of a warming which would occur in the immediate future. Scientific conferences were held in 1961 and 1962 for discussion of this problem. In accordance with the recommendations of the first of these conferences, beginning in 1961 the plans for scientific investigations by the Main Administration of Hydrometeorology included studies of the anthropogenic change in global climate. It should be noted that these measures were carried out in the USSR considerably earlier than abroad, where similar investigations were organized only in the 1970's.

In the early 1970's specialists in our country published studies in which they evaluated the concept of an important influence on the climate of the near future from the accumulation of carbon dioxide in the atmosphere formed as a result of combustion of fossil fuel. The same conclusion was drawn in the resolutions of a series of national and international symposia and in the reports of a number of scientific organizations published in the years 1976-1979.

For example, it was noted in a report of the United States National Academy of Sciences that in the coming centuries the main influence on climate will be exerted by the increase in the concentration of carbon dioxide in the atmosphere. This can lead to an increase in the mean air temperature at the earth's surface by more than 6°C; the temperature increase in the high latitudes will be several times greater. The authors of the report postulated that the danger of a change in climate may require suspension of the use of carbon fuel in the near future.

In 1979 the problem of an anthropogenic change in climate was examined at the World Climate Conference in Geneva. In a report at this conference Ye. K. Fedorov stated: "Climatic changes in the future are inevitable. They are becoming appreciable and possibly will be irreversible in the next few decades... In this connection it is obvious that it would be necessary to formulate some strategy, that is, a system of preplanned actions which for mankind would ensure the avoidance of negative effects of possible climatic changes... What are the principal elements of such a strategy? It goes without saying that the first and foremost problem is the prediction of climatic changes..."

Without question, an immediate solution of the problem mentioned by Ye. K. Fedorov is necessary. The practical importance of the problem of climatic conditions of the future is determined, in particular, by the fact that the economy of all countries is essentially dependent on modern climatic conditions. Appreciable climatic changes will require great capital investments in order to ensure adaptation of economic activity to the new conditions.

Information on the climate of the future is necessary for the planning of many structures which will be used over a number of decades, for example, in the planning of hydroelectric power stations. It is evident that with a change in climate, and especially with a change in the quantity of falling precipitation the existing regime of river runoff cannot be maintained, and accordingly the designers of hydroelectric power stations must take into account not only information on runoff, but also on the runoff regime in the future. Another example of the practical importance of data on the possible change in climate is the validation of a project for the shifting of the runoff of rivers. Since it is proposed that this project be carried out over the course of several decades, it is clear that in this case it is impossible to limit ourselves to the use of data on modern climate and the river runoff regime -- the validation of the project should provide for allowance for the probable change in climatic conditions.

Many consequences of a global warming can be favorable for the national economy of our country since a considerable part of its territory is situated in the zone of a cold climate where the development of agriculture is difficult, where much money is spent on the heating of dwellings in the cold season of the year, etc. However, it is impossible to expect that the probable changes in climate will not create new and complex economic problems both in our country and abroad.

A change in the precipitation regime can be of particularly great importance because in many regions of the earth the resources of fresh water even now are inadequate for meeting the existing needs and in the future with a further increase in population this deficit should become still more acute. Under these conditions the decrease in the precipitation sums which may occur in some regions will lead to definite difficulties.

There are a great many other problems of practical importance which will arise with a change in global climate. Among these, for example, is the problem of the soil permafrost regime, whose change will exert an influence on the conditions for the construction of different structures in the permafrost zone. A decrease in the area of sea polar ice can improve navigation conditions in the high latitudes. Major consequences can follow an increase in the level of the world ocean as a result of melting of part of the continental ice cover, which would lead to the inundation of a number of coastal regions.

Without enumerating the other practical problems related to the impending changes in global climate, we note that all these problems must be taken into account in long-range economic planning.

Allowance for possible climatic changes is of special importance in the long-range planning of power production because changes in climate themselves are significantly dependent on the structure of the energy balance.

Up to the present time the meeting of the needs of the national economy for data on climate has been accomplished by furnishing materials characterizing the climate of the last several decades. It is obvious that such data can be used in characterizing the climate of the next few years when its anthropogenic changes will be relatively small. However, for a correct answer to many inquiries there must be information on the climate of the future for a time interval of several decades. In this case the use of data on the climate of the past can lead to major errors having dire economic consequences. In order to avoid such errors it is necessary to supplement materials on the meteorological regime of the past with a prediction of this regime in the future. It can be surmised that a proper solution of this problem will lead to a substantial increase in the economic effect of climatic data.

The increase in the concentration of atmospheric carbon dioxide is determined to a considerable degree by the formation of CO_2 as a result of the combustion of coal, petroleum and other types of fuel. A considerably lesser quantity of CO_2 enters into the atmosphere in the manufacture of cement.

The change in CO_2 production with time in the course of the mentioned processes is represented in Fig. 5 at a semilogarithmic scale. The quantity of carbon dioxide produced in a year is expressed in millions of tons of carbon. This figure shows that except for three relatively short time intervals (World War I, economic crisis of the 1930's, World War II) the total entry of CO_2 into the atmosphere increased exponentially, increasing by 4-5% per year.

It is evident that due to the limitation of reserves of carbon fuel the rate of this increase sooner or later should decrease. However, a fact worthy of note is that it follows from the data in Fig. 5 that there is a reverse tendency in the increase in CO_2 production: the rate of increase in this production in the second half of the 20th century was somewhat greater than the rate of its increase at the beginning of the century.

It can be concluded from the data in Fig. 5 that changes in the concentration of atmospheric carbon dioxide over a period of years and decades are now completely determined by anthropogenic factors. The natural components of the balance of atmospheric carbon dioxide correspond to its receipt or expenditure during gas exchange between the atmosphere and the lithosphere and with interaction between the atmosphere and the plant world (for the most part due to noncoincidence of expenditure of carbon dioxide in photosynthesis and its receipt from oxidation of organic matter). Both these components of the natural cycling of carbon have the order of $n \cdot 10^{13}$g/year, which is approximately a hundred times less than the present-day entry of carbon into the atmosphere, as is clear from the data in Fig. 5. It follows from this figure that the anthropogenic production of carbon dioxide became the principal component of its balance in the atmosphere more than a hundred years ago. Thus, a century was needed for this important fact to be discovered by reliable observations.

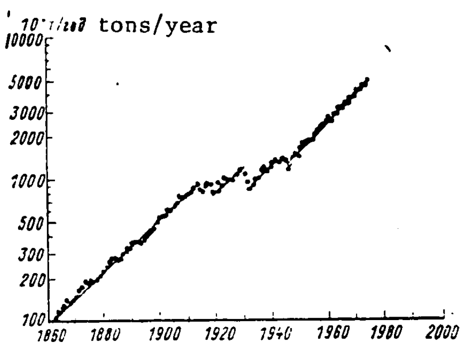

Fig. 5. Increase in CO_2 production.

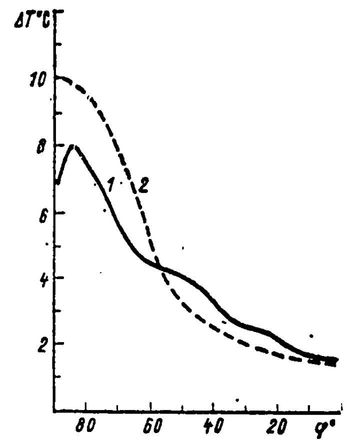

Fig. 6. Air temperature change at different latitudes.

It must be postulated that an additional anthropogenic source of carbon dioxide for the atmosphere is a decrease of the reserves of carbon in the plant cover under the influence of economic activity (primarily with the cutting of forests) and in the soil (decrease in the quantity of humus when working the soil). Although an appreciable percentage of the carbon dioxide ejected into the atmosphere is dissolved in the waters of the ocean and is expended in an increase in the biomass of plants, only about half of the total quantity of CO_2 entering the atmosphere in the course of economic activity is expended in this way. As a result a rapid increase in the concentration of CO_2 is ensured; according to data from observations made during recent years, CO_2 is increasing by approximately 0.5% per year from its value in the preindustrial era.

In addition to carbon dioxide, the atmospheric greenhouse effect can be caused by an increase in the volume of a number of small impurities in atmospheric air (freons, nitrogen oxides and several other gases) due to economic activity. Although relatively small concentrations of these gases can exert an appreciable influence on climate, the release of all gases of such a type can be controlled, that is, be kept at a relatively low level by economically feasible methods. Accordingly, they will exert an influence on the climate of the future only in the absence of monitoring of the state of atmospheric air. In such a case the increase in the concentration of the mentioned gases will lead to an additional warming, intensifying the warming caused by the increase in the CO_2 concentration.

In contrast to the gases constituting small admixtures to atmospheric air, the entry of carbon dioxide into the atmosphere as a result of economic activity is so great that the cessation of this process in the next few decades is evidently technically infeasible. This makes it necessary to evaluate the climatic changes caused by an increase in the CO_2 concentration. Numerous investigations carried out on the basis of use of different models of the theory of climate are devoted to this problem.

Since there are no precise models of the theory of climate, the problem of the reliability of the results of computations of climatic changes on the basis of existing approximate models is sometimes considered inadequately clear. In order to check these computations it was possible to use empirical materials on change in the meteorological regime in its annual variation, data on modern changes in climate, and materials on climates of the geological past. Some results of computations of changes in mean global temperature at the earth's surface in the future are represented in Table 3.

Table 3

Change in Mean Air Temperature (°C) in Comparison With Mid-19th Early 20th Centuries

Source, years	2000	2025	2050
Budyko, 1972	0.7	1.7	3.2
Kellogg, 1977	1.2	---	4.0
Bach, 1978	0.8-1.2	---	2-4
Flohn, 1978	1	2.5	4

It can be concluded from the data in the table that different investigations give close results in determination of climatic conditions of the future. It is worth noting that already in 1972 estimates of changes in mean air temperature were obtained which were very close to the results which are now regarded as most reliable.

It is of considerable importance that in the middle and especially in the high latitudes the anthropogenic changes in climate will be greater than those values which are included in Table 3.

Figure 6 gives the changes in mean annual air temperature at different latitudes in the northern hemisphere with an increase in mean global temperature by 3°C. Curve 1 in this figure was constructed using computations based on use of a model of general circulation of the atmosphere and curve 2 is based on paleoclimatic materials relating to the end of the Tertiary. It follows from these data, which are in good agreement, that the temperature in the high latitudes is increasing approximately three times more rapidly than the mean global temperature.

It can be surmised that an increase in air temperature in the Arctic by 8-10°C will lead to the destruction of perennial polar sea ice. This conclusion follows both from an empirical analysis of the correlations of the modern regime of ice with thermal conditions, and from computations using different theoretical and semiempirical models. It is more difficult to solve the problem of the future of the glacier in Antarctica during the development of a global warming. Due to the possibility that with the partial destruction of this glacier there will be a rise in ocean level and inundation of extensive coastal territories this problem is of great practical importance. It is discussed in a number of investigations, from which it can be seen that this problem has not been clarified adequately and is in need of further study. The problem of the influence of warming on the moistening regime of the continents is also of considerable importance. The results of computations using models of general circulation of the atmosphere and conclusions from use of paleoclimatic analogues lead to the conclusion that after several decades there can be an appreciable increase in precipitation in regions of excess moistening and a decrease in its totals in regions of unstable and inadequate moistening in the middle latitudes of the continents.

Data now available make it possible to draw a number of conclusions concerning the climatic conditions of the future which can be used in meeting the needs of the national economy. However, these data are very schematic and inadequate for the complete satisfaction of the mentioned needs. The problem of obtaining detailed information on the climatic conditions of the future is central for modern climatology.

Prospects for investigations of climate. The restructuring of climatology which is now transpiring, together with many outstanding advances in the study of climate, is creating a number of ambiguities which to some degree are inevitable in the rapid development of any scientific discipline. The appearance of a great many new results in some cases is leading to a contradiction between recent advances in climatology and concepts which only recently were considered as fact. Accordingly, sometimes it appears that there are disagreements in solution of a number of problems in modern climatology, although in actuality there are usually no disagreements among specialists who for many years have been engaged in the study of climate.

It should be stated that for the rapid and precise solution of the most timely problems in modern climatology there must be a considerable improvement in the organization of research in the field of climate.

Prospects have now opened up for the extensive development of the principal directions in modern climatology, among which are the following:

1. Formulation of detailed and realistic models of the theory of climate.
2. Empirical study of modern climate and its changes when using effective statistical methods.
3. Empirical study of climates of the geological past.
4. Physical explanation of the patterns of natural changes of climate.
5. Detailed computations of anthropogenic changes in climate and evaluation of climatic conditions of the future.
6. Study of the influence of climate on the hydrological regime and the entire complex of processes forming the geographic medium.
7. Study of the dependence of agriculture and other branches of economic activity on climate.

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THE HELIOGEOPHYSICAL SERVICE, ITS TASKS AND PROSPECTS FOR DEVELOPMENT*

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 (manuscript received 22 Jan 81) pp 63-76

[Article by S. I. Avdyushin, candidate of technical sciences, Institute of Applied Geophysics]

[Text]

Abstract: The article examines the main problems involved in the development and operation of the heliogeophysical service, which makes observations, analyzes these observations and disseminates to departments and national economic organizations data from such monitoring and predictions of the state of circumterrestrial space for use for the purpose of supporting space flights, radiobroadcasting, radiocommunication, navigation and other practical and scientific problems. The directions in development of the heliogeophysical service are outlined.

In this era of vigorous development of radiocommunication and the conquest of space a highly important task is solution of the problem of monitoring and predicting the conditions in circumterrestrial space, including the state of the magnetosphere, ionosphere and upper atmosphere.

It is becoming increasingly important to know the physical properties of the medium in which the flight of space vehicles and manned ships is occurring; what influence this medium exerts on the propagation of radio waves, the orientation and navigation of a space vehicle, man's vital functions in space; how the parameters of this space medium change with time, in other words: what is the space weather at a particular moment and what is its prediction?

Investigations of recent decades have indicated that the physical conditions in circumterrestrial space are determined for the most part by the earth's magnetic field, by the gas and aerosol components of the upper atmosphere which are constantly being affected by solar electromagnetic and corpuscular radiation.

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* Main content of a report at an expanded session of the Presidium of the Scientific and Technical Council, State Committee on Hydrometeorology and Environmental Monitoring, 13 October 1980.

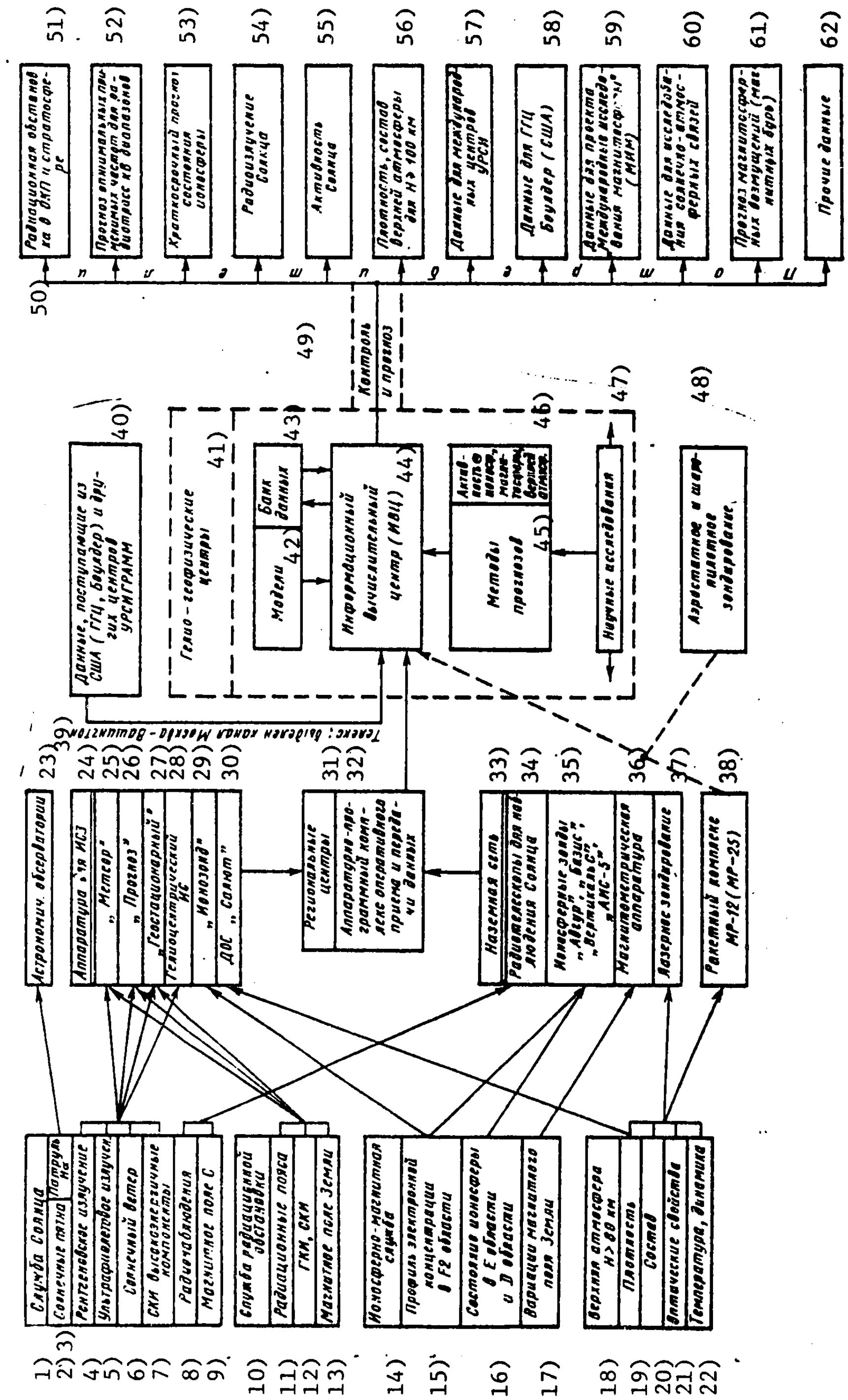

Fig. 1. Structure of heliogeophysical service.

KEY TO FIGURE 1

1. Solar service
2. Sunspots
3. Hα patrol
4. X-radiation
5. UV-radiation
6. Solar wind
7. SCR high-energy components
8. Radio observations
9. Solar magnetic field
10. Radiation conditions service
11. Radiation belts
12. GCR, SCR
13. Earth's magnetic field
14. Ionospheric-magnetic service
15. Electron concentration profile in F2 region
16. State of ionosphere in E and D regions
17. Variations of earth's magnetic field
18. Upper atmosphere H> 80 km
19. Density
20. Composition
21. Optical properties
22. Temperature, dynamics
23. Astronomical observatory
24. Instrumentation for artificial earth satellites
25. Meteor
26. Prognoz
27. Geostationary
28. Heliocentric artificial earth satellites
29. Ionosonde
30. Salyut MSS
31. Regional centers
32. Instrument-programming complex for operational data reception and processing
33. Surface network
34. Radiotelescopes for observing sun
35. Ionospheric probes "Avgur," "Bazis," "Vertikal' S" and "AIS-5"
36. Magnetometric apparatus
37. Laser sounding
38. MR-12 (MR-25) rocket complex
39. Telex: Moscow-Washington channel allocated
40. Data received from United States (heliogeophysical center, Boulder) and other centers--URSIGRAM
41. Heliogeophysical centers
42. Models
43. Data bank
44. Information-computation center
45. Forecasting methods
46. Activity of ionosphere, magnetosphere and upper atmosphere
47. Scientific investigations
48. Balloon and pilot balloon sounding
49. Monitoring and prediction
50. Users
51. Radiation conditions in space and stratosphere
52. Prediction of optimum useable frequencies for radiopaths in SW range
53. Short-range prediction of state of ionosphere
54. Solar radioemission
55. Solar activity
56. Density, composition of upper atmosphere for H> 100 km
57. Data for international centers URSI
58. Data for heliogeophysical center Boulder (USA)
59. Data for project International Investigations of Magnetosphere
60. Data for investigating solar-atmospheric relationships
61. Prediction of magnetospheric disturbances (magnetic storms)
62. Other data

The variability of solar electromagnetic and corpuscular radiation leads to a whole series of geophysical effects which can be regarded as a direct manifestation of solar-terrestrial relationships. Some of these relationships have already been established. For example, such phenomena near and at the earth as magnetic storms, auroras, sudden disruptions of radiocommunication, ionospheric disturbances and changes in radiation conditions in circumterrestrial space are unquestionably related to processes transpiring on the sun. However, other manifestations of solar-terrestrial relationships, such as fluctuations in the yield of different crops, the frequency of recurrence of droughts in individual regions of the earth, cyclicity in the appearance of some epidemic diseases, and influence on the health of persons suffering from cardiovascular diseases still require a further careful study. They may be an indirect manifestation of the direct influence of the sun on the earth, for example, through meteorological conditions.

Thus, the monitoring of solar activity and the ability to predict it, in combination with the registry of geophysical phenomena, in principle make it possible to monitor and predict the state of the upper atmosphere, ionosphere and circumterrestrial space.

The task of solving this problem has been assigned to the USSR State Committee on Hydrometeorology and Environmental Monitoring. For this purpose since 1975 the State Committee on Hydrometeorology has had a heliogeophysical service, including an ionospheric-magnetic service, a service for monitoring radiation conditions in circumterrestrial space and a solar radio service. In creating the observation network, the system for the collection, processing and dissemination of information the heliogeophysical service has relied heavily on the experience and technical equipment of the hydrometeorological network, including meteorological satellites, an automated information-computation system, etc.

A number of observations necessary for the service (geomagnetic variations, ionospheric sounding, optical and radio observations of the sun) are being carried out by the observatories of other departments (Academies of Sciences, Ministry of Higher and Secondary Specialized Education) independently or in collaboration with the State Committee on Hydrometeorology and Environmental Monitoring.

In the course of creation of the heliogeophysical service the following principal problems are now being solved (see Fig. 1):

-- development and creation of satellite, rocket and surface apparatus intended for routine observations and the carrying out of investigations of heliogeophysical parameters;

-- creation of a main heliogeophysical prognostic center and regional centers outfitted with modern information and computer equipment making it possible to automate the collection, routine processing, analysis and dissemination of information and predictions to users;

-- development of methods for short- and long-range predictions of space weather based on investigations of the patterns of behavior of heliogeophysical phenomena and the creation of mathematical models of the magnetosphere, ionosphere, upper atmosphere and radiation conditions in circumterrestrial space;

-- study of the types of information needed by the serviced organizations and departments and the perfecting of the forms of output.

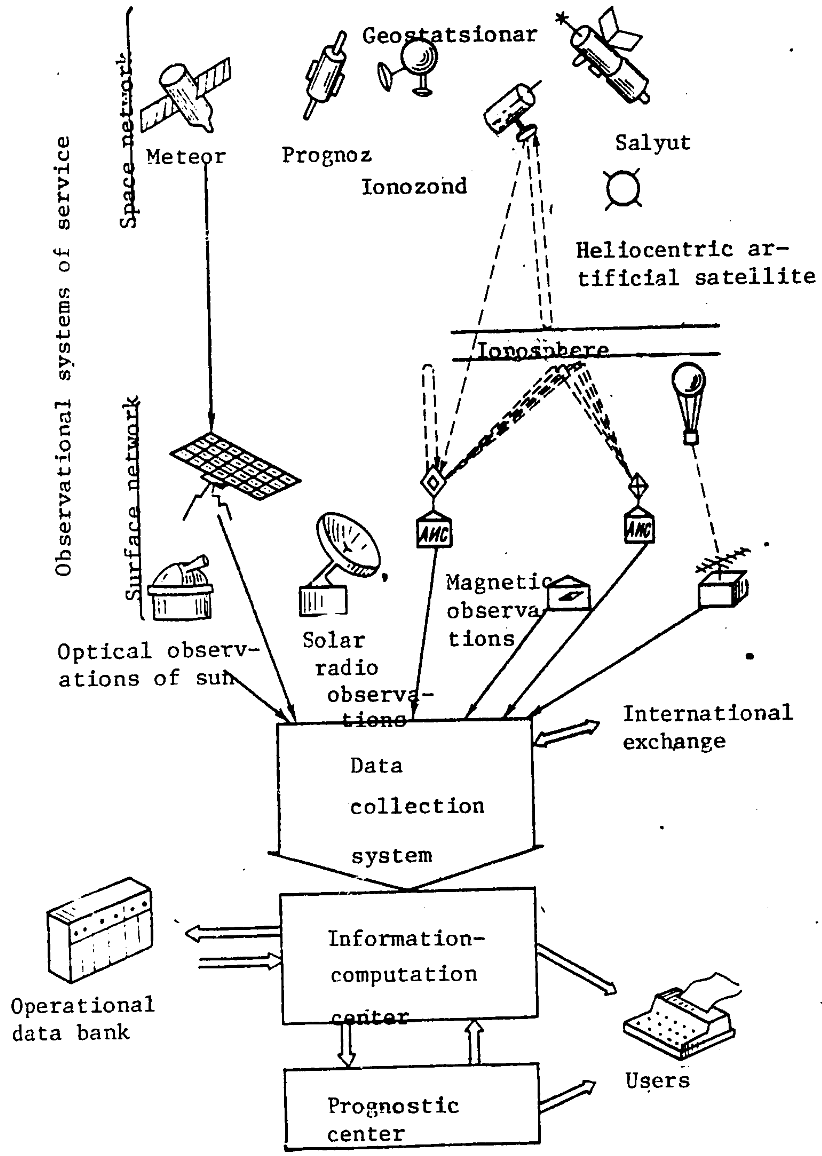

Fig. 2. Heliogeophysical service observation systems and elements.

Observational Systems of Service

The monitoring of radiation conditions in circumterrestrial space, state of the ionosphere and magnetosphere, and solar activity as well, must be accomplished by space and surface apparatus (see Figures 2 and 3).

The "Meteor-2" satellite monitors streams and the spectral distribution of charged particles (electrons and protons) in the earth's radiation belts and in the polar regions [2], which in combination with other measurements makes it possible to compute radiation conditions on the flight trajectories of the manned "Salyut"-"Soyuz" spaceships.

The monitoring of the state of the ionosphere over the territory of the USSR is accomplished using vertical sounding stations of the AIS-5 type which in the immediate future will be replaced by more modern ionosondes.

In order to monitor the state of the ionosphere on a global scale (and this is important in computing transcontinental radio trajectories) it is necessary to develop slant sounding and sounding of the ionosphere from a satellite. The creation of slant sounding and sounding from a satellite of the "Ionozond" type will make possible a qualitatively new approach to solution of the problem of monitoring the state of the ionosphere.

The monitoring of variations of the earth's magnetic field will be accomplished by artificial earth satellites and magnetovariation stations located in the territory of the USSR.

The monitoring of density and neutral composition of the upper atmosphere in the future should be carried out directly aboard the "Salyut" space stations.

In order to predict the state of the magnetosphere, ionosphere, circumterrestrial space and the upper atmosphere it is necessary to create a network for making observations of geoeffective solar radiations. These are solar corpuscular, UV and X radiations, the fluxes of which vary greatly in dependence on its activity. Important information on active regions on the sun is obtained by observations in the radio and optical ranges. Accordingly, the existing geophysical control network must be supplemented by a heliophysical network, including optical telescopes and radio telescopes for continuous observations of flares and magnetic fields on the sun and also solar satellites: artificial earth satellites of the "Prognoz" type, which will make it possible to monitor geoeffective solar radiations in the earth's neighborhood and a heliocentric satellite making it possible to monitor the activity of the solar surface invisible from the earth.

In addition, in order to study and patrol the interaction of the solar wind with the earth's magnetosphere it is necessary to monitor the streams of radiations and parameters of the medium at the boundary of the magnetosphere. For this purpose it is necessary to use a geostationary satellite which carries instrumentation making it possible to monitor geoeffective solar radiations and the parameters of the earth's magnetosphere.

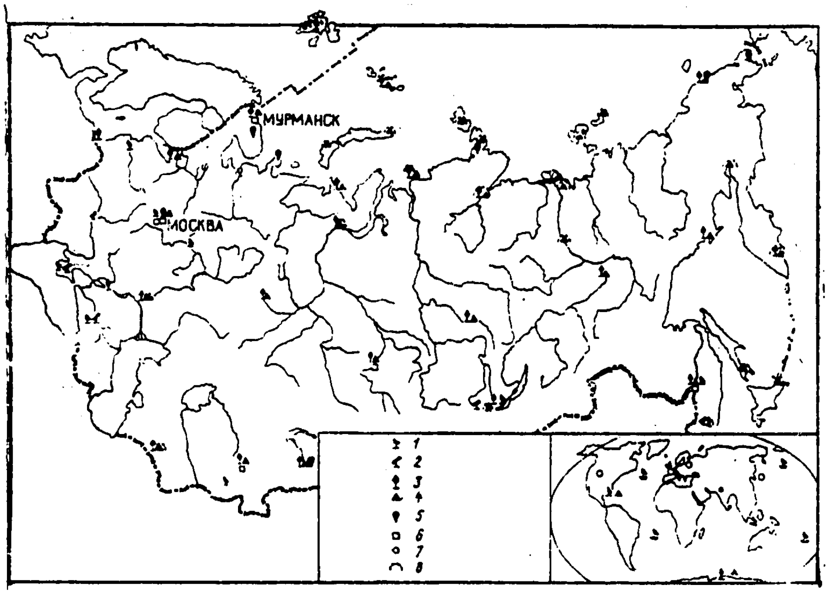

Fig. 3. Surface network of heliogeophysical service. 1) radio observations of sun; 2) optical observations of sun; 3) ionospheric stations; 4) magnetic stations; 5) stratospheric soundings; 6) regional prognostic centers of service: Murmansk, Tashkent, Novosibirsk, Khabarovsk, Moscow; 7) international warning centers; 8) planned stations.

Surface Network of Service

The collection of data from surface and space observation facilities is accomplished at regional centers (see Fig. 3). The collection network is based on use of standard telegraphic communication lines, the communication channels of the "Pogoda" automated data transmission system and allocated communication channels. The telemetric data arriving from space vehicles is subjected to automated processing using specialized apparatus and is introduced into electronic computers at the regional centers for primary checking and analysis. Then this information is fed through the data transmission channels to the electronic computers at the prognostic heliogeophysical center.

In the future, with the development of observation facilities, plans call for the development and creation of additional regional centers ensuring the automated collection of heliogeophysical data from distant space vehicles with the use of satellite data transmission facilities.

Heliogeophysical Center (HGC)

An analysis of the technology of collection, the process of reworking of heliogeophysical data, preparation and output of current and prognostic data determines the structure of the information-computer complex at the heliogeophysical center (see Fig. 4) [1].

The structure of the information-computation complex should ensure:
-- collection of data from observation points (or from regional centers) through automatic channels and their input into an electronic computer at the rate of receipt;
-- identification and selection of the arriving data;
-- processing of data in a regime close to real time;
-- storage of operational data;
-- analysis and preparation of current and prognostic information;
-- display and dissemination of information to users.

Since the requirement of routineness is dominant in all stages of the technological cycle, the center is constructed on the basis of high-output communication facilities and computers with separation of the functions among the elements of a multiapparatus information-computation complex.

The functions of collection and dissemination of data are handled by a communication processor which ensures the input of data into the computation complex, identification of data and their intermediate storage on magnetic carriers, the reliability of the received data, preliminary processing of part of the data (at the level of the input formats), data transmission to other subsystems, routine dissemination of data along communication lines.

Using a special program it is possible to ensure the control of the input of data from communication channels into electronic computers and their output into the communication channel. In addition, the program ensures the preliminary processing of data and organizes an information interaction with other terminals in the system.

The functions of carrying out of numerical computations for the purpose of obtaining quantitative data for the diagnosis and prediction of weather in space and the organization of the storage of data necessary for complex analysis are accomplished by a central processor which is a powerful electronic computer with a high speed, operational memory with a considerable volume, memory on magnetic carriers and a well-developed operational system.

At the heliogeophysical center there should be a bank of operational data (BOD) which will ensure the organization and use of data in formalized methods for checking and computing a prediction of space weather.

Provision is made for two regimes for access to data: retrospective search for information and its selective distribution.

The bank of operational data makes it possible to obtain requested summaries, graphically represent heliogeophysical data on displays in a dialogue regime, document information using a curve plotter and employ information in any processing programs as initial data.

The programmed support of the bank of operational data is based on the principle of a nondependence of data on the processing programs, which makes it possible to introduce into the bank of operational data new types of information.

The dissemination of information to users is realized on the basis of terminal processes outfitted with a complex of necessary peripheral equipment and having intercomputer exchange with the central processor.

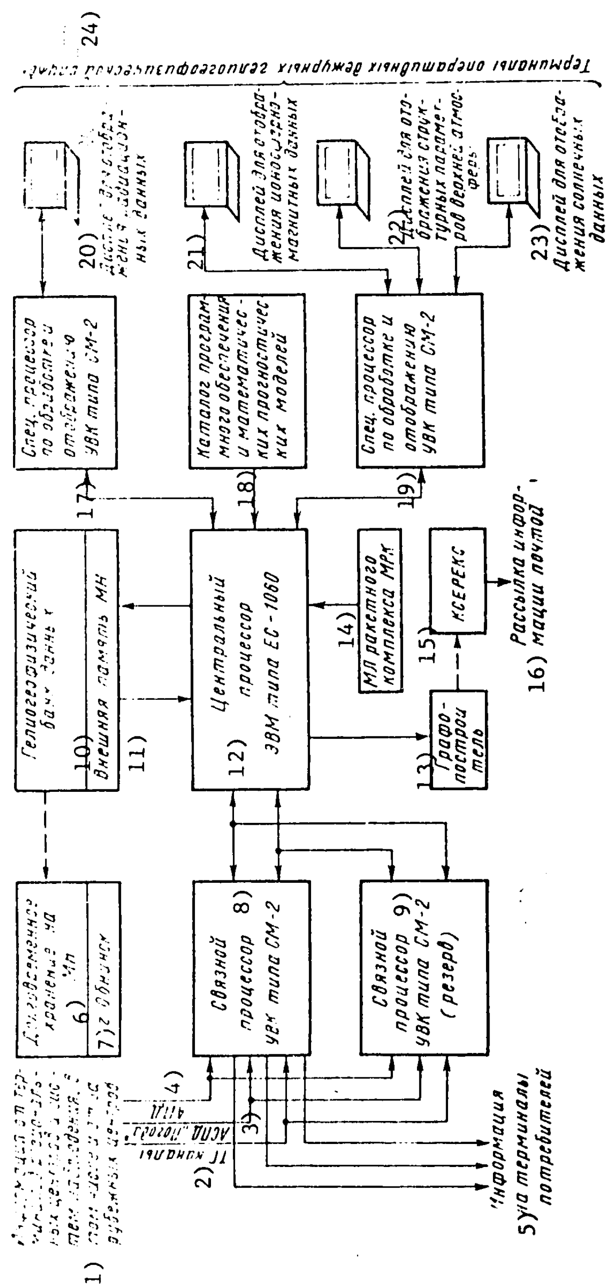

Fig. 4. Structure of information-computation complex.

KEY TO FIGURE 4

1) Information from terminals of regional centers and observation systems, including from foreign centers
2) Telegraphic communication lines
3) "Pogoda" automated data processing system
4) Automatic data transmission
5) Data at terminals of users
6) Long-term storage on magnetic carriers
7) Obninsk
8) Communication processor for input control, type SM-2
9) Communication processor for input control, type SM-2 (reserve)
10) Heliogeophysical data bank
11) External memory -- magnetic carriers
12) Central processor of YeS-1060 electronic computer
13) Curve plotter
14) Magnetic tapes of MRK rocket complex
15) KSEREKS (Xerox)
16) Dispatch of information by mail
17) Special processor for processing and display, for input control, type SM-2
18) Catalog of programmed support and mathematical prognostic models
19) Special processor for processing and display, for input control, type SM-2
20) Screen for display of radiation data
21) Screen for display of ionospheric data
22) Screen for display of structural parameters of upper atmosphere
23) Screen for display of solar data
24) Terminals of operational "on-duty" heliogeophysical service

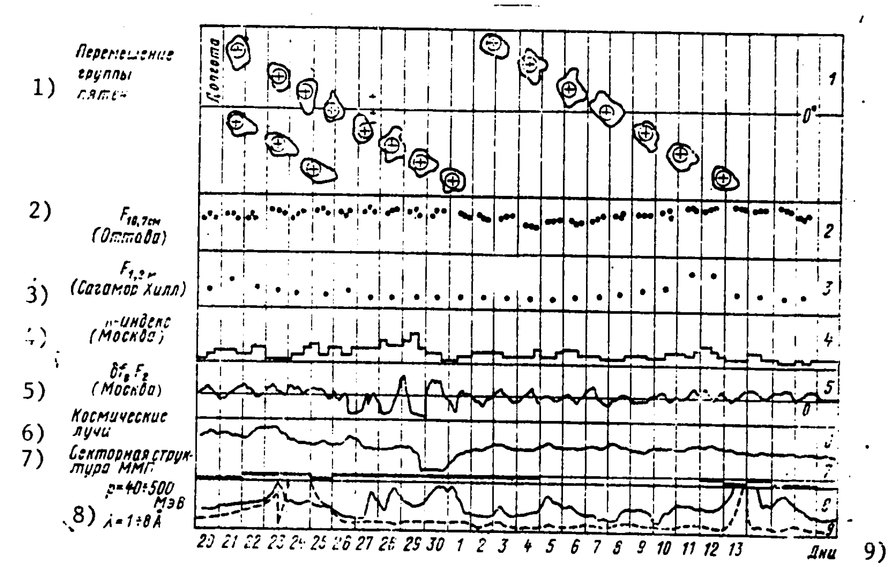

Fig. 5. Synoptic map of heliogeophysical phenomena.

KEY:

1) Movement of spot group
2) Ottawa
3) Sagamore Hill
4) K-index (Moscow)
5) Moscow
6) Cosmic rays
7) Sectoral structure of IMF
8) MeV
9) Days

At the present time the experimental information-computation center (EICC), which since 1970 has been carrying out the partial collection (for the most part from the "Meteor-2" satellite), processing and analysis of heliogeophysical information, has shown the correctness of the ideas applied in creation of the heliogeophysical center. At the EICC an M-600 universal computer complex is used as a channel communication processor and the role of a central processor is played by two "Minsk-32" electronic computers, the technical and systemic possibilities of which are severely limited.

Short-Range Predictions of Ionospheric and Magnetic Disturbance

The prognostic centers issue four types of short-range predictions of ionospheric and magnetic disturbance: monthly, five-day, two-day and semidaily [6]. The basis for the prediction is a synoptic map of heliogeophysical phenomena, a schematic example of which is shown in Fig. 5. The map shows the following information (from top to bottom): active formations on the sun (flocculi, spots, flares); a stream of solar radioemission at λ = 10.7 cm and 1.2 m; the three-hour K-index of magnetic activity for Moscow station; deviations of the critical frequencies f_0F2 for Moscow station; intensity of cosmic rays according to data from a space monitor; sectoral structure of the interplanetary magnetic field (IMF); fluxes of electrons with E = 40-500 MeV and X-radiation with λ = 1-8 A.

In the compilation of a monthly prediction on the basis of the corresponding tendencies in the development of a recurrent phenomenon predictions are made of periods of possible geomagnetic disturbances and manifestations of different ionospheric phenomena (f_0F2 disturbances, E_s layer, absorption). The synoptic map of the sun makes it possible to correct the recurrent prediction, taking into account the active formations appearing on the solar disk during the current rotation.

The monthly prediction includes a prediction for each day in the coming month, taking into account the following parameters:
-- magnetic field disturbances for Moscow station;
-- deviations of the critical frequencies of the F2 layer (δf_0F2) in units from the median for the stations Moscow, Kiev, Alma-Ata, Irkutsk, Khabarovsk, Krenkel' and Murmansk;
-- the intensity and probability of appearance of the E_s layer for Murmansk and Krenkel' stations;
-- the probability of appearance of absorption and diffusivity for Murmansk and Krenkel' stations.

Monthly predictions are issued on the 25th of each month and are sent to requestors by mail and to the regional service centers by telegraph.

A refinement of the monthly prediction of magnetic and ionospheric disturbance is the five-day prediction in which the emphasis is shifted from recurrency to really transpiring events (synoptic map). In this process an allowance is made both for phenomena transpiring on the sun during the preceding several days (flares, appearance of new active regions and degradation of old regions) and prediction of solar activity.

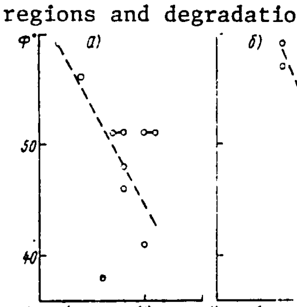

Fig. 6. Delay times δf_0F2 relative to the onset of a magnetic storm. a) 2-5 November 1975; b) 9-10 November 1975.

The five-day prediction includes the median values f_0F2 and the coefficient M-3000-F2 for 22 Soviet stations and 3 foreign stations (Boulder, Juliusru, Wallops). The prediction is issued on the 5th, 10th, 15th, 20th, 25th and 30th (31st) of each month, is sent out to users by telegraph and is transmitted in a radio summary.

A further refinement of the anticipated ionospheric disturbance is given in a two-day prediction, including the qualitative characteristics of the degree of disturbance of the ionospheric F2 region for the five principal regions in the Soviet Union: polar cap (Krenkel' station), auroral zone (Murmansk station), European USSR (Moscow station), East (Yakutsk station) and Middle Asia (Alma-Ata station).

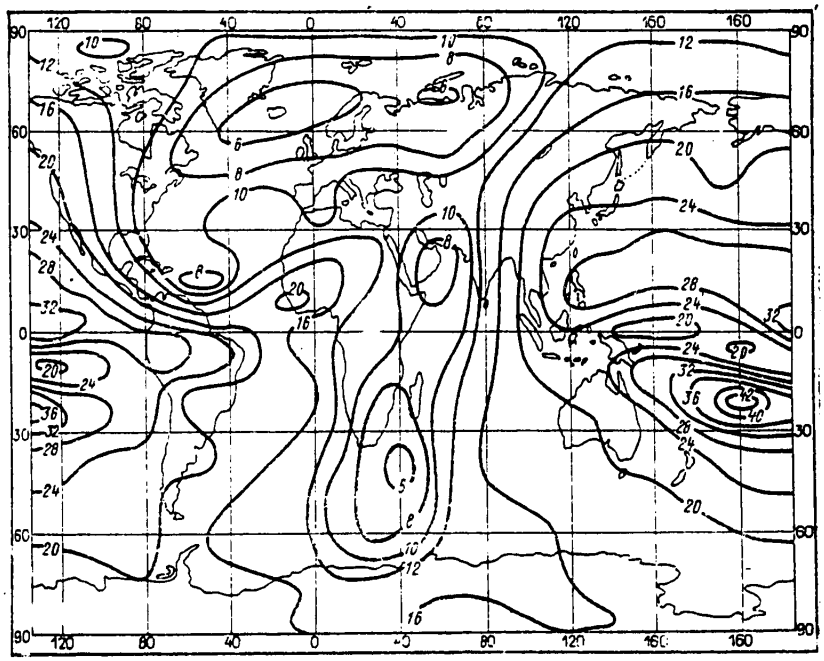

Fig. 7. Map of global distribution of the critical frequency of the F2 layer with reception range 4,000 km (0400 hours Moscow time).

The final refinement of the prediction of ionospheric and magnetic disturbance is given in a semidaily prediction in which the main reliance is on the current magnetic and ionospheric data, taking into account the final velocity of propagation of an ionospheric disturbance from the high to the middle latitudes. For example, during the daytime the minimum on the δf_0F2 curve (maximum of negative disturbance) sets in at Moscow on the average an hour later than at Leningrad, and at Kiev an hour later than at Moscow. The delay times δf_0F2 relative to the commencement of a magnetic storm for stations situated at different latitudes are given in Fig. 6. It can therefore be seen that the mean velocity of propagation of a negative disturbance along the meridian is about 100 m/sec (which is close to the mean velocity of meridional circulation at the altitudes of the F2 region). The reaction of the low-latitude ionosphere is a manifestation of instability of the F2 layer.

In the absence of clearly expressed disturbance a prediction of the deviation of critical frequencies is given on the basis of a comparison of the really observed f_0F2 values and the median, given by a five-day prediction.

Long-Range Predictions of Ionospheric and Magnetic Disturbance

The prognostic centers issue two types of long-range prediction: maps of the prediction of the distribution of the maximum useable frequencies (MUF) for the earth and predictions of the propagation of radio waves along specific paths. The basis for the compilation of these predictions is a description of the global distribution of the parameters of the F2 layer in space and time in the form of a set of spherical harmonic functions proposed by the specialists of the USSR Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation [5].

The monthly prediction of the MUF is issued 4-6 months in advance and contains maps of the global distribution of two main parameters: critical frequency of the F2 layer with vertical incidence of radio waves (f_0F2) and the critical frequency of the F2 layer with the slant incidence of radio waves and a distance to the reflection point equal to 4,000 km (MUF-4000-F2) (Fig. 7). The input parameter in the preparation of a MUF prediction is the smoothed sunspot number W. At the present time work is being carried out for the replacement of this parameter by more informative parameters characterizing the amplitude or expected attenuation of the signal.

Figure 8 shows an example of MUF prediction for the Moscow-Yakutsk path for March 1979.

It should be noted that long-range predictions, made on an electronic computer, give the mean pattern of behavior of the predictable parameters and reflect only regular variations (with latitude, longitude, season, solar activity, etc.) of the parameters of ionospheric layers.

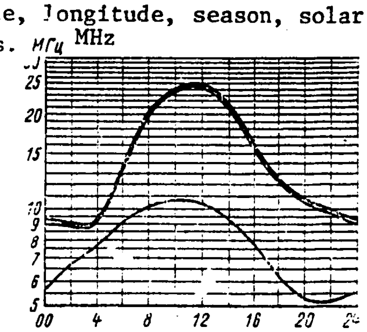

Fig. 8. Example of prediction of range of useable frequencies for Moscow-Yakutsk radio trajectory (Moscow time).

The activity of the prognostic centers described above makes it possible to provide most users with the basic types of current information and predictions. However, there must be further improvement in the observation system and methods for making predictions in order to achieve a significant increase in data output and in order to enhance the reliability of the predictions. A method based on physical models of the ionosphere should be a fundamentally new prediction method. At the present time the testing of specially created physical models is being carried out at the main prognostic center from the point of view of the possibility of their use for different types of predictions.

Methods for predicting the D region have been extremely poorly developed, whereas the need for such prediction is constantly increasing. The organization of observations of the D region by the partial reflections method will make it possible to evaluate and disseminate to users information on the current state of the lower ionosphere and also to accumulate data for developing prediction methods. It should be noted that the prediction of the electron and ion concentrations in the D region can differ substantially from the now existing ionospheric prediction because according to modern concepts this state can be influenced by both heliogeophysical and meteorological factors.

Prediction of Radiation Conditions

Radiation conditions in circumterrestrial space are very closely tied in to solar activity because the principal source of radiation danger is streams of charged particles generated by a solar flare. The physical mechanism of a solar flare has not been thoroughly studied and therefore at present it is impossible to formulate a unified and reliable method for predicting radiation conditions. Existing models of solar activity do not contain schemes of the genesis and development of an active region and do not make it possible to predict the time of a flare and the fact of injection of solar cosmic radiations (SCR).

At the heliogeophysical center [7] methods are being developed for predicting the time of onset and diagnosis of development of solar flares. The overall problem is reduced to the formulation of a prediction of evolution of an active region based on image recognition theory.

The prediction essentially involves successive evaluations of whether the observed active region belongs to one class of events or another (dangerous and nondangerous flares); the boundary of separation into classes is the background level of the flux density of protons with $E_p > 55$ MeV. The initial data are the results of observations of radiation in the optical, X- and radio ranges because precisely the characteristics of these radiations correlate best with corpuscular radiation occurring during solar flares. The characteristics of X- and radio radiations are the most significant in the identification of dangerous flares.

An investigation of the relationship between the characteristics of occurrences of solar cosmic radiations with the parameters of heliogeophysical phenomena accompanying a flare made it possible to establish a number of patterns which served as a basis for prediction methods.

On the basis of these methods the service regularly issues the following prognostic data:
-- qualitative predictions of flare activity, state of the magnetosphere and radiation conditions for two days (daily) and for 27 days (weekly),
-- prediction of the development of streams of protons accompanying flares on the sun, including on the spaceship flight trajectory,
-- integral flux of SCR from a flare.

A method for predicting the development of fluxes of cosmic rays and the integral flux during the entire event has now been developed and is used in the operation of the service. It uses a model of isotropic diffusion and data from initial registry of SCR fluxes in auroral zones on the "Meteor-2" satellite [3].

The diagnosis of the current state of radiation conditions along the trajectories of space vehicles in circumterrestrial orbits requires a conversion from observations of the fluxes of penetrating radiations in the orbit of the "Meteor-2" artificial earth satellite in the high-latitude zones of the earth's magnetosphere to a description of the overall structure of particle fluxes, and in particular, in the orbits of the manned spaceships (MSS) "Salyut"-"Soyuz." This conversion must be accomplished, first of all, for protons of solar cosmic radiation, taking into account the real distribution of threshold geomagnetic rigidities, dependent on the degree of magnetospheric disturbance.

With the use of this model, on the basis of the initial spectra of protons in the polar caps and magnetospheric disturbances, a working catalogue was created for the integral spectra of SCR protons for the flight trajectory of the "Salyut" - "Soyuz" MSS.

With further development of prediction methods an allowance will be made not only for the physically validated prediction prerequisites, but also the possibility of a rapid, routine determination of the characteristics and parameters of the used heliogeophysical phenomenon.

Investigations of recent years have demonstrated that an important factor determining the propagation of protons generated in a flare is photospheric magnetic fields. Investigations of SCR events, jointly with photospheric magnetic fields for the periods of the maximum and decline of the 20th solar activity cycle, and also in the stage of increase of the 21st cycle, made it possible to discover a relationship between the characteristics of propagation of protons with energies from 5 to 90 MeV and the macroscale magnetic structure. The synoptic maps of the sun constructed from photographs in the H_α line reveal the macroscale structure of weak magnetic fields and have the property of continuity over a great extent.

With the use of the determined characteristics of propagation of solar flare protons and with allowance for the influence of the configuration of macroscale magnetic fields on the sun [4] on the propagation of SCR protons a method was developed making it possible to predict the following parameters of proton events:

-- the total flux of protons with $E_p > 5$-10 MeV and $E_p > 40$-60 MeV, normalized to maximum intensity;

-- the time of onset of the maximum of the intensity of a SCR event with $E_p > 5$ MeV;

-- the decay constants for fluxes of protons with energies $E_p > 5$ MeV;

-- the onset and duration of the event;

-- the rigidity indices of the integral spectra at the intensity maximum and at the beginning of the event at the half-maximum level.

On the basis of data from radio observations in the centimeter range methods were developed for predicting the parameters of proton events:

-- flare coordinates;
-- an evaluation of the probability of registering an event with a stipulated intensity;
-- prediction of the upper limit of a proton flux with $E_p > 10$ MeV.

As already mentioned, the state of the interplanetary medium exerts a considerable influence on the propagation of solar protons. Accordingly, the problems involved in the diagnosis and prediction of the parameters determining the state of interplanetary space also play an important role in predicting radiation conditions. It has been established in a number of studies that the characteristics of SCR are related to the direction of the radial component of the interplanetary magnetic field. Conditions in the interplanetary medium are determined for the most part by the density and velocity of the solar wind.

The principal direction in the development and improvement of work on prediction of radiation conditions is the creation (on computer carriers) of global dynamic models of radiation conditions with a limited number of controllable parameters for each phase of the solar cycle. The evaluation and prediction of these parameters will be accomplished on the basis of an operational computer data bank.

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It is planned that investigations of the energy, structure, dynamics and optical characteristics of the upper atmosphere and ionosphere be carried out under a multisided program which includes scientific programs for observations using MR-12 (or MR-25) rockets both on the basis of a set of measured parameters and on the basis of the effects of solar activity and other factors (that is, seasonal, diurnal, latitudinal, longitudinal and other effects). These investigations require the carrying out of joint synchronous satellite and rocket experiments on scientific research ships used as mobile rocket polygons. The collected experimental data will be used in developing methods for the physical model prediction of heliogeophysical parameters.

An improvement of the ionospheric-magnetic network provides for the creation of slant, transionospheric sounding with the use of artificial earth satellites, sounding by the partial reflections method, outfitting of the network of magnetic stations with instrumentation and apparatus for measuring variations of the magnetic field in the range 0-1 Hz with the possibility of broadening the range to 10 Hz.

For the purpose of increasing the probable success of geophysical predictions and increasing the number of predictable parameters an important task is the creation of an operational solar service in the X-, UV, radio and optical ranges. For this it is necessary to organize a continuous, around-the-clock patrol of optical, UV-, X-radiations and radioemission from the sun. In this connection plans call for the development of a complex of satellite instrumentation and creation of a surface network of stations outfitted with radio telescopes. For continuous around-the-clock monitoring of radioemission it is desirable that provision be made for the installation of radiotelescopes in the western hemisphere and on the scientific research ships of the State Committee on Hydrometeorology and Environmental Monitoring operating in the Atlantic and Pacific Oceans.

In conclusion it should be noted that in order to achieve the most complete and highest-level satisfaction of users with current data and predictions during the Eleventh Five Year Plan it is necessary to develop objective prediction methods with use of the latest computers, modern methods for measuring heliogeophysical parameters, with the use of a broadened observational network of the service, outfitted with more modern apparatus designed at a modern scientific and technical level.

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MODERN PROBLEMS IN OCEANOGRAPHIC RESEARCH*

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[Article by A. F. Treshnikov, corresponding member USSR Academy of Sciences, and F. S. Terziyev, candidate of geographical sciences, Arctic and Antarctic Scientific Research Institute and State Oceanographic Institute]

[Text]

Abstract: The authors formulate the principal tasks of the State Committee on Hydrometeorology in the field of oceanographic research. The review gives an analysis of its pesent status and outlines paths for further development. It is shown that the basis for study of the seas and oceans should be a program of in situ experiments which constitute an embodiment of the theoretical schemes. In addition to the collection of information on the world ocean, plans call for the extensive study of atmospheric processes. There is a need for strengthening fundamental investigations in the field of oceanography and especially theoretical studies directed to a study of thermodynamic processes in the world ocean for the purpose of developing and improving methods for sea and weather predictions. In the field of practical research an important place is occupied by the problems involved in a study of the regime of seas in connection with the successful exploitation of mineral and biological resources of the shelf zone, the problem of evaluating the consequences of chemical contaminations in ecosystems and the development of scientifically sound recommendations on the dynamics of the contamination level. The importance of different aspects of the problem of a deficit of continental fresh runoff is emphasized.

* Main content of a report at an expanded session of the Presidium of the Scientific and Technical Council, State Committee on Hydrometeorology and Environmental Monitoring, 13 October 1980.

The role of the oceans and seas in the life of mankind is increasing without interruption. This is attributable, in particular, to man's increasing need for the use of the biological and mineral resources of the oceans and seas, which to the present time are not being fully used. Work was begun on the exploitation of the mineral resources of the oceans and seas relatively recently, but even now more than 20% of all petroleum and gas production is from the continental shelf and in the coming 10-15 years its production at sea should become dominant. Equally important are oceanological investigations for creating a scientific basis for finding and choosing promising regions for the exploitation of fish and other biological objects because the dynamics of development of biological communities is directly related to vertical and horizontal movements of waters and their turbulent mixing.

The transport of heat by ocean currents and the processes of interaction between the ocean and the atmosphere are of primary importance for solving problems involved in weather prediction and creation of a theory of climate.

The role of sea transport is increasing and it now accounts for 10-14% of the entire mass of transported freight. The accumulation of a considerable part of the contaminations of industrial and domestic character in the seas and oceans is bringing to the forefront the problem of preserving the ocean medium. The successful solution of the above-mentioned problems is unthinkable without a thorough and profound study of the physical, chemical and biological processes in the oceans and the seas.

The resolutions of the 25th CPSU Congress point out the necessity for "expanding complex investigations of the world ocean." Accordingly, the principal tasks of the State Committee on Hydrometeorology in the field of oceanography are:

1. Study of the hydrometeorological regime of the seas and oceans.
2. Supplying interested organizations with hydrometeorological information.
3. Monitoring the state of the ocean medium and chemical contamination regimes.
4. Prediction, including super-long-range prediction, of the hydrological conditions and ecological consequences of natural and anthropogenic influences on the sea and ocean.

A solution of these problems is possible only on the basis of work on the fundamental problems of oceanology, among which are the following:

-- study of circulation of waters of the world ocean and its variability at different time and space scales;

-- study of macroscale interaction between the atmosphere and ocean for the purpose of long-range prediction of weather and creation of a theory of climate;

-- study of the ice cover of the polar regions, its dynamics and role in climatic changes;

-- study of the hydrometeorological conditions on the shelf zone of USSR seas;

-- investigation of the ecological consequences of chemical contamination of waters of the world ocean and formulation of effective proposals and measures for prevention of their negative effects on the environment.

The enumerated problems constitute the basis of oceanological investigations of institutes of the State Committee on Hydrometeorology and Environmental Monitoring.

We will briefly discuss the results of investigations of the mentioned problems in the Tenth Five-Year Plan and the prospects of these investigations in the Eleventh Five-Year Plan.

The investigation of the problem of macroscale interaction between the atmosphere and the ocean was carried out both by the formulation of numerical models and primarily on the basis of in situ observations.

In situ investigations in the ocean during the last ten years have assumed an enormous scale. A considerable share of these investigations has been carried out by the Soviet Union, which has the largest scientific research fleet. Taking only the last five years into account, the number of voyages of scientific research ships, the number of hydrological stations occupied and the volume of collected information add up to very impressive figures. However, it is not the volume of work on this problem which attracts attention, but the qualitative changes in the strategy for carrying out expeditionary investigations of the world ocean, manifested in a tendency to study the ocean on the basis of extensive programs. For example, during recent years such large-scale interdepartmental research programs as TROPEKS-72 and TROPEKS-74, "Musson-77," MONEKS-79, PGEP-79 (FGGE-79), "POLEKS-Sever," "POLEKS-Yug," "Tayfun," POLIMODE and a number of others have been carried out or are continuing. An important point is that for the most part these programs have been directed not only to the collection of information on the ocean, but have provided for extensive study of processes in the atmosphere and interaction between the atmosphere and ocean, as a result of which there is every basis for calling them complex programs of in situ experiments.

The great attention which recently has been devoted to this type of programs is not some sort of passing phase. Multisided programs make it possible to coordinate the efforts of institutes and departments and for their implementation use major technical resources. For example, 10 scientific research ships, 2 aircraft detachments of the high-latitude "Sever" expedition, 2 aircraft laboratories and an extensive network of surface aerological stations participated in the experiment "POLEKS-Sever-76." Along these lines still greater possibilities are afforded by international programs for in-situ investigations, of which GATE was an example. It should be particularly emphasized that the basis for the mentioned programs is definite theoretical premises. This is responsible for a clearly defined direction in the collection of data with specific purposes in mind. This, in the long run, considerably increases the effectiveness of the scientific research.

Without dwelling in detail on an exposition of the results of the enumerated in situ experiments, we note that studies for investigation of heat exchange between the ocean and the atmosphere were carried out in all latitude zones of the earth from the Central Arctic and the Antarctic Ocean to the tropical regions. As a result it was possible to obtain estimates of heat flows through leads and young ice in the Central Arctic and estimates of the heat balance components in the region of the North European Basin and to the north of the polar frontal zone of the Antarctic Ocean. Valuable information on energy exchange between the ocean and the atmosphere in the tropical zone was obtained in the tropical experiment and the results of investigations under the "Musson" and MONEKS programs made it possible to draw a number of important conclusions concerning the influence of the Somali

Current on the monsoonal process, which is of great interest for solving problems relating to monsoonal circulation in this region and a more extensive region of the southern and eastern parts of Asia.

A generalization of the collected data for the purpose of ascertaining the global patterns of heat exchange between the ocean and the atmosphere is one of the highly important problems on which the institutes of the State Committee on Hydrometeorology and Environmental Monitoring are working.

In discussing the prospects for in situ investigations, there is every basis for assuming that in the future they will be carried out on the basis of this sort of program.

The problem of studying the mean circulation of the waters of the world ocean and its variability remains one of the principal problems for investigation. As already mentioned, it is closely related to the problem of interaction between the ocean and the atmosphere because heat transport by currents and heat loss from the ocean in energy-active zones are two of the most important factors involved in the forming of weather anomalies. For this reason it is necessary to discuss a program proposed by Academician G. I. Marchuk for investigations of the interaction between the ocean and atmosphere for the purpose of long-range prediction of weather and development of the theory of climate, called "Razrezy" (Profiles). Covering a wide range of problems, this program provides for carrying out a complex of in situ investigations for the purpose of detecting so-called energy-active zones of the world ocean, that is, zones of active interaction between the ocean and the atmosphere and estimates of heat transport by the main systems of currents in the Atlantic and Pacific Oceans. In addition to in situ experiments, within the framework of the program plans call for carrying out a cycle of theoretical investigations. The timeliness of the formulated problems and the wide range of the problems to be studied dictate that the realization of the "Razrezy" program is planned as a mission of the State Committee on Science and Technology and a whole series of institutes of the State Committee on Hydrometeorology, USSR Academy of Sciences and other departments will participate. It can be assumed that the "Razrezy" program will be one of the major multisided programs of the Eleventh Five-Year Plan in the field of hydrometeorology.

The implementation of a broad complex of in situ observations requires a new approach to the problems of collecting, checking and automating the processing of the collected data. Without discussing the tasks in this field in detail, we will note only what is most important. Most of the users require information on the actual state of the sea during the current period, that is, a knowledge of the areal (sometimes three-dimensional) distribution of hydrometeorological elements (temperature, level, currents, etc.). Under present-day conditions the system of observations in the seas and oceans does not allow this because the world ocean is too great. A solution of the problem can be obtained by the introduction of telemetric and satellite observation systems. A draft of such a system was developed by the State Oceanographic Institute as the coordinating organization and has been partially realized in the form of a component part of the OGSOS system. An improvement in the accuracy of observations from satellites will occur with the planned introduction of the new satellite system. A multisided plan for work on improvement of methods for the processing of satellite information and the reduction of its receipt to an operational regime has been developed by the Leningrad Division of the State Oceanographic Institute in collaboration with the State Scientific Research Center for the Study of Natural Resources. The realization of the planned programs will make it possible, at definite times, to obtain oceanological information at global scales and with the necessary discreteness and accuracy.

However, any reasonable increase in the number of observation stations and observation systems will not be able to solve the problem of obtaining oceanological information by the use of actual observations alone. Here the problem of developing four-dimensional diagnostic methods for the processing and assimilation of sea information based on hydrothermodynamic models of processes transpiring in the sea and ocean moves to the forefront. The experience in application of such an approach in meteorology gives positive results, and if it is taken into account that meteorologists have recourse to the use of this method, having at their disposal information exceeding by a factor of 1,000 times, in the opinion of specialists, the volume of oceanological information, it becomes clear how urgent and necessary is the problem of the development of diagnostic methods in oceanography.

The multisided character of the in situ experiments which have been made make it possible to obtain extensive information on the structure of circulation of waters in the investigated regions and also on the propagation and transformation of water masses. We will discuss only results which from our point of view are of fundamental importance.

In discussing the processes transpiring in the earth's polar regions it is first of all necessary to emphasize that up to the present time discussions are proceeding on the possibility of the influence of the heat of Atlantic waters on hydrometeorological conditions, including on the ice cover of the Arctic basin. The basis for such doubts is the fact that Atlantic waters are "buried" under a relatively thick layer of surface and intermediate waters having a stable stratification, which precludes the direct transfer of heat upward by convection. On the other hand, waters heated to 3°C enter into the Arctic basin and waters cooled to 0.5°C emerge from it. Nevertheless, the relative year-to-year constancy in the distribution of temperatures of Atlantic waters gave reason to speak of their "conservatism."

Oceanological observations of the "Sever" expedition, carried out annually since 1973 and entering into the complex of "POLEKS-Sever" investigations, made it possible for the first time to cast light on this problem. It was found that the variability of the heat content of Atlantic waters is very great. It is possible to discriminate two time scales of fluctuations of the heat content of Atlantic waters, to wit: long-period fluctuations having an epochal character and associated with a change in water temperature and shorter-period, interannual fluctuations caused by changes in the thickness of the layer of Atlantic waters. Similar fluctuations have also been detected in the intensity of the anticyclonic circulation of waters. According to the surveys made, the center of the anticyclonic circulation varies relatively little in space. The principal changes are related to the the intensity of this circulation, as is reflected in dynamic heights and its total area. These changes are then manifested in the interannual variability of the ice content of the marginal seas in the eastern sector of the Arctic. It is also important that the changes in the hydrological conditions of the Arctic basin are associated with atmospheric circulation, and this makes it possible to conclude that they are caused by global factors.

A joint examination of data from oceanological surveys in the Arctic basin and data obtained by scientific research ships in the North European basin leads to still another interesting result.

As early as 1898 F. Nansen determined that more than 8% of the volume of the Norwegian Sea is occupied by cold bottom waters with a temperature of -1.3°C.

Later observations, carried out in the 1950's, did not reveal bottom waters with a temperature below -1.1°C. In this connection doubt was even laid to rest concerning the reliability of the observations of F. Nansen. However, since 1970 the temperature of the bottom waters began to decrease and in 1977 fell to -1.2°C. A comparison of the temperature variation of Atlantic waters in the Arctic basin and the temperature of bottom waters in the Norwegian Sea indicated that the cooling in the Arctic, developing since the 1940's, affected not only the atmosphere, but also the deep layers of the ocean distant 500 and even 2,000 m from its surface. These were the first data in the world literature indicating that climatic changes penetrate to great depths. Since bottom waters are propagated for many thousands of kilometers, it can be postulated that the influence of the processes of warming and cooling of these waters affects the entire world ocean. A study of these processes is only beginning and for the time being it is difficult to make judgments concerning their role. But from what has been said it follows that it is important to continue investigations of Atlantic deep waters of the Arctic basin because such investigations lead to an understanding of macroscale thermal processes and provide a physical basis for ice, hydrological and meteorological predictions.

The investigations carried out in the Antarctic Ocean under the "POLEKS-Yug" experiment made it possible to ascertain the spatial structure of the Antarctic Circumpolar Current (ACC) and evaluate the principal scales of its variability. The problem of the structure and dynamics of the ACC is closely related to the problem of studying the frontal zones of the Antarctic Ocean. As indicated by recent observations, the position of the Polar Front Zone for the most part corresponds to the configuration of the main flow of the ACC, and the eddy formation processes in the frontal zone exert a substantial influence on the dynamics of the mean flow. It must be emphasized that investigation of the frontal zones of the Antarctic Ocean is of great importance in a study of the formation and propagation of water masses. The most important problems are related to the formation and propagation of antarctic intermediate waters and antarctic bottom waters, which, penetrating far beyond the limits of the Antarctic Ocean, exert an influence on the global circulation.

Proceeding to the warmer regions of the temperate and low latitudes, it is necessary to discuss the results obtained from the POLIMODE and GATE programs. The principal objective of the POLIMODE program is a study of the synoptic variability of currents in the Atlantic Ocean, and in particular, eddy formations in the ocean. The discovery of eddies in the ocean was a major event in modern oceanology. The existence of eddies considerably changes our ideas concerning processes in the ocean and brings to the forefront a number of problems new for oceanology, to the solution of which the POLIMODE program is directed.

One of the largest international expeditions of recent years was the expedition under the GATE program. Although the expedition was for the most part directed to the study of atmospheric processes, a cycle of oceanological investigations was carried out in the course of the experiment. In particular, it was possible to obtain the quantitative characteristics of the system of equatorial currents and especially such a complex phenomenon as the meandering of currents in the surface layer and at the deep horizons. A study was made of the variability of equatorial and tropical westerly currents and especially the subsurface Lomonosov Countercurrent. A study of long-wave movements in this current (waves with a length of about 3,000 km) made it possible to obtain information on the variability of the thermodynamic characteristics of tropical waters and to make an approach to solution of the problem of the formation of heat anomalies in the tropical zone of the Atlantic caused by meandering of the subsurface current in the horizontal and vertical planes and its emergence at the surface.

Investigations of the principal regions of the Pacific Ocean made it possible to obtain serious results for a complex and most dynamically active region of the ocean affected by the Kuroshio. Quantitative estimates were obtained of the variability of oceanographic fields in this region, the meandering of the main and secondary currents of the Kuroshio system, and also the thermodynamic characteristics of the principal quasiconstant meanders and circulations.

During recent years a major step has been taken in study of the tropical zone of the Pacific Ocean, and in particular, important conclusions were drawn with respect to the processes associated with the heat reserve of tropical waters and the thermal anomalies in these regions, on which, in the last analysis, the heat regime of the Kuroshio system and the hydrological conditions in the northwestern part of the ocean, one of the principal fishing regions of this ocean, are dependent.

During the Eleventh Five-Year Plan in situ investigations of water circulation in the ocean and its variability at different time scales will be continued both in connection with implementation of the "Razrezy" project and in a number of independent projects, such as "POLEKS-Sever," "Yuzhnyy okean," "Vestpak," "Tayfun" and others.

In the implementation of expeditionary studies under the mentioned projects provision is made for an investigation of the structure of circulation of waters in the energy-active zones of the world ocean and the variability of the principal ocean currents, study of the interaction between the ACC and macroscale circulations in the subtropical regions and in the regions to the south of the ACC, instrumental investigations of the eddy structure of individual regions of the ocean and obtaining of quantitative estimates of the transport of antarctic intermediate and bottom waters into adjacent regions of the world ocean.

In discussing the prospects for further fundamental investigations in the field of oceanology it is first and foremost necessary to emphasize the important role of theoretical studies directed to an investigation of the dynamics and thermal state of the waters of the world ocean. Such problems as formulation of models of general circulation of the ocean, mesoscale variability, formation of the density structure of the active layer and macroscale interaction between the ocean and the atmosphere must be developed still further, especially at the organizations and scientific research institutes of the State Committee on Hydrometeorology, since the practical aspects of these problems are usually beyond the scope of the institutes of the USSR Academy of Sciences.

In the field of practical investigations studies directed to the creation of methods for sea hydrological predictions, including ice predictions for arctic and freezing seas, are of great importance. In the past special emphasis in our country has been placed on the development of physicostatistical methods for sea predictions. Experience shows that future successes in the field of sea and ice predictions must be tied in to the development of methods based on hydrothermodynamic models of predicted processes. Some results have already been attained in this direction. Hydrodynamic methods for predicting the redistribution of ice in arctic seas, a method for predicting the growth and melting of ice, and a method for predicting the thickness and temperature of the homogeneous layer in the North Atlantic have been developed and are in use. A method for predicting wind waves on the basis of a bispectral model is in the introduction stage. Plans call for the further development and creation of methods for predicting the temperature distribution in the active layer of the ocean, predicting the temperature field in seas and bringing about further improvement in methods for predicting waves and levels on the basis of hydrodynamic models.

An important task here is the proper relationship in the development of fundamental and practical investigations at the institutes of the State Committee on Hydrometeorology and their mutual enrichment.

The following results have been attained in work on the study of sea ice covers of the polar regions and their dynamics.

I. It has been established on the basis of materials collected during the last four decades that changes in the ice cover of the Arctic Ocean occur consistently with changes in the thermal regime of the atmosphere for the hemisphere; it was found that an important role is played by the structure of the salinity field of the upper layer of the ocean in the formation, propagation and stability of the ice cover. The decisive importance of the halocline for the existence of the ice or ice-free regime of the Arctic Ocean has been established. The conclusion that the arctic ice cover is resistant to changes in external climate-forming factors has been confirmed. It was discovered that under modern conditions the principal regulator of the areas of arctic ice has been a change in the area of propagation of the halocline, organically related to freshened surface waters.

On the basis of investigations of mesoscale dynamic processes in the most variable marginal zone of the arctic sea cover it was possible to clarify the principal features of the structure of drift fields in this zone, the characteristics of deformation of the ice cover were established and the influence of different factors on the dynamics of sea ice was ascertained.

Specialists have developed a physicomathematical model of change in the state of the ice cover in arctic seas during the summer in which for the first time an allowance has been made for a number of thermal and dynamic processes exerting a substantial influence on changes in the thickness, continuity and other characteristics of the ice cover. On the basis of this model it was possible to create a numerical method for computing and predicting ice distribution in the western arctic seas.

A new direction is being developed in investigations in the field of improvement in the methodological principles for prediction work for the purpose of objectivization of the search for optimum predictors in hydrometeorological fields and development of prognostic schemes for different times in advance. The preliminary results which have been obtained have indicated a great promise of this direction for long-range ice prediction.

A method has been developed for mapping the distribution and dynamics of sea ice on the basis of television photographs of artificial earth satellites. This method includes a system of interpretation criteria making it possible to determine the principal characteristics of the ice cover and an operational graph-optical method for geographical tie-in ensuring a high accuracy in the plotting of ice boundaries and features.

In the south polar region, on the basis of materials from satellite observations, it has been possible to establish the principal spatial characteristics of distribution of the ice cover, the main position of ice masses has been clarified and preliminary results have been obtained on the seasonal and long-term variability of the ice cover in the Antarctic Ocean.

II. One of the urgent tasks in the field of further study of the ice cover is the creation of a global system for the collection, processing and dissemination of ice information. Accordingly, in the years immediately ahead there will be a changeover from visual methods for ice aerial reconnaissance to instrumental methods on the basis of the extensive use of artificial earth satellites, aircraft outfitted with side-view radar sets of the "Nit'" system, thickness gages, IR radiometers and profilometers. The collection, processing and dissemination of information will be automated within the framework of the ice information system being created at the present time.

Work will be continued on investigations of the physical laws of formation of the ice cover and the mechanisms of spatial-temporal variability of ice conditions in the oceans and seas for the purpose of predictions.

In the Antarctic Ocean region the main efforts will be concentrated on detecting the long-term tendencies and patterns of development of the ice cover and evaluating the influence of changes in the ice cover on the dynamics of climate in the south polar region.

Among the most important scientific and technical problems of the present day are the problems of investigating the ecological consequences of chemical contaminations of waters of the world ocean (including oceans, seas and estuaries) and the development of scientifically sound proposals and measures for prevention of their negative effects on the earth's ecology.

Ten years of investigations by the leading oceanographic institutes of our country have made it possible to draw a number of important conclusions on this problem, to wit:
-- the propagation of a number of contaminating substances (especially petroleum and organochlorine hydrocarbons) with exceeding of the maximum admissible concentrations has a global character;
-- the concentration of these substances in the surface microlayer considerably changes the physicochemical properties of the water at the surface of the seas and oceans (surface tension, viscosity, chemical composition, heat capacity, selective absorption of short-wave radiation, etc.);
-- the petroleum film in the seas and on the shelf zones extends over an area occupying about 10% of the area of the world ocean.

The prediction of the dynamics of levels of water contamination in the North Atlantic and the northern part of the Pacific Ocean, prepared at the State Oceanographic Institute, indicates that by 1990 the mean concentrations of petroleum hydrocarbons will increase by a factor of 2-2.5 and the area of coverage of the ocean surface will increase up to 20%.

According to the experimental computations of the Main Geophysical Observatory and the State Oceanographic Institute, at the present time and in the future the penetration of photosynthetically active radiation in the ocean will be lessened by 10-40% over the area of the Atlantic, being 10 and 20% of its entire area respectively.

According to investigations of the All-Union Scientific Research Institute of Fishing and Oceanography, in the case of low concentrations of petroleum products and pesticides the rate of photosynthesis of sea algae is reduced on the average by 25%. In the 1960's-1970's in the North Atlantic there was an intensifying decrease in the number of species of phytoplankton and a decrease in the biomass of zooplankton forms. Among the factors aggravating the negative effect of petroleum is the large-scale superposing of the fields of maximum contamination on areas of maximum biomass and productivity in the world ocean.

According to investigations of the Main Geophysical Observatory, carried out using a three-level model of atmospheric circulation and on the assumption that about 25% of the area of the North Atlantic is covered by films, it was established that there is a significant (up to 20-25%) decrease in evaporation from the ocean surface and this in turn leads to a maximum decrease in zonal precipitation in the latitude zone 30-50°N by 0.6-0.8 mm per day and to an increase in aridity in North Africa.

The investigations of the contamination of waters in the world ocean carried out during the Tenth Five-Year Plan bring to the forefront problems which are related to an evaluation of the influence of chemical contaminations on the ecosystems of the most productive regions of the world ocean (shelf and frontal zones, marginal and epicontinental seas, circumpolar zone, estuaries), formulating a prediction of the dynamics of the level of contamination and its influence on the ecosystem and determination of the maximum admissible discharges through the principal channels for the entry of contaminating substances into the sea. Also of great importance is an evaluation of the consequences of chemical contaminations of the world ocean on the energy-, heat-, gas- and moisture exchange of the ocean with with the atmosphere, the prediction of these consequences and their influence on the earth's climate, including the development of measures for preventing the chemical contamination of the surface and the active layer of the oceans and seas.

An urgent practical problem closely related to the problem of study of contamination of the seas and oceans, brought to the forefront by the modern level of the economy and industry in the well-developed countries, is the problem of monitoring of the disposal of wastes and other materials in the sea. The basis for the disposal of wastes in the seas and oceans is the great oxidizing capacity of the waters of the world ocean, making it possible to rework a considerable volume of organic and also inorganic substances. However, the localization of wastes in individual water bodies has the result that these basins are saturated with contaminants, the destruction processes do not affect the entire mass of wastes and the quality of sea water here deteriorates sharply.

During the Tenth Five-Year Plan investigations of hydrometeorological conditions on the shelf zone of the world ocean and national seas were made and in these investigations descriptions of hydrometeorological conditions in the shelf zone were prepared. A new approach was developed for study of the dynamic characteristics of the hydrological regime of seas, the basis for which is computation of waves, currents, level and ice drift on the basis of data on the wind field regime over the sea. This will make it possible to obtain the spatial characteristics of the hydrometeorological regime of sea areas, including those for which there are few or no observations.

In the field of study of the shelf in the coming five-year plan it is proposed that multisided hydrometeorological investigations be made of the seas of the USSR, their shelf zone and the mouths of rivers for the purpose of exploitation of resources and preservation of the sea. The essence of the investigations is a systematic generalization of the totality of present-day knowledge of the hydrometeorology of the seas, processes and phenomena in their interrelationship and interaction, a study of the patterns of formation of the fields of oceanographic elements and their variability with time, an improvement in the existing physical and mathematical models and the formulation of new models, making it possible to fill the gap in our knowledge concerning the regime of seas and formulate scientific principles for control of the regime of the seas for lessening or eliminating the negative consequences of anthropogenic effects on the sea. The plan calls for the implementation of special additional investigations of an experimental and theoretical character on the basis of available in situ experimental data and theoretical research, as well as the preparation of a monographic generalization of the hydrometeorology of most of the seas in the Soviet Union.

In examining the prospects for oceanological investigations, it is impossible not to mention some practical problems which in their national economic importance at the present time have become especially important. In particular, this applies to the problem of the influence of a deficit of continental fresh-water runoff into the seas and oceans. Recently there was a change in the entry of river waters into the seas and oceans both as a result of natural factors and as a result of man's economic activity. During the last 10 years 3,000 km^3 of fresh water have been withdrawn without return, and in the future this quantity will increase still more. As a result of the decrease in the level of the Caspian Sea alone there will be a loss of about 1,000 km^3, which will exceed the present-day losses by a factor of two, whereas at the beginning of the century they were only 400 km^3. The intensive change in the entry of fresh water into the seas and oceans will exert a substantial influence on the regime of the world ocean, especially in its coastal regions and seas, which in turn exerts a negative effect on the biological productivity of these regions. These processes transpire most intensively in the connecting link of fresh sources (rivers) and seas -- in the mouth regions of rivers where the interrelationship between the plant and animal worlds and their habitat changes tens and hundreds of times more rapidly than in other regions of the earth's land and water media.

The above-mentioned complex of scientific problems quite fully demonstrates how many difficult and at the same time important problems are facing oceanographers, who must combine all their efforts and clearly coordinate the plans for their further scientific investigations in order to carry out tasks of great importance -- the most complete possible study of the world ocean for creating the scientific principles for the use of its resources for the well-being of the Soviet people.

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PRINCIPAL RESULTS AND PROSPECTS FOR THE DEVELOPMENT OF INVESTIGATIONS IN THE FIELD OF HYDROLOGY IN RELATION TO THE PROBLEMS OF SHIFTING OF PART OF THE RUNOFF OF NORTHERN RIVERS TO THE SOUTH*

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[Article by A. A. Sokolov, professor, State Hydrological Institute]

[Text]

Abstract: The author briefly examines the principal results of hydrological investigations in the Tenth Five-Year Plan and the tasks of hydrology in the light of the Principal Directions in Economic and Social Development of the USSR during the Period 1981-1985 and for the Period Ending in 1990.

In connection with the increase in the role of the water factor in economic and social development, investigations in the field of hydrology of the land during recent years have considerably expanded and have acquired a particularly great timeliness. They have been directed to solution of the problems formulated by the Party and the government for the rational use and conservation of water resources. The State Hydrological Institute has about 20 scientific subdivisions, two major experimental bases (the Valday Scientific-Research Hydrological Laboratory and the Main Experimental Base of the State Hydrological Institute), a computation center and experimental-production workshops. Each year it organizes a number of major expeditions in the Far East, in Western Siberia, in the Trans-Volga region and in other regions of the USSR.

The principal scientific and practical problems on whose solution the State Hydrological Institute has worked during the Tenth Five-Year Plan, are:

-- formulation of the principles and scientific-methodological basis for a national system for observations of the regime, balance and quality of surface waters;
-- study of the water resources and water balance of river basins, economic regions of the territory of the USSR, continents and earth;

* Main content of a report at an expanded session of the Presidium of the Scientific and Technical Council, State Committee on Hydrometeorology and Environmental Monitoring, 13 October 1980.

-- formulation of methods for evaluating anthropogenic changes in the regime, balance and quality of waters and prediction of these changes over the long run, taking into account the growth of population and the development of the national economy;
-- hydrological support of the planned measures for the interzonal redistribution of river runoff;
-- study of hydrological phenomena and processes and development of methods for computing the elements of the hydrological regime for planning and construction;
-- investigation of sediments, channel processes and formulation of methods for computing and predicting channel deformations and water erosion in the planning of antierosion measures, water intakes, petroleum and gas lines across rivers and other engineering structures;
-- improvement in hydrological predictions for the support of water management and other branches of the national economy;
-- hydrological support for the largest national economic measures, construction projects and territorial-industrial complexes.

We will briefly discuss the principal results and prospects for investigations of the mentioned problems.

Problems in the Development and Improvement of the Hydrological Network

The network of points for hydrological observations is the basis for the development of hydrological science and filling the needs of the national economy. Accordingly, the State Hydrological Institute has devoted and is devoting great attention to the problem of its development and improvement.

During recent years the State Hydrological Institute has revised at a modern level and has republished regulations, instructions and manuals on observations in the hydrological network which will ensure unity and comparability of measurements.

At the present time, in connection with the aggravation of the water problem, there is an on-going transformation of the entire system for registry, integration and processing of hydrological data. A unified system for a national inventory of waters and their use in the national economy is being created. This system is intended to bring together, on a unified scientific-methodological basis, the network of observations of the State Committee on Hydrometeorology, the USSR Geology Ministry and the USSR Water Management Ministry, taking in the regime and quality of all types of waters: rivers, lakes, glaciers, ground waters and seas, taking into account the use of waters in the national economy.

The unified system for the inventory of waters, as indicated by the experience of its introduction, makes possible a considerable increase in the level of hydrological support of the needs of the national economy. At a new level it makes it possible to solve one of the most complex problems -- restoration of the natural regime of runoff and determination of non-return losses in regions with intensive economic activity.

In connection with the introduction of a unified system for the inventory of waters, the methodological and instrument-apparatus complex of network observations is experiencing radical changes. Its improvement is directed to an increase in the reliability of hydrological information, an acceleration of measurements and the introduction of new measurement techniques (ultrasound, radar, aerospace methods). With allowance for modern water management problems the State Hydrological Institute has formulated principles for optimizing systems for hydrological observations, the makeup, frequency and accuracy of measurements.

On this basis the State Hydrological Institute, in collaboration with the administrations of the Hydrometeorological Service, has prepared a plan, being implemented at the present time, for the rationalization, development and technical outfitting of the hydrological network in 1975-1980. This plan provides for measures for eliminating some lag, observed in recent decades, in the quantitative growth and qualitative condition of hydrological posts, behind the rates of development of the country's water economy, especially in its Asiatic part -- in the Far East, in Western and Eastern Siberia.

The network will include about 8,000 river posts of which 3,500 will be control (key) posts; there will be an increase in the percentage of "informational" posts (up to 60%), especially in the basins of large reservoirs. During the years of the Tenth Five-Year Plan the increase will be more than 900 posts.

During recent years there has been a considerable increase in the role of the State Hydrological Institute and zonal scientific research institutes in the organizational and methodological direction of the network. It can be stated with satisfaction that multisided inspections have acquired regularity and effectiveness.

In connection with the noted plans for the interzonal redistribution of river runoff the State Hydrological Institute has been formulating methodological principles and proposals for creating an observation system ensuring the collection of the most reliable information for the planning and refinement of prediction of changes in the regime, balance and quality of waters in the regions of withdrawal, transport and use of the shifted runoff.

In discussing the problems related to the hydrological network it is impossible not to note that the technical outfitting of the network and the level of hydrological instrument making still do not correspond to modern requirements. The State Committee on Hydrometeorology adopted a resolution on the creation (jointly with the Instrument Making Ministry) of assembled complexes of hydrometeorological instruments. The implementation of this resolution will be of the greatest importance for the development of hydrological science.

Water Resources, Water Balance and Water Inventory

In connection with the increase in water consumption, the development and implementation of measures for the rational use and conservation of water resources, the State Hydrological Institute, in collaboration with the administrations of the Hydrometeorological Service, has carried out a careful inventorying of the secular reserves and renewable resources of fresh waters. Methods have been developed for computing all the components of the hydrological cycle: precipitation, runoff, evaporation, changes in the reserves of ground and soil water. As a result of these investigations it has been possible to estimate the water balance, water resources and water supply of the country as a whole, union republics, individual regions, river and sea basins. These data served as the basis for long-range plans for the multisided use of water resources in the USSR.

The basis for the planning of the use of water resources is the materials from the State Water Inventory (SWI), constituting a systematized summary of information on USSR water resources. The multivolume edition of the inventory, being the principal source of data on the water resources of the USSR, will consist of three series: 1) information on the extent of hydrological study of territories, 2) principal hydrological characteristics (PHC), 3) regional reference manuals on the resources of surface waters.

The second series is the most important inventory series for the national economy. It will be systematically supplemented with new data, which will make it possible to maintain information on water resources at a modern level.

The systematizing of data on water resources and the compilation of a water inventory manually, as indicated by experience, would require enormous efforts and together with publication would require 10-15 years. During this time the data included in the inventory would become out-of-date.

In this connection the State Committee on Hydrometeorology, the USSR Geology Ministry and the USSR Water Management Ministry have been assigned the task of creating an automated system for the State Water Inventory taking in all types of waters and data on the use of water resources in all branches of the national economy.

The technical specifications for an automated data system for the State Water Inventory have now been developed, work is being done on creating a data bank. The generalization of these data using an electronic computer will make it possible to provide an operational modern evaluation of the state of water resources and the water balance of the country.

The State Hydrological Institute, in collaboration with the All-Union Scientific Research Institute of Hydrometeorological Information-World Data Center and the scientific organizations of the USSR Geology Ministry and the USSR Water Management Ministry, has done much work on determining the makeup and format of inventory publications. Methodological recommendations have been drawn up and introduced on the preparation of annual data on the resources of surface and ground water and on their use.

In the Eleventh Five-Year Plan the automated system for the SWI should be completely introduced into operation. On its basis the State Hydrological Institute, the All-Union Scientific Research Institute of Hydrology and Engineering Geology and the Central Scientific Research Institute for the Multisided Study of Water Resources during the Eleventh Five-Year Plan are planning to prepare a new edition of the USSR Water Inventory in which there will be a generalization of data on surface and ground water resources and an analysis of the present-day water balance for individual regions, river basins and the country as a whole.

A major attainment is the work carried out by the State Hydrological Institute in collaboration with the Main Geophysical Observatory, Arctic and Antarctic Scientific Research Institute, Institute of Water Resources and Geological Institute, USSR Academy of Sciences on study of the global hydrological cycle at the scale of the entire earth. The results of these investigations have been published in the monograph MIROVOY VODNYY BALANS I VODNOGO BALANS I VODNYYE RESURSY ZEMLI (World Water Balance and Water Resources of the Earth) and the ATLAS MIROVOGO VODNOGO BALANSA (Atlas of the World Water Balance). These fundamental studies have been presented as a contribution of Soviet scientists to the program for the International Hydrological Decade.

The monograph and atlas give a generalization of the results of Soviet and foreign investigations of the moisture cycle and water balance of the earth. New data are given on the water reserves on the earth, their distribution over areas, periods of natural renewal of individual types of natural waters; there are also computations of the water balance of major river basins, natural water bodies, reservoirs, regions and continents, the world ocean and the entire earth's surface. Taking into account the great interest in these published studies, by a resolution of UNESCO they have been published in the English and Spanish languages.

In the Eleventh Five-Year Plan provision is made for the development of investigations of the world water balance, bearing in mind the evaluation of natural and anthropogenic changes in total moistening at different space and time scales for the water regime of rivers, lakes, ground water, glaciers, continents, the world ocean and the earth as a whole.

Anthropogenic Changes of Water Resources

The problem of quantitative and qualitative changes in the water regime and water balance during recent years has become especially acute as a result of the ever-increasing effect exerted on hydrological processes by anthropogenic factors and the appearance of a threat of quantitative and qualitative exhaustion of water resources.

Investigations of this complex problem are being made on a broad front by many scientific institutes of the State Committee on Hydrometeorology, USSR Academy of Sciences, USSR Water Management Ministry, USSR Geology Ministry and other ministries and departments under the unified plan of the State Committee on Science and Technology.

As a result of these investigations conclusions were drawn having great scientific and practical importance for the planning, rational use and conservation of water resources, for solving problems relating to internal seas, validation of the volumes, times and regime for shifting part of the runoff of northern rivers to the south.

For the first time on a unified methodological basis, with the broad use of materials from long-term hydrometeorological observations, an evaluation was made of the changes in the annual runoff of the principal rivers of the USSR, inflow into internal seas and the total river runoff of individual regions in the country as a whole under the influence of economic activity during the period from 1936 through 2000.

The most intensive change in the runoff of the southern rivers of the country, as indicated by investigations, began from 1955-1960 (Fig. 1). By 1975 the mean annual runoff at the mouths of the Dnepr, Don, Kuban', Dnestr, Ural, Ili, Syrdar'ya, Amudar'ya, Terek and Sulak had decreased in comparison with the natural period by 17-30%. A still more significant decrease in the runoff of the southern rivers of the USSR must be anticipated over a long period. Already by 1985 the annual runoff of many rivers, for the most part as a result of irrigation in basins, will decrease by 30-50%, and by 2000 -- by 40-80%.

As a result of the investigations it was possible to determine not only the total decrease in runoff, but also to ascertain the role of individual anthropogenic factors (irrigation, drainage, urbanization, etc.) in this process (Fig. 2).

The fundamentally new conclusions drawn with respect to possible changes in river runoff under the influence of anthropogenic factors in extremal cases, in years with exceptionally little and abundant water, are of great scientific and practical importance. In particular, it was established that for most of the river basins in years with a very small water volume the absolute decrease in runoff under the influence of economic activity will be considerably greater than in average years and especially in years with an abundance of water and sufficiently moistened years.

KEY:

1) Volga
2) Don
3) Ural
4) Dnestr
5) Dnestr
6) Kura
7) Terek + Sulak
8) Ob'
9) Syrdar'ya
10) Kuban'
11) Amudar'ya
12) Ili
13) Yenisey
14) Amur
15) Severnaya Dvina
16) Pechora
17) Neva
18) Zapadnaya Dvina
19) Lena

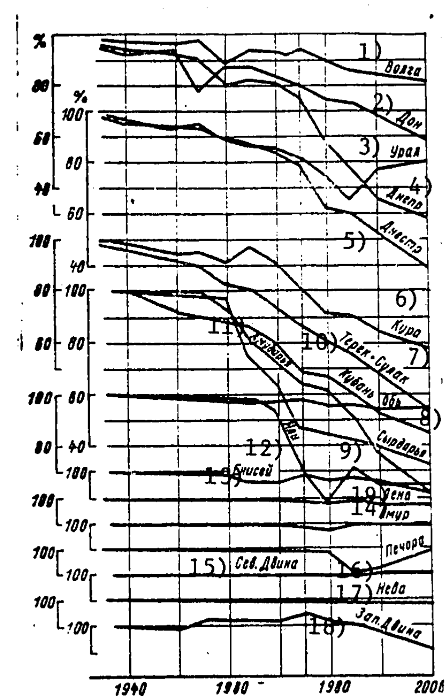

Fig. 1. Change in the mean annual runoff of rivers of the USSR under the influence of economic activity during 1936-2000. For the Kura, Terek and Sulak, Syrdar'ya, Amudar'ya and Ili Rivers the normal runoff at the mouth was assigned the value 100% for a conventional natural period; for others -- the natural water resources of the basin were assigned this value.

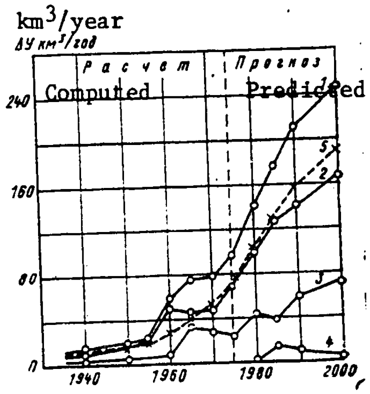

Fig. 2. Dynamics of changes in river runoff in the USSR under the influence of economic activity. 1) decrease in total river runoff in USSR, including: 2) for rivers of the southern regions of the USSR, 3) for the rivers of Siberia and the Far East, 4) for the rivers of the northern slope of the European USSR, 5) decrease in river runoff in the USSR due to nonreturn water losses in basins (without accumulation in reservoirs).

If the total river runoff of the USSR as a whole is considered, its decrease under the influence of economic activity is small and in 1940 was 14 km^3/year or 0.3%; by 1975 it had attained 92 km^3/year (2.2%), and without allowance for the accumulation of water in reservoirs -- 72 km^3/year. By 1985 it is expected that there will be a decrease by 170-175 km^3/year ($\approx$ 4%), and by 2000 -- by 240-250 km^3/year ($\approx$ 5.5%); without allowance for accumulation in reservoirs these values are about 130 and 190 km^3/year respectively.

The principal decrease in runoff will occur in the rivers of the basins of the Black Sea, Sea of Azov, Caspian Sea, Aral Sea and Lake Balkhash, where already by 1975 there had been a decrease in runoff on the average by 13%, but a still more significant decrease is anticipated in the future: by 1985 -- on the average by 23%, and by 2000 -- by 31%. At the present time the rivers of the southern regions with natural resources of river runoff estimated at approximately 540 km^3/year, or 12% of the total river runoff of the USSR, account for 78% of the total decrease in river runoff in the country under the influence of economic activity.

An analysis of the role of individual anthropogenic factors in the change of river runoff in the USSR during the considered period indicated that beginning with the modern period and in the future irrigation will become the principal factor in economic activity, favoring the greatest decrease in annual river runoff.

The conclusions drawn as a result of the investigations of the State Hydrological Institute were sent to planning organizations and were used in preparing a scientific and technical prediction of the multisided use and conservation of water resources in the USSR during the period up to 1990.

At the present time investigations of the influence of anthropogenic factors on river runoff are continuing in the direction of a refinement of predictions of changes in the regime, balance and quality of waters.

The following is proposed for the immediate future:
-- improvement in methods for evaluating the influence of economic activity on the hydrological regime, including the use for these purposes of mathematical models of the formation of river runoff in watersheds;
-- preparation of recommendations on the restoration of natural river runoff and allowance for the influence of individual types of economic activity on the elements of the hydrological regime of rivers under different physiographic conditions;
-- in the example of a large river drainage basin with the intensive use of water resources (of the Volga River type) formulate a simulated mathematical model of the formation and use of runoff for a quantitative evaluation and prediction of the influence exerted on the hydrological regime by the most diversified combination of natural and anthropogenic factors operative in the drainage basin.

The solution of these problems will make possible the effective and scientifically sound implementation of the functions assigned to the State Committee on Hydrometeorology with respect to the monitoring of natural water bodies which are in intensive economic use.

Hydrometeorological Validation of Interzonal Redistribution of Water Resources

The interzonal redistribution of water resources with respect to its scales, national economic importance and influence on the environment is among the most important scientific and technical problems of the day. The necessity for carrying out such work is dictated by objective factors: the extremely nonuniform natural distribution of water resources over the territory of the country, the acute shortage of water resources in the economically most developed part of the country and the need for fresh water in internal water bodies, especially the Caspian Sea, Sea of Azov and the Aral Sea, for maintaining their biological productivity.

There are many proposals, schemes and variants of interzonal redistribution of water resources, among which the best developed in planning respects are variants of shifting of part of the runoff of the northern rivers of the European part to the south and from the Ob' River from Belogor'ye village through the main canal for the shifting of runoff to Kazakhstan and Central Asia.

The planned volume of the first stage in the shifting of part of the runoff of the northern rivers of the European USSR into the Volga basin in different schemes is from 23 to 37 km^3/year and for Siberian rivers -- 25 km^3/year with a subsequent increase to 60 km^3/year.

As a result of the investigations carried out by the institutes of the State Committee on Hydrometeorology, the following data have been obtained:
-- for the northern rivers of the European USSR and Siberian rivers, from whose basins plans call for the removal of runoff (Neva, Onega, Sukhona, Severnaya Dvina, Pechora, Ob', Irtysh), preliminary quantitative estimates of the changes in annual, seasonal and intraannual distribution of runoff, maximum water discharges and levels, floodplain inundation processes, backwater phenomena, water temperature, heat flow, freezing and breaking-up processes, chemical composition of water for different posts along the lengths of rivers below the intended water intakes;

-- for the lakes of the northwestern USSR affected by any future shiftings of runoff (Lakes Ladoga, Onega, Kubenskoye, Lacha and Vozhe), estimates in changes in the water balance, level regime, systems of currents and water quality;
-- for the territory of Western Siberia, estimates of possible changes in the structure and water-heat regime of swamp landscapes;
-- for the mouth reaches and seas of the arctic zone, computation methods and models for evaluating changes in the water and channel regimes of multiarm deltas, the dynamics of waters and contaminations, thermal regime of mouth embayments; preliminary predictions of the future regimes of the mouth region of the Ob' River, Kara and Pechora Seas;
-- for the main Irtysh-Central Asia channel for the shifting of waters, estimates of the lateral inflow of water and sediments, computation of water losses on evaporation from the water surface, preliminary data on channel processes, the balance and regime of sediments, and also ice processes; approximate (with different assumptions) predictions of water quality in the channel and data on the influence of the channel on adjacent water bodies;
-- for regions to which the water is to be shifted, estimates of the possible changes in the quality of water in the basins of the Volga, Kama, Amudar'ya and Syrdar'ya, the hydrological regime at the mouths of southern rivers, total inflow, level regime and salinity of internal seas in connection with the development of economic activity in their basins and possible shiftings of runoff;
-- preliminary estimates of changes in the meteorological regime and heat balance of the underlying surface, moisture cycle in the atmosphere and climatic conditions accompanying the shifting of part of the runoff of northern and Siberian rivers.

The results which have been obtained make it possible to draw a general, basic conclusion on the considered problem: the implementation of the first stage in shifting part of the runoff of northern and Siberian rivers will not result in global changes in hydrometeorological conditions; however, the planned measures may exert a substantial influence on the water regime and microclimate of regions of redistribution of water resources, but this influence will have a local character.

The results of investigations and evaluation of changes in hydrometeorological conditions under the influence of the interzonal redistribution of river runoff have been published in the monograph MEZHZONAL'NOYE PERERASPREDELENIYE RECHNOGO STOKA (Interzonal Redistribution of River Runoff), in a collection of reports presented at the Seventh Congress of the USSR Geographical Society and in the Transactions of the State Hydrological Institute, Arctic and Antarctic Scientific Research Institute, Main Geophysical Observatory and State Hydrochemical Institute.

A promising variant of the shifting of the runoff of northern rivers, making possible the most complete solution of the problem of control of the regimes of the Caspian Sea and the Sea of Azov, is the shifting of the waters of the Onega River with the construction of a reservoir for long-term regulation in Onega Bay. However, a more detailed scientific validation of this variant is required.

The first and foremost task in further investigations is a refinement of the preliminary conclusions drawn concerning all the considered and additional hydrometeorological characteristics applicable to different variants of the first and second stages of redistribution of water resources on the basis of:

-- implementation of multisided expeditionary investigations in regions affected by the shifting of runoff;
-- formulation of simulated mathematical models of the functioning of systems for the shifting of such waters, making it possible to take into account all possible combinations of meteorological conditions, water volume and economic use of waters (including models of the mouth reaches of rivers and basins of internal seas).

Study of Hydrological Phenomena and Processes and Improvement in Methods for Engineering Computations

Engineering-hydrological computations, that is, determination of so-called computed hydrological characteristics, lying at the basis of projects for different kinds of engineering structures, are one of the principal fields of practical application of hydrological science.

For the development and improvement of computation methods the State Hydrological Institute has carried out investigations of the patterns of formation of runoff and other regime elements on the basis of an analysis and generalization of data from long-term network observations. For a more profound understanding of the mechanism of hydrological phenomena and processes there have been extensive experimental field investigations at the Valday Scientific Research Hydrological Laboratory, zonal water balance stations and laboratory investigations at the Main Experimental Base of the State Hydrological Institute. These investigations made possible a considerable development of the theoretical basis of runoff formation processes, clarification of the role of different factors and formulation of physicostatistical computation schemes.

A highly important achievement of the State Hydrological Institute was the work done in the 1960's and 1970's on analysis of the methods employed in practical engineering for determining the so-called computed hydrological characteristics and the preparation of an all-union norm-setting document on hydrological computations (SN-435-72). This norm-setting document, for the first time in our country and abroad, on a unified scientific-methodological basis regulates the determination of the following computed characteristics: annual runoff and its long-term fluctuations; distribution of runoff within the year; maximum runoff of spring high water and rain-induced high water; minimum runoff; highest water levels.

The use of the SN-435-72 in the national economy gave a high economic effect. In the designing of highways, roads and cities alone this saving was about 20 million rubles.

In 1980 the State Hydrological Institute, with the participation of other scientific and planning organizations, is preparing a second edition of this norm-setting document on the basis of a generalization of the experience of its use in engineering practice in the course of the last eight years.

In addition to the national norms for determining the computed characteristics of the hydrological regime, the State Hydrological Institute has prepared a number of interdepartmental norms and has introduced them into practical work:
-- for computing evaporation from a water surface and from a land surface;
-- for computing the silting of reservoirs;

-- for hydrological validation of antierosion measures;
-- for computing channel deformations in designing river crossings for petroleum and gas lines;
-- for designing dispersal outlets for waste waters, for dilution, mixing and self-purification, etc.

In the Eleventh Five-Year Plan it is proposed that there be further improvement in engineering computation methods and an increase in their accuracy. The planned research, providing for an improvement in the mathematical model for the formation of meltwater and rain runoff, will make it possible to take a new step on the path of increasing the accuracy and reliability of engineering computations.

Plans also call for preparing a norm-setting document for taking into account the influence of economic activity in the designing of engineering structures and territorial-industrial complexes. The introduction of this norm-setting document for the first time will make it possible to take into account the change in the water regime under the influence of economic activity not after, but prior to the implementation of different water management measures.

Development of the Theory of River Sediments and Channel Processes and its Use in the Solution of Practical Problems

The study of channel processes occupies one of the important places in the activity of the State Hydrological Institute. The hydromorphological theory of the channel process developed at the State Hydrological Institute and its practical application for solution of many engineering problems has put the State Hydrological Institute into the ranks of the leading scientific institutes in this field in our country.

The stimulus for the development of a theory of sediments and channel processes was the large-scale construction of water intakes, underwater gas and petroleum lines, crossings of power transmission lines, bridge supports, dikes, navigation and irrigation canals.

For the first time in engineering practice, at the State Hydrological Institute, on the basis of the hydromorphological theory of the channel process, recommendations have been formulated and put into practice for evaluating the channel process in construction planning, in particular, in the planning of crossings for pipelines and power transmission lines, outlets dispersing waste waters, etc.

In discussing the development of the theory of channel processes in the works of scientists at the State Hydrological Institute and their use for the solution of practical problems it is impossible not to note the fundamental studies relating to the poorly developed fields of prediction of the forming of shores of reservoirs and channel processes in the interbasin shifting of river runoff.

During recent years specialists at the State Hydrological Institute have generalized long-term investigations of river sediments, this being finalized in the creating of the concept of a multisided science, taking in the theory and method for computing the transport of sediments and geographical generalization of the parameters of sediment runoff. The results of these investigations, published in a two-volume monograph, have been given a high evaluation by the State Committee on Hydrometeorology (Glushkov-Uryvayev Prize).

Improvement of Methods for Hydrological Predictions

In connection with the development of the water economy and the construction of the stages of gigantic reservoirs the role and importance of routine hydrological predictions are constantly increasing.

The investigations of the USSR Hydrometeorological Center and the State Hydrological Institute during the Tenth Five-Year Plan were directed to:
-- development of methods for long-range predictions of the seasonal inflow of water into major reservoirs on the rivers of the country and the runoff of unregulated rivers in zones where these predictions are of great importance for the servicing of the national economy;
-- development of methods for short-range predictions of discharges and levels in rivers during a period of high water and rain-induced floods;
-- study of the processes of formation of surface runoff and development of mathematical models as a basis for the further development of methods for long- and short-range predictions.

Important results of studies in the first direction were:
-- development of methods for long-range predictions of the seasonal inflow of water and its distribution in time to the reservoirs on the Volga, Kama, Don and Dnepr (USSR Hydrometeorological Center, State Hydrological Institute, Ukrainian Scientific Research Institute), seasonal inflow into the Vilyuyskoye Reservoir and in the future the reservoir for the Ragunskaya Hydroelectric Power Station on the Vakhsh River (USSR Hydrometeorological Center);
-- development of a method for predicting spring runoff and the maximum discharges of high water in the Pechora basin -- in the zone of the future shifting of waters (USSR Hydrometeorological Center).

In the field of short-range predictions of water discharges and levels the studies which were most important in practical results were the methods, approved by the Central Methodological Commission, for short-range predictions of water inflow into Volga reservoirs during the period of high water and the meltwater runoff of mountain rivers, based on the realization of mathematical models (USSR Hydrometeorological Center). An important contribution was the work of the State Hydrological Institute on the improvement of methods for short-range predictions on the basis of allowance for the water reserves in the channel network.

Among the investigations in the third direction we should note studies for creating methods for computing heat and moisture transfer in the frozen soil and the indices of water absorptivity of basins, also approved by the Central Methodological Commission (State Hydrological Institute, USSR Hydrometeorological Center). The results of these investigations made possible a substantial refinement of the presently used methods for computing the losses of meltwater during the period of spring high water.

As before, the most important practical problems in the field of hydrological predictions during the immediate future (5-10 years) remain the development and improvement of methods for predicting water inflow into reservoirs for different times in advance.

In order to achieve the further development of investigations in the field of hydrological predictions it is necessary to carry out a number of auxiliary studies. The following, in particular, can be mentioned:
-- during 1981-1982 development of a long-range plan for expanding the observation network and methods for computing and predicting the inflow of water to the projected major reservoirs of the USSR;
-- creation, in the example of the Volga and Ob' basins, of hydrometeorological data banks on technical carriers, necessary for carrying out investigations and developing methods for hydrological predictions;
-- improvement of methods for computing the actual inflow of water into major reservoirs during different time intervals (day, ten-day period, month, season) for the purpose of subsequent publication of these data in the publications of the SWI and storage on technical carriers.

In the field of fundamental investigations a task of hydrological predictions in the immediate future is the further development of unified models of the formation of melt and rain water and investigations of individual processes associated with this, especially the absorption and retention of melt and rain water in river basins.

At the present time a sort of transitional process is taking place in the field of hydrological predictions: traditional methods have virtually reached the limit of their capabilities, but mathematical modeling methods, deemed to alter the situation in a better direction, remain unrealized. It is becoming increasingly evident that the methods and capabilities of hydrological predictions must be closely tied in to the principles of the overall strategy for the use of water resources and their control.

Among the problems in the sphere of meteorological predictions on which the development of hydrological predictions is dependent, the following should be among the first to be solved:
-- quantitative prediction of rain precipitation;
-- prediction of temperature and precipitation during the period of formation of the spring high water.

Hydrological Validation of the Most Important National Economic Measures

In addition to theoretical and experimental investigations of hydrological phenomena and processes, during the Tenth Five-Year Plan much work was carried out which was directly related to the hydrological validation of the most important measures of the Party and government on the development of the national economy.

In connection with the planned broad development of irrigated agriculture and melioration of lands in the nonchernozem zone, at the State Hydrological Institute over the course of the last 15 years investigations have been carried out which are of great importance for increasing the yield of lands which can be improved. At the State Hydrological Institute extensive investigations have been made of the water and heat balances of irrigable lands in Rostovskaya Oblast, in the Northern Caucasus, in Kazakhstan, in Central Asia and in the Trans-Volga region.

As a result of 15 years of investigations, specialists at the State Hydrological Institute have developed and are successfully introducing into the practice of irrigated agriculture a new hydrometeorological method for ascertaining the shortage of water supply for agricultural crops, relying on a detailed allowance for all the components of the water and heat balances in an agricultural field. The experimental introduction of this method in the Trans-Volga region over a period of years revealed its high effectiveness (yield increment by 5-15% or more). An important characteristic of this method is the possibility for a scientific validation not only of the irrigation norms and regime, but also the norms for non-return water losses and the norms for water returned to the channel.

The results of long-term investigations for the hydrological validation of meliorative measures in the arid zone have been published in the monograph GIDROLOGIYA OROSHAYEMYKH ZEMEL' (Hydrology of Irrigated Lands) (Glushkov-Uryvayev Prize). At the present time the method for determining irrigation norms and regimes developed at the State Hydrological Institute is being successfully introduced into the automated control systems of water management systems in the Trans-Volga region.

The discovery of new deposits of petroleum and gas in the Ob' basin and in the subpolar regions during recent years has laid the basis for intensive economic exploitation of the northern part of the West Siberian Lowland. In this connection, during the last 15 years specialists at the State Hydrological Institute, under an agreement with Giprotyumen'neftegaz, have carried out multisided expeditionary investigations of swamps and swampy lands. Their main task has been obtaining initial data and characteristics of the water regime necessary for the development of engineering measures related to the drainage and exploitation of lands where petroleum and gas are being produced (Samotlorskoye, Shaimskoye, Fedorovskoye, Var'yegonskoye, Kholmogorskoye, Povkhovskoye, Komsomol'skoye, Urengoyskoye and other deposits).

The results of these investigations have been published in the monograph BOLOTA ZAPADNOY SIBIRI, IKH STROYENIYE I GIDROLOGICHESKIY REZHIM (Swamps of Western Siberia, Their Structure and Hydrological Regime). The TIPOLOGICHESKAYA KARTA BOLOT ZAPADNO-SIBIRSKOY RAVNINY (Classification Map of Swamps on the West Siberian Plain) was compiled and published.

Investigations in Western Siberia will also be continued during the Eleventh Five-Year Plan.

The construction of the Baykal-Amur Railroad and the economic exploitation of adjacent territories has brought to the forefront a whole series of problems related to the almost complete lack of study of the hydrometeorological regime of this extensive territory. In this connection, in accordance with the instructions of the State Committee on Hydrometeorology, the State Hydrological Institute, in collaboration with the administrations of the Hydrometeorological Service and other scientific research institutes, since 1975 has been carrying out multisided expeditionary hydrometeorological investigations of water resources, the water balance, mudflows, high waters, ice encrustations and avalanches in the region of the Baykal-Amur Railroad for validation of the planning, construction and subsequent economic exploitation of the territory of the Baykal-Amur Railroad.

The preliminary results of investigations by the State Hydrological Institute have been generalized in the monograph VODNYYE RESURSY BAM (Water Resources of the Baykal-Amur Railroad Zone), containing recommendations on computation of the main hydrological characteristics necessary for the planning of construction. Eleven specialists of the State Hydrological Institute have been awarded medals "For Participation in Construction of the Baykal-Amur Railroad" by the Presidium of the RSFSR Supreme Soviet.

During the Eleventh Five-Year Plan it is proposed that investigations in the Baykal-Amur Railroad zone be continued and expanded. Particular attention will be devoted to study and prediction of possible anthropogenic influences on hydrometeorological conditions, water regime, water balance and quality.

In connection with the development of working of ore deposits by the strip method, during which with a decrease in the ground water level there are radical changes in the regime of surface waters, the State Hydrological Institute in preceding years carried out extensive water balance investigations in the neighborhood of the Kursk Magnetic Anomaly and the northwestern bauxite deposits. During the Tenth Five-Year Plan similar investigations were carried out in the neighborhood of the Kartauzskiye phosphorite deposits and in other places.

As a result of these investigations not only was a prediction given for the change in the water balance in these regions, but materials were collected and conclusions were drawn which are of great scientific importance for a study of the interaction between surface and ground water.

Among the investigations directly related to solution of major water management problems we should mention multisided investigations of Lake Issyk-Kul' for clarifying the reasons for a decrease in its level and the development of recommendations with respect to the quality of its waters and investigations of the hydrological regime and present-day water balance of the Amudar'ya and Syrdar'ya basins for the purpose of predicting changes of inflow into the Aral Sea.

Recently the State Hydrological Institute has been participating actively in solution of the Lake Sevan problem, working on a more precise determination of the water balance in connection with measures for stabilizing its level.

During the Eleventh Five-Year Plan the State Hydrological Institute is planning to carry out multisided investigations in the basin of Lake Balkhash.

During 1981-1985 plans call for a further strengthening of the creative and professional relationships between the State Hydrological Institute and many planning and production agencies.

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PRINCIPAL RESULTS OF AGROMETEOROLOGICAL INVESTIGATIONS IN THE TENTH FIVE-YEAR PLAN AND PROSPECTS FOR THEIR FURTHER DEVELOPMENT

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[Article by I. G. Gringof, candidate of biological sciences, and Yu. A. Khvalenskiy, candidate of physical and mathematical sciences, All-Union Scientific Research Institute of Agricultural Meteorology]

[Text]

Abstract: The article gives the results of agrometeorological investigations carried out in the Tenth Five-Year Plan by organizations of the State Committee on Hydrometeorology, especially those organized by the All-Union Scientific Research Institute of Agricultural Meteorology in 1977. Ways to bring about the further development of scientific research work in the field of agrometeorology are outlined.

The long-range agrarian policy of the CPSU Central Committee provides for a further intensification of agriculture by means of mechanization, land improvement and increased use of chemical fertilizers, and also the introduction of new high-yield varieties of agricultural crops, taking into account the agroclimatic resources in different soil-climatic zones of our country.

The central task of the Eleventh Five-Year Plan, as defined in the "Principal Directions in the Economic and Social Development of the USSR for 1981-1985 and for the Period Ending in 1990," adopted by the 26th CPSU Congress, is "ensuring the further increase in the well-being of the Soviet people." The foodstuffs program is becoming a new stage in the development of the agrarian policy of the Party.

The operational and scientific subdivisions of the State Committee on Hydrometeorology are giving serious, ever-increasing assistance to the upgrading of agriculture. Operational agrometeorological support of agriculture is based on scientifically sound methods for evaluating and predicting the status, productivity and distribution of agricultural crops.

During the Tenth Five-Year Plan agrometeorological investigations have developed at the USSR Hydrometeorological Center, Institute of Experimental Meteorology (All-Union Scientific Research Institute of Agricultural Meteorology), at all the regional institutes and many hydrometeorological observatories and administrations of the Hydrometeorological Service. One of the clear manifestations of the attention of the Party and the government to the development of scientific research in the field of agrometeorology was the organization of the All-Union Scientific Research Institute of Agricultural Meteorology (VNIISKhM -- Vsesoyuznyy Nauchno-Issledovatel'skiy Institut Sel'skokhozyaystvennoy Meteorologii) in late 1977.

The principal tasks of the new institute are:
-- development and improvement of methods for agrometeorological prediction of the productivity of the principal agricultural crops and their introduction into the routine practice of agrometeorological support of the country's agriculture;
-- investigation of agroclimatic resources for the purpose of solving practical problems in the effective distribution of agricultural crops, development and implementation of the USSR Agroclimatic Survey;
-- formulation of recommendations on allowance for weather conditions in carrying out all types of agroengineering measures in agriculture;
-- development and improvement of methods and instruments for the remote evaluation of the status and productivity of agricultural crops and natural pastures;
-- improvement of methods and instruments for surface agrometeorological observations;
-- development of an automated subsystem for the collection, processing, transmission and storage of routine and regime agrometeorological information.

During the Tenth Five-Year Plan there was serious development of investigations directed to the development of the agrometeorological aspects of the quantitative theory of the formation of yields of agricultural crops. As a result, the most complete model of processes of energy and mass exchange in the "soil-plant-atmosphere" system has been created. The task of computing the final productivity of an agrocoenosis with known environmental conditions was formulated from beginning to end as a boundary-value problem in mathematical physics. The solution of a closed system of differential equations describing the exchange processes in two contacting media (surface air and the soil), joined together by plants, with boundary conditions stipulated in the undisturbed atmosphere over crops and in the soil, makes it possible to obtain the vertical profiles for all heat balance components for a crop of any stipulated structure growing on a soil with stipulated hydrophysical constants.

The successes of theoretical investigations made it possible for the first time for agrometeorological purposes to create a dynamic model of yield formation whose parameters have already been identified for a number of the most important agricultural crops: barley, clover, potatoes, spring wheat, etc. On the basis of "weather-yield" dynamic models it has been possible to develop methods for evaluating the agrometeorological conditions for yield formation (for spring barley, clover, potatoes), and also to predict the mean oblast yield of spring barley. For the first time it was possible to formulate a physicomathematical model for predicting the wintering of winter grain crops. Some of these methods have already been introduced into practical work or are in the production tests stage.

During the Eleventh Five-Year Plan there is to be a further improvement in the theory of agrometeorological processes. First of all there must be a more detailed allowance for the dependence of plant growth processes on hydrometeorological conditions and the conditions for mineral nutrition. Models must be formulated making it possible to solve the problems involved in optimizing the water and thermal regimes of plantings of agricultural crops, to evaluate the effectiveness of artificial modification work directed to the prevention or weakening of the negative consequences of the influence exerted on the yield by extremal hydrometeorological conditions. Studies in this direction must lay the theoretical basis for creating a new system for the agrometeorological support of agriculture in our country.

The development and improvement of methods for agrometeorological predictions of the yield of agricultural crops have proceeded on a broad front: the yield of grain crops and potatoes in the main regions of their cultivation, perennial sown grasses in the nonchernozem zone of the RSFSR and in Kazakhstan, tea and sugar beets in Georgia, cotton and vegetable-melon crops in Central Asia.

In cooperation with the hydrometeorological services and meteorological services of a number of oocialist countries the "Manual on Agrometeorological Predictions of the Yield of the Principal Agricultural Crops" was prepared.

Efforts were undertaken for increasing the advance time for agrometeorological predictions. For example, methods were developed for predicting the yield of spring wheat prior to sowing for a number of regions.

At the present stage it was possible to define clearly two directions for the improvement of methods for making agrometeorological predictions. These are governed by both the practical requirements for routine hydrometeorological support of agriculture and advances in the field of mathematical modeling and development of remote methods for the collection of agrometeorological information. A number of methods for predicting crop yield, for example, the yield of spring barley and potatoes, have already been developed for some regions of the country on a new methodological basis -- in dynamic models of the growth, development and formation of crop productivity.

In the development of methods for predicting yield more extensive use has been made of new types of information obtained employing remote methods. For example, a method for predicting the yield of grain and pasture vegetation over the territory of Central Asia and Kazakhstan has been developed using aerial photometric information on biomass.

The use of remote information on the state of agricultural crops and the soil over large areas and advances in the field of mathematical modeling should become the basic direction in the improvement of methods for agrometeorological predictions, an increase in their accuracy in the new five-year plan.

During the past five years work has actively proceeded on the improvement of methods for the remote determination of the state of the soil, state and productivity of agricultural crops over extensive areas using aviation and space vehicles.

The following methods have been developed: for remote determination of the projective coverage of the soil by winter crops during the autumn and spring; for determination of damage to potato crops by phytophthora; for determination of areas of beating down of crops; for determining the sparseness and damage of cotton plants. A method was created for predicting the yield of grain crops on irrigated and unirrigated lands in Central Asia and Kazakhstan, based on the dependence of the grain yield on the mean oblast quantities of above-ground biomass of fields of grain crops determined by the aerophotometric method. A method was developed for computing the yield of desert pasture vegetation on the basis of data from aerophotometric investigations and satellite photographs.

A series of aircraft instrument outfits was created and delivered for the implementation of a gamma survey over large areas for the purpose of determining the water reserves in the snow and in the cultivated soil horizon in several agricultural regions of the country. Methods have been developed for ascertaining soil moisture content, snow depth and water reserves in the snow cover in agricultural fields using aircraft gamma-spectral surveys.

In general, in the system of the State Committee on Hydrometeorology investigations on the development of remote methods for the collection of information on the state and yield of agricultural crops and pasture vegetation over great areas are at the level of the best attainments in the country and abroad. During the Eleventh Five-Year Plan this work direction will be further developed and will be tied in with the development of airborne operational measurement systems for evaluating the state of the soil, sown crops and their yield with a corresponding system for the registry and automated processing of the collected information.

During recent years there has been some broadening of work on the creation of instruments for surface agrometeorological observations by the network of stations and posts. For example, the "FON-M" and "Zhavoronok" biometric field photometers have been developed for routine instrumental measurement of the quantity of above-ground plant biomass, the density in fields and the degree of weediness. The first will be used in any types of soils and the second in regions with light-colored soils. In 1980 field tests of these photometers were initiated and are intended for extensive use by agrometeorologists and agronomists.

Testing of a universal conductometric instrument KIR-101 is being completed. This indicator is intended for the routine detection of plants which have perished due to low temperatures and for determining the wilting point.

In accordance with the technical specifications of the All-Union Scientific Research Institute of Agricultural Meteorology, in the new five-year plan development will be completed for an instrument measuring complex for vehicle agrometeorological investigations. In essence, this will make it possible to create agrometeorological field laboratories set up on the chassis of cross-country vehicles of the UAZ-452 and GAZ-66 types, designed in two variants: for the implementation of standard agrometeorological programs for field observations by hydrometeorological observatories, weather bureaus and agrometeorological stations (first variant); for carrying out a complex of special agrometeorological and biological observations within the framework of scientific research work (second variant).

Work is continuing on the creation of a portable soil drill; development is proceeding on an ecological gasometric chamber, etc.

During the new five-year plan work will be completed on the revising of the RUKOVODSTVO PO OPREDELENIYU AGROGIDROLOGICHESKIKH SVOYSTV POCHVY NA GIDROMETSTANTSIYAKH (Manual for Determining the Agrohydrological Properties of Soils at Hydrometeorological Stations), the NASTAVLENIYA GIDROMETEOROLOGICHESKIM STANTSIYAM I POSTAM, VYP 11 (4-e IZDANIYE) (Instructions for Hydrometeorological Stations and Posts, No 11 (4th Edition)), and other aids, and these will be published.

A major cycle of studies has been carried out by the scientific research institutes of the State Committee on Hydrometeorology for the formulation of recommendations on the agrometeorological validation of different technological procedures for the cultivation of agricultural crops for a number of regions in the country. Among these are recommendations on allowance for agrometeorological conditions in the distribution of nitrogen fertilizers on grain crops, recommendations on the undersowing and resowing of damaged and poorly developed fields of winter wheat, on the times of sowing of spring grain crops in Western Siberia and cotton in Central Asia. Methods have been developed for predicting the influence of agrometeorological conditions on the development of a predator of the potato, the Colorado potato beetle, and diseases of this crop in the nonchernozem zone, methods for predicting the mass propagation of a number of predators of agricultural crops in the territory of Transcaucasia, and a method for evaluating the effectiveness of snow retention over the territory of Kazakhstan. Methodological recommendations have been formulated on an evaluation of the economic effectiveness of the use of agrometeorological information in agriculture. The potential economic effectiveness of use of recommendations on allowance for hydrometeorological conditions in agricultural work is estimated at 33.5 million rubles per year.

The "Principal Directions in Economic and Social Development of the USSR for 1981-1985 and for the Period Ending in 1990" call for a substantial increase in the supplying of mineral fertilizers and highly effective plant protection agents to agriculture. The task is set of increasing the role of the agrochemical service in agriculture and its responsibility for the effective use of mineral fertilizers, lime and chemical plant protection agents. Accordingly, the importance and necessity for developing agrometeorological recommendations making it possible to take into account the existing and anticipated weather conditions with the application of large amounts of fertilizers and crop chemical protection agents, directed to an increase in the effectiveness of use of these agents, is increasing still further.

In the field of agroclimatic investigations during the Tenth Five-Year Plan much work was done for evaluating the agroclimatic conditions for crop cultivation and validation of the distribution of agricultural crops in the zone of the Baykal-Amur Railroad and in Transcaucasia, rice in the Ukraine. A series of reference aids was prepared. The map AGROKLIMATICHESKIYE RESURSY NECHERNOZEMNOY ZONY YeT SSSR (Agroclimatic Resources of the Nonchernozem Zone of the European Territory of the USSR) was published, as well as the reference manuals SREDNIYE MNOGOLETNIYE I VEROYATNOSTNYYE KHARAKTERISTIKI ZAPASOV VLAGI V POCHVE POD OZIMYMI I RANNIMI YAROVYMI KUL'TURAMI (Mean Long-Term and Stochastic Characteristics of Moisture Supplies in the Soil Under Winter and Early Spring Crops) for the European USSR and Eastern Siberia. Similar reference manuals have been prepared for publication for the territory of the Uzbek, Kirgiz and Tajik SSRs, for the territory of Western Siberia, and also the ATLAS VLAGOZAPASOV POD OZIMYMI I YAROVYMI ZERNOVYMI KUL'TURAMI NA YeTS (Atlas of

Moisture Supplies Under Winter and Spring Grain Crops in the European USSR). Work on the preparation of reference manuals on the agroclimatic regime of the territory of the country, intended for a wide range of users, will be continued.

In order to improve the system for supplying users with agroclimatic information, and also for coordinating all investigations in this field, carried out by different ministries and departments, during the Eleventh Five-Year Plan specialists will formulate the methodological principles for creating and implementing the USSR Agroclimatic Inventory.

The "Principal Directions in the Economic and Social Development of the USSR for 1981-1985 and for the Period Ending in 1990" provide for the continuation of work on improving the distribution of agricultural production by zones and regions of the country, an increase in the level of its specialization and concentration. In the light of this task, investigations directed to an evaluation of the influence of anomalous agroclimatic conditions on the yield of the principal agricultural crops for the purpose of optimizing the distribution of agricultural production are assuming particular importance and seriousness.

During the Tenth Five-Year Plan a new method was developed for the multisided regionalization of agricultural crops, optimum in the sense of a reduction of losses of the gross yield due to the unfavorable weather conditions. It is necessary to solve the problem, more difficult in scientific and organizational respects, of implementing the developed approach and introducing the practical results of computations into the planning of agricultural production.

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Work has been completed on the development of a first variant of a system for the processing of routine agrometeorological information. On the basis of a YeS electronic computer, the system, together with the modernized KN-21M(2) code, is undergoing the stage of inventor's tests at the Belorussian Territorial Hydrometeorological Center. Also lying ahead is more intensive work on the introduction of the system for the processing of routine information into practical use and on mathematical support for the creation of a bank of agrometeorological data. Work along these lines is an important aspect of the new system for the hydrometeorological support of the country's agriculture. The availability of a modern information base would make possible a substantial increase in the effectiveness of scientific research work in the agrometeorological field.

During the Tenth Five-Year Plan a textbook by Yu. I. Chirkov, entitled AGROMETEOROLOGIYA (Agrometeorology) was published for the students at agricultural colleges in the country, as well as a study aid by A. M. Shul'gin entitled AGROMETEOROLOGIYA I AGROKLIMATOLOGIYA (Agrometeorology and Agroclimatology), to a certain degree filling a gap which has persisted for many years in the agrometeorological literature. Nevertheless, during the Eleventh Five-Year Plan it is necessary to form creative teams of authors for preparing modern textbooks and aids for students at hydrometeorological colleges and technical schools.

The Scientific Council on the "Agrometeorology" Problem, organized by an order of the State Committee on Hydrometeorology in late 1980, should bring together the scientific community of our country, focus efforts on the development of key problems in agrometeorology and favor an improvement in the coordination of all agrometeorological investigations carried out in the system of the State Committee on Hydrometeorology and in other ministries and departments.

During the past five years Soviet agrometeorologists have assumed an active part in agrometeorological research together with specialists of the socialist countries within the framework of multilateral and bilateral cooperation. For example, on the basis of such investigations in 1979 the third, final part of the monograph AGROKLIMATICHESKOYE RAYONIROVANIYE PYATI OSNOVNYKH SEL'SKOKHOZYAYSTVENNYKH KUL'TUR NA TERRITORII SOTSIALISTICHESKIKH STRAN YEVROPY (Agroclimatic Regionalization of the Five Principal Agricultural Crops in the Territory of the Socialist Countries of Europe) was published.

During the Eleventh Five-Year Plan scientific cooperation with the agrometeorologists of the countries of the Socialist Economic Bloc will be further developed.

Major work must still be done by Soviet agrometeorologists within the framework of activity of the Commission on Agricultural Meteorology of the WMO and other international organizations. In particular, the following work must be done: determine the influence of climatic variability on agriculture, clarify the role of forests in the global balance of CO_2, the water and energy balances, determine the agrometeorological aspects of land use in arid and semiarid territories subjected to the greatest extent to the processes of advance of the desert, clarify the meteorological aspects of the implementation of agricultural work in the tropical and subtropical regions. Work will be continued on the development of "weather-yield" models and study of the problems involved in the influence of weather on the state of livestock.

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EFFECT OF SOLAR ACTIVITY ON THE TEMPERATURE REGIME IN THE POLAR ATMOSPHERE

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[Article by G. A. Kokin, doctor of physical and mathematical sciences, L. A. Ryazanova, candidate of geographical sciences, and G. F. Tulinov, doctor of physical and mathematical sciences, Central Aerological Observatory and Institute of Applied Geophysics]

[Text]

Abstract: On the basis of an analysis of experimental data from rocket and radiosonde sounding on Kheys Island it was possible to ascertain the characteristics of change in meteorological parameters and the state of different layers of the atmosphere in dependence on the solar activity level in the 11-year cycle.

The purpose of this study was a determination of the relationship between the change in solar activity during the 11-year cycle and the temperature regime of different layers of the atmosphere during winter in the polar region.

During the polar winter the direct influence of solar radiation in the electromagnetic wavelength range is minimum and therefore the effects associated with disturbance by the sun should be manifested most clearly. At the same time, the effect of corpuscular streams in this region is maximum and their contribution to energy should be clearly conspicuous. Taking these circumstances into account, we will examine the change in the temperature regime during the period of the 11-year solar activity cycle in the polar region.

As characteristics of solar activity we used the minimum temperature of the exosphere T_{exo}, which reflects the joint effect of radioemission at a wavelength 10.7 cm ($F_{10.7}$) and geomagnetic disturbance (K_p index). A validation of the selected characteristic and the computation method were given in [5].

The mean monthly and mean seasonal T_{exo} values during the period from 1966 through 1976 were compared with the values of the mean monthly and seasonal temperatures over Kheys Island, obtained on the basis of radiosonde and rocket measurements [8]. As a characteristic of thermospheric temperature at altitudes greater than 80 km we used data from experimental measurements by the different methods employed in [2, 6, 7, 9, 10].

Table 1

Mean Winter Values T_{exo} and Temperatures Over Kheys Island in Years of Solar Activity Maximum and Minimum

H km	Mean winter temperature, K during 1968-1971	during 1974-1976	Temperature differences during mentioned periods, K
Exosphere	1233	996	237
165	662	1025	-363
70	217	202	15
45	233	263	-30
5	235	233	2

There were two maxima in the mean winter T_{exo} values (December-January-February) during the period 1966 through 1976: the first, main maximum, observed in 1968, which was 1330 K, and a second, observed in 1970, and equal to 1230 K. Minimum solar activity was observed in 1976, with T_{exo} = 990 K. Thus, during the investigated period the maximum amplitude of the mean winter T_{exo} values was more than 300 K.

In order to compare T_{exo} with the temperature values in different layers of the atmosphere all the data were grouped into two main periods: solar activity maximum (1968-1971) and minimum (1974-1976).

As an example, the table gives the mean winter T_{exo} values and mean winter temperature values at altitudes 5 km (troposphere), 45 km (stratosphere), 70 km (mesosphere) and 165 km (thermosphere).

After examining the table the conclusion can be drawn that in the years of the solar activity maximum and minimum the temperature regime of the atmosphere in the polar region is different. The temperature values in the years of the solar activity maximum are higher in the mesosphere and troposphere and lower in the thermosphere and stratosphere than during the period of low solar activity. Thus, the reaction to the change in solar activity during the 11-year cycle in different layers of the atmosphere is different. We note that the indicated differences in temperature are significant in all layers other than the troposphere.

Figure 1, which shows the vertical temperature profiles over Kheys Island for the periods of the maximum (1) and minimum (2) of solar activity, clearly reveals the altitudinal boundaries of the above-mentioned temperature changes.

We should note that sufficiently good agreement between temperature isothermy in the thermosphere, measured by rocket methods, and temperature of the exosphere, computed on the basis of data on the $F_{10.7}$ and K_p indices, is indicated.

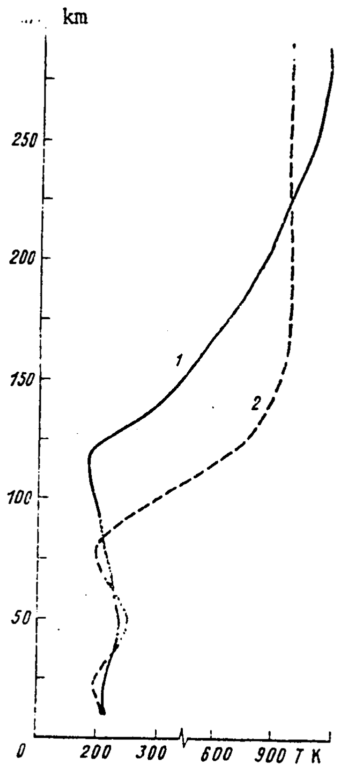

Fig. 1. Temperature change over Kheys Island during the years of the solar activity naximum (1) and minimum (2).

During the period of the solar activity maximum the temperature in the isothermy region was T = 1200 K, and T_{exo}, as indicated above, was 1233 K; during the period of the minimum T = 1025 K, T_{exo} = 992 K. The mentioned sufficiently good agreement of these data is evidence of the reliability of the results of rocket measurements.

The antiphase character of the temperature changes in different layers of the atmosphere has been noted before; it has been observed most clearly during periods of powerful stratospheric-mesospheric warmings. During these periods there are substantial restructurings of the thermal and circulation regimes. It is possible that restructurings of structure and circulation also occur with changes in the solar activity level.

The character of the relationship between solar activity and the temperature regime of different layers of the atmosphere can also be judged from regression curves constructed in linear and quadratic approximations and shown in Fig. 2. The figures near the dots indicate the year for which the mean temperature value was obtained.

The greatest scatter of points relative to the approximating curve is observed at the level 5 km, which indicates, evidently, a predominating influence of the variability of tropospheric processes and the effect of the underlying surface.

At the 70-km level the maximum deviation of the point relating to 1969 is evidently attributable to the strong mesospheric warming observed during this period.

Now we will examine some possible reasons for such a significant change in the temperature regime in dependence on variation in the level of solar activity during the 11-year cycle, especially the temperature change in the atmosphere during a period of rise in this level.

In our opinion, the redistribution of the thermal and energy regimes is attributable to the totality of a whole series of factors, among which we can mention long planetary waves, turbulent thermal diffusivity and vertical currents. In a one-dimensional approximation the thermal diffusivity equation can be written [1] in the form

$$Wc_p\rho\left(\frac{dT}{dz}+\Gamma\right)=\frac{d}{dz}\left[K_z c_p \rho\left(\frac{dT}{dz}+\Gamma\right)\right]-Q, \qquad (1)$$

where W is the vertical component of wind velocity, K_z is the vertical component of the coefficient of turbulent mixing, c_p is specific heat capacity at a constant pressure, ρ is air density, Q is the specific heat absorbed in a unit time due to radiation factors, dT/dz is the vertical temperature gradient, $\Gamma = g/c_p$ is the superadiabatic temperature gradient, g is the acceleration of free falling.

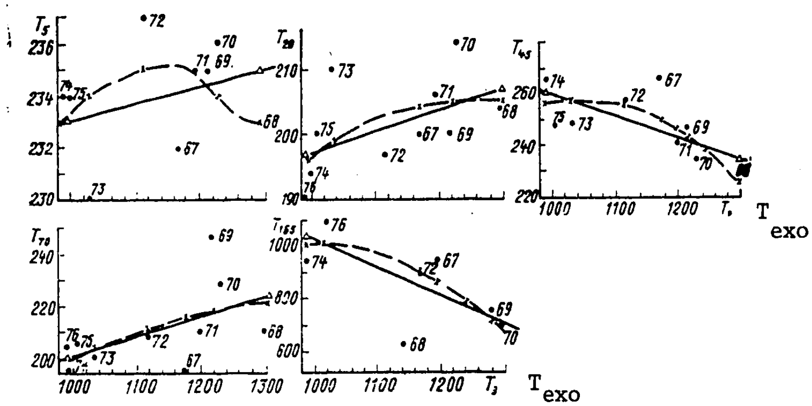

Fig. 2. Regression relationships between minimum exospheric temperature T_{exo} and temperature at the levels 5, 20, 45, 70 and 165 km.

The solution of equation (1) with the boundary condition: with z = 0

$$dT/dz = (dT/dz)_0,$$

has the form

$$\frac{dT}{dz} = -\Gamma + \frac{(K_z c_p \rho)_0}{K_z c_p \rho}\left[\left(\frac{dT}{dz}\right)_0 + \Gamma\right] e^{\int_0^z \frac{W}{K_z} dz} + \frac{e^{\int_0^z \frac{W}{K_z} dz}}{K_z c_p \rho} \int_0^z Q e^{-\int_0^\xi \frac{W}{K_z} dz} d\xi, \qquad (2)$$

where $(K_z c_p \rho)_0$ is related to z = 0.

It follows from (2) that the vertical temperature gradient is formed due to such parameters as K_z, W, ρ and Q. We will examine each parameter separately.

Atmospheric turbulence is governed for the most part by atmospheric stability relative to external factors. A stability characteristic is the value of the Richardson number Ri. A modification of this number, expressed through the horizontal temperature gradient, was obtained in [3].

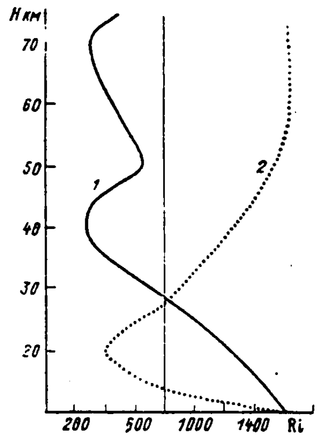

Fig. 3. Change in Ri for period of maximum (1) and minimum (2) solar activity.

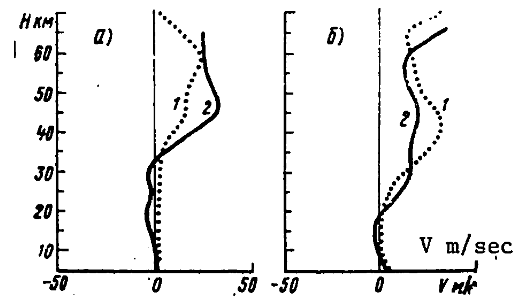

Fig. 4. Change in zonal (a) and meridional (b) wind velocities over Kheys Island for levels of high (1) and low (2) solar activity.

The Ri values were computed for levels of increased and reduced activity using rocket sounding data. The results of the computations are given in Fig. 3. A study of this figure indicates that in almost the entire stratomesosphere the period of increased solar activity is characterized by an unstable state of the atmosphere. Accordingly, during this period the prerequisites exist for the development of more intense turbulence. It can be anticipated that in this case there will be a broader spectrum of turbulent fluctuations and accordingly, K_z at the time of the solar activity maximum will be greater than during the time of the minimum. Thus, during the period of the solar activity maximum as a result of increased turbulent mixing there should be a decrease in the vertical temperature gradient.

Vertical currents W should also lead to a temperature redistribution. The W value can be evaluated through the horizontal components of wind velocity. It follows from the continuity equation that

$$W = -\frac{1}{\rho}\int_0^z \left[\frac{\partial(\rho u)}{dx} + \frac{\partial(\rho v)}{\partial y}\right] dz, \qquad (3)$$

where u and v are the zonal and meridional components of wind velocity. In a geostrophic approximation we obtain

$$W = -\frac{1}{a\rho}\int_0^z \mathrm{tg}\,\theta\,\rho v\,dz, \qquad (4)$$

where θ is the complementary angle to local latitude, a is the earth's radius.

Approximate integration in the Δ z layer gives

$$W \simeq \frac{H}{a} \ln \frac{p_0}{p_z} \overline{v}, \tag{5}$$

where H is the altitude of the homogeneous atmosphere, p_0 and p_z are the pressures at the lower and upper levels of the Δz layer, $\overline{v}$ is the mean velocity of the meridional wind component in the Δz layer. Evaluations show that with $\Delta z \approx 10^5$ cm and $a \approx 6 \cdot 10^8$ cm $W \approx 2 \cdot 10^{-4} \overline{v}$.

On the basis of experimental data we computed the mean $\overline{v}$ values for the levels of high and low solar activity. The results of the computations are given in Fig. 4. Using these data it is possible to evaluate the change in W with transition from the maximum to the minimum of solar activity. Estimates show that during the period of the solar activity maximum in the layer from 10 to 20 km W has a very low ($\approx 2 \cdot 10^{-2}$ cm/sec) value and is directed downward. Below 20 km, due to descending currents, it is evident that there will be a temperature increase. Above 20 km and to an altitude of 60 km because of ascending currents there should be a temperature decrease because the $\overline{v}$ value during the period of the solar activity maximum is less than during the period of the minimum. It is evident that this process to a considerable degree should be neutralized by turbulent thermal diffusivity. In actuality, the dimensionless value WH/K_z characterizes the relative contribution of these processes. $W_{min} \simeq 0.6$ cm/sec and $W_{max} \simeq 0.4$ cm/sec at an altitude 40-45 km. K_z, according to [1], is of the order of magnitude 10^5 cm^2/sec, $H \simeq 6 \cdot 10^5$ cm. Accordingly, $WH/K_z \approx 0.4 \cdot 6 \cdot 10^5/10^5 \approx 2$ during the period of the maximum and $WH/K_z \approx 3$ during the solar activity minimum period. If it is taken into account that with transition from the solar activity minimum to the solar activity maximum K_z should increase, then evidently in the considered range of altitudes at the solar activity maximum the WH/K_z value will even be somewhat less than during the period of the solar activity minimum.

Thus, both these mechanisms should lead to a change in the vertical temperature profile, as is actually observed. In addition to a change in stratification there is also a change in the level of the mesopause. Its altitude increases with the solar activity minimum and is situated at 120-125 km, whereas with the minimum it lies at about 80 km. The fact that in the altitude range 90-220 km the thermospheric temperature during the period of the solar activity maximum is lower can evidently be evidence of an increasing role of turbulent transfer. This same factor should increase the altitude of the mesopause and the level of the turbopause.

A decisive role should also be played by descending movements which possibly caused a temperature increase in the mesosphere during the solar activity maximum.

Using data from rocket sounding we calculated the vertical density profiles for Kheys Island station. It was found that during a period of increased solar activity the density in the stratomesosphere increases in comparison with the solar activity minimum. This circumstance should lead to a decrease in dT/dz during a period of increased solar activity because density is present in the denominators of the second and third terms of expression (2).

Now we will proceed to an examination of the influence of Q on formation of the vertical temperature profile. It is evident that during the period of the polar night over Kheys Island there is virtually no solar radiation leading to heating of the atmosphere. It is possible that radiation scattered by the thermosphere enters into the stratosphere and mesosphere and is absorbed there, but its contribution is negligible. Accordingly, the radiation regime of the stratomesosphere is characterized by radiation cooling. It is possible that heating of the atmosphere occurs as a result of injections of corpuscular radiations through the polar cusps, but in our opinion any estimate of the contribution of this factor to the thermal regime of the stratomesosphere would be highly approximate.

$$\left(\frac{dT}{dz}\right)_{max} - \left(\frac{dT}{dz}\right)_{min} \sim \frac{(Q_a - Q_e)_{max} - (Q_a - Q_e)_{min}}{Wc_p\rho}\left(1 - e^{\frac{W}{K_z}\Delta z}\right), \quad (6)$$

where Q_a and Q_e are the absorbed and emitted radiation energy.

It follows from the experimental data that the following condition is satisfied in the stratomesosphere

$$\left(\frac{dT}{dz}\right)_{max} - \left(\frac{dT}{dz}\right)_{min} < 0. \quad (7)$$

Condition (7) is satisfied in a case when

[π = a; μ= e]

$$[(Q_n - Q_u)_{max} - (Q_n - Q_u)_{min}]\left(1 - e^{\frac{W}{K_z}\Delta z}\right) < 0.$$

The value $1 - e^{\frac{W}{K_z}\Delta z} < 0,$

since $W/K_z \Delta z \approx 0.4$ with $\Delta z \approx 10^5$, $K_z \approx 10^5$ and $W \approx 0.4$.

Accordingly, the following condition is satisfied

$$(Q_a - Q_e)_{max} < (Q_a - Q_e)_{min}.$$

If it is assumed that at the solar activity minimum $Q_a < Q_e$, accordingly the same condition must also be satisfied during the period of the solar activity maximum. Emission must increase to a greater extent than absorption. However, if during the period of the solar activity minimum $Q_a > Q_e$, it is obvious that during the solar activity maximum the difference $Q_a - Q_e$ should decrease in comparison with the period of the minimum. This can occur only in a case when the emission increases more in this period than absorption.

Thus, in both the considered cases during a period of increased solar activity there should be an increase in radiation cooling.

The principal factor responsible for this process, according to [4], is CO_2 emission in the band 15μm. However, CO_2 is a quite conservative component and one should scarcely expect its changes in different periods of solar activity. A second, less active factor responsible for the radiation balance is atmospheric ozone, emitting in the 9.6μm band. However, its contribution to the radiative cooling process is less significant than the CO_2 contribution.

It was demonstrated in [4] that up to the 60-km level radiative cooling by O_3 emission does not exceed 1°C/day. Even a significant (by several times) increase in the O_3 concentration during a period of increased solar activity, which to all intents and purposes is an improbable event, scarcely will lead to the anticipated effect. Still another component responsible for radiative cooling is water vapor. It was also demonstrated in [4] that in the case of use of a "moist" model of the stratomesosphere the effect caused by this component is -8 K per day at an altitude of 50 km. Thus, water vapor plays a substantial role in the radiation balance of the stratomesosphere.

At the present time the literature contains no data on the water vapor concentration in the polar region, but it was demonstrated in [11] that the water vapor concentration in the stratomesosphere increases from the tropical to the middle latitudes. There is an annual variation of humidity with a maximum in the winter and a minimum in the summer. If it is postulated that such a pattern can be extrapolated into the high latitudes, it is then possible to explain the increase in radiative cooling during winter over Kheys Island. It can also be assumed that the fact of an increase in radiative cooling during the period of the solar activity maximum is associated with the increasing role of solar protons in the physicochemical processes transpiring in the stratosphere and mesosphere and possibly responsible for an increase in the concentration of H_2O molecules.

It can therefore be concluded that in the polar region all the principal meteorological parameters (temperature, wind, density, pressure), altitude of characteristic levels (mesopause and others), characteristics of the thermodynamic state of the stratosphere and mesosphere (turbulence, vertical currents, instability), as well as radiation factors and physicochemical processes change or should change with transition from the maximum to the minimum of solar activity in the 11-year cycle.

Some assumptions concerning the role of individual factors presented here are quite speculative and unquestionably should be backed up by rigorous mathematical computations. However, it is impossible to carry out such computations at the present time due to the lack of a number of required physical characteristics.

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PRELIMINARY RESULTS OF IMPLEMENTATION OF THE FGGE PROGRAM

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[Article by K. Ya. Kondrat'yev, corresponding member, USSR Academy of Sciences, Main Geophysical Observatory]

[Text]

Abstract: This is a review of the preliminary results of implementation of the FGGE program. The emphasis is on an examination of the space observation system, including both the collection of information by means of satellites and the use of satellites for the localizing, collection and dissemination of data from different observation platforms (drifting sea buoys, balloons, aircraft). The volume of observations carried out during the FGGE period is characterized and the results of processing of the mass of data are briefly examined. The author discusses some results of analysis of FGGE data and numerical modeling, the purpose of which was an evaluation of the informational contribution of different components of the observation system to a weather forecast for a time up to five days.

Within the framework of the scientific program for the next, 23d plenary session of COSPAR, held during the period 2-14 June 1980 in Budapest, a symposium was organized to discuss the results of functioning of observation systems and the preliminary results of implementation of the First Global Experiment (FGGE) of GARP. The symposium, attended by a representative group of specialists from different countries, made possible a sufficiently clear evaluation of the degree of implementation of the FGGE observational program and discussion of results. Naturally, the specific character of COSPAR as an international committee on space research determined the priority of the "space aspect" of the FGGE program. It is well known, however, that it was specifically the use of space observation vehicles, together with means for the collection and dissemination of information from different platforms, which made a decisive contribution to the attainment of the principal FGGE goal -- obtaining a global mass of meteorological and oceanographic data for one year.

Table 1

FGGE Observational Systems

Observation system		Entire FGGE period	SOP	Periods of intensive observations
Principal observation system				
WWW surface observation system	WWW network	+		
Operational satellite observation system	5 geostationary satellites	+		
	4 satellites in polar orbits	+		
Special observation system				
Drifting buoys	368 buoys	+		
Constant-altitude balloons	313 balloons		+	
Shipboard wind observations in tropics	40 ships (SOP-1) 43 ships (SOP-2)		+	
Probes dropped from aircraft	9 aircraft (339 takeoffs)			+
Experimental satellite	"Nimbus-7"	+		
Transmission of data from aircraft via satellites ("PDSS")	17 aircraft	+		
Coordinated system of aircraft observations ("SSSN")	80 aircraft	+		
Special aerological soundings on islands	12 stations		+	

The principal scientific goals of the FGGE program are: 1) achievement of a better understanding of the laws of atmospheric dynamics for increasing the reliability of weather forecasts; 2) evaluation of the limits of weather predictability; 3) validation of an optimum observation system meeting the needs of numerical weather forecasting; 4) study (on the basis of data for a year observation period) of the physical mechanisms causing climatic changes at time scales from several weeks to several years and also the development and checking (on the basis of observational data) of models of climate.

Naturally, the primary task in summarizing FGGE results is an evaluation of the degree of implementation of the planned observation program. However, it is still more important to analyze the informational contribution of new observation systems supplementing the usual observational facilities of the World Weather Watch (WWW). This, in particular, relates to space observation systems, as well as their use for localizing automatic platforms, collection of the corresponding information and its transmission to surface centers. All these matters have been discussed in detail in reports at the symposium on FGGE results. A number of reports contained general information, overlapping to a considerable degree, on the functioning of the FGGE observation system (D. Rasmussen, WMO; H. Goetz, Hungary; W. McGovern, United States; D. Corby, Switzerland).

Table 1, presented by D. Rasmussen, characterizes the principal and special (intended for special observation periods -- SOP) space observation systems used in combination with drifting buoys, constant-level balloons, shipboard wind observations, probes dropped from aircraft, aircraft observations, etc. Most of the data from ordinary observations from the enumerated platforms was collected and (or) transmitted by means of satellites.

The data mass included the results of observations of 3,104 surface and sea meteorological stations and 1,375 aerological stations. Table 2 gives a generalized summary of the results of observations by means of satellites in polar orbits. The principal contribution was from "TIROS-N" data, this continuously functioning during the whole of 1979. A factor of great importance is the presence aboard third-generation American meteorological satellites ("TIROS-N" and "NOAA-6") of the "Argos" system instrument complex, ensuring localization of drifting buoys and constant-level balloons, and also the collection of data from them. The functioning of the "Argos" system, developed by French specialists, was reproachless. This system, described by M. Taillad (France) and intended for use at least until 1986 includes the following principal components: 1) observation platforms on which are mounted measuring devices and radio transmitters; 2) two simultaneously functioning satellites; 3) a data processing and dissemination center located in Toulouse (DPDC). Up to 32 different sensors with the volume of data transmitted by each of them up to 256 bits can be mounted on the OP. All OPs function at one and the same frequency (401, 650 MHz) and transmit information in series lasting approximately 1 sec each 40-200 sec. If the OP is situated in the zone of reception from a satellite, the information from it will be received, processed on board and stored in an on-board memory unit until it is transmitted to the DPDC. Successful reception of information is ensured at least in a radius of about 2,600 km relative to the subsatellite point (with a minimum angle of elevation of 5°).

Table 3 illustrates the possibility of interrogation of OPs from satellites. The basic principle for the reception of data is the implementation of random contacts between a satellite and the OP. In order to separate the OP transmissions in time use is made of their asynchronization in different periods of repetition of transmissions. The separation of transmissions by frequency is accomplished by the use of a different Doppler shift of the carrier frequency for transmitters on different

Table 2

System of FGGE Polar Satellites and Receipt of Level IIb Data From Them

In this table: * denotes that data output is not determined specifically and no level IIb data have yet been received; ** denotes that the receipt of data for the last few months of 1979 is likely; *** denotes that data will be received for supplementing level IIb data.

Name of satellite	Purpose of satellite	Time of launching	Remote sensing data	Data on radiation of cloudless sky	Ocean surface temperature	Wind velocity at ocean surface	Total atmospheric moisture content	Data from remote sounding of stratosphere	Localization of platforms and data collection	Additional information
NOAA-5	Second-generation meteorological satellite	29 Jul 1976	+	+	+					
Seasat	Oceanographic satellite	2 Jun 1978								Failed
TIROS-N	Third-generation meteorological satellite	13 Oct 1978	+	+	+		+		+	
NIMBUS-7	Experimental meteorological satellite	24 Oct 1978			+ * ***	+ * ***	+ * ***	+		
Meteor	Experimental meteorological satellite	25 Jan 1979	+ *	+ **	+ ***					
NOAA-6	Second third-generation meteorological satellite	27 Jun 1979	+	+	+		+		+	Remote sounding instrumentation failed

OP. If the transmissions are separated by frequency, up to four transmissions can be received simultaneously. With a duration of the repeated transmissions of not less than 10 minutes during one satellite revolution there is interrogation of each OP situated within the limits of the reception zone.

Table 3

Possibilities of Interrogation of Measurement Platforms From Satellites

Latitude, degrees	Number of interrogations		
	minimum	average	maximum
0	6	7	8
±15	8	8	9
±30	8	9	12
±45	10	11	12
±55	16	16	18
±65	21	22	23
±75	28	28	28
±90	28	28	28

A determination of the OP coordinates is made only by means of measurement of the Doppler shift of the carrier frequency of the received signal. With known satellite orbital parameters a successful determination of OP coordinates is possible in those cases when for the particular orbit there are five measurements of the Doppler shift with a different geometry of signal reception (this requires, for example, separation of the first and last signals with a time interval not less than 420 sec). If the position of the OP is determined using data for two revolutions, it is important that the measurements on the preceding revolution be made within the limits of the interval 30 minutes - 3 hours relative to data for the next revolution. Among 100 OP which the satellite "sees" in the course of one revolution, 60 may be localized with complete reliability (in 24 cases the geometrical test is not satisfied). A high frequency stability of the OP transmitter is of very great importance. With a stability of about 10^{-9} it is possible to determine position with an accuracy to 150 m (level Ib) and 500 m (level IIIb). Since the "Argos" system is free of systematic errors, the averaging of coordinates of fixed platforms over a period of several days increases the accuracy of localization to not less than 100 m.

The "Argos" system was designed to function with 99% assurance of its operations. Such a high reliability is guaranteed by a duplication of virtually all the important elements of the system. All the telemetric information from American meteorological satellites received by ground stations is sent to a data processing center located in Suitland (USA) and from there the data of the "Argos" system are transmitted to Toulouse. The data received by the DPDC are processed and disseminated at a real time scale. Upon receiving requests from users the DPDC carries out a specialized processing of data. The theoretically possible time interval between the moments of reception of data of the OP and the transmission of data by the DPDC at the request of users varies from 1 hour 20 minutes to 3 hours, but in actuality delays for technical reasons have led to a considerable lengthening of this interval. As an average for six months 57, 85 and 97% of the entire volume of information was received not later than 3, 6 and 10 hours respectively. A telex is used most frequently for the transmission of data to users. Table 4 characterizes the proposed use of the "Argos" system for different purposes in 1980-1981. Estimates of the prospects for expanding use of the "Argos" system are illustrated in Table 5.

Table 4

Use of "Argos" System for Collecting and Disseminating Different Information

Functions	Number of objects 1980	1981
Data collection only		
Fixed stations	54	74
Localization of OP and data collection		
Buoys	454	472
Balloons	5	0
Icebergs	60	5
Ships	112	160
Sea animals	39	49
Total	724	760

One of the principal FGGE achievements was the simultaneous functioning of five geostationary meteorological satellites (GMS): three American geostationary environmental satellites (GEOS); "Meteosat," launched by the European Space Agency (ESA) and a Japanese GMS (Table 6). The basic information from the GMS was data on the fields of the wind vector at two levels, reconstructed on the basis of movement of lower- and upper-level clouds.

In the United States two organizations have reconstructed the wind fields: the Environmental Protection Agency and the Center for Engineering and Space Research at the University of Wisconsin. GEOS data over the Indian Ocean were processed at the Wisconsin center (separately with low and high spatial resolution), by the French Dynamic Meteorology Laboratory and the West German Aerospace Institute. The Japanese Meteorological Agency and the ESA were responsible for the processing of data from the Japanese GMS and the "Meteosat" respectively. The JMA also was responsible for reconstruction of the temperature fields of the ocean surface. A total of 5,100 wind velocity and wind direction values were determined on the average for each day. For 1,060 "geostationary days" (with involvement of five GMS) during the period of 212 days from 1 December 1978 through 30 June 1979 at least two series of data on the wind field were received for 90% of the days.

Three complications arose during the time of FGGE implementation:
1) partial failure of GEOS-2 in late December 1978, which made it necessary to replace this satellite first with the satellite GMS-1 and then GMS-2 in order to ensure continuity of observations at the point where GEOS-East was situated;

2) beginning with 24 May 1979 there was intermittent (from time to time) failure of the GEOS-1 IR channel (Indian Ocean), which limited the restoration of data to one series a day; however, in the course of SOP-2, in the absence of data for the IR channel, the wind fields were reconstructed at 0600 and 1200 hours GMT;
3) failure of "Meteosat" on 25 November 1979, which was not of great importance because it occurred late in the FGGE period.

The results of an analysis of the mass of FGGE data, discussed in a report by D. Zillman (Australia), revealed the major role which was played by drifting sea buoys localized and interrogated by satellites in obtaining meteorological and oceanographic data for the southern hemisphere. Seven countries set out 364 buoys (the FGGE program called for 300 buoys) which were placed in the oceans of the southern hemisphere from the ships of 12 countries (these were primarily commercial vessels making voyages to Antarctica); 19 buoys were dropped from aircraft. The instrumentation on these buoys ensured measurements of atmospheric pressure and water temperature. This information was especially important for the tie-in of satellite temperature profiles. If it is assumed that the data for each buoy are representative within the limits of a circle with a radius of 500 km, the maximum coverage with observational data in May 1979 for the zone 20-65°S attained 80%, which provided a denser network of pressure data than in the northern hemisphere. Statistics on the malfunctioning of buoys revealed that during the 240 days only 2% of the buoys failed.

The tracking of buoy trajectories made it possible to obtain a wealth of surface information on currents in the southern hemisphere. The reports of D. Zillman (Australia), D. Luteharms and H. Valentine (South African Republic) gave interesting examples of analysis of the dynamics of currents and revealed the presence of a major anticyclonic eddy in the Tasman Sea, rings and other mesoscale characteristics of ocean circulation. Three typical circulation components were registered to the south of Africa: a wind-induced coastal upwelling in the Benguela system, the main westerly Alguhas boundary current (a study was made of intensification of the upwelling front to the west of Capetown under the influence of this current) and the zonal flow of the Antarctic Circumpolar Current. All these components are highly variable, which means that classical hydrophysical observation systems are inadequate and the joint analysis of IR satellite images, hydrographic data and observations from drifting buoys is promising.

The use of data on temperature of the ocean surface made it possible to carry out synoptic mapping of temperature of the ocean surface in the high latitudes of the southern hemisphere with a reliability and detail not possible earlier. The construction of maps of the mean monthly values and anomalies of temperature of the ocean surface on the basis of buoy and ship data affords new possibilities for studying the ocean and atmosphere. Buoy data make an important contribution to information on the high latitudes. However, discrepancies in buoy and ship data on temperature of the ocean surface can be noted.

Buoy observations were important for operational synoptic analysis and weather forecasting in the southern hemisphere during the FGGE period. Data on atmospheric pressure are usually adequate for a far more reliable clarification of macroscale circulation over the ocean in the middle and high latitudes than was possible earlier. There is a small but statistically significant increase in the reliability of

Table 5

Evaluation of Prospects for Multibranch Use of "Argos" System

Area of use	Number of OP		Required localization accuracy	Necessary routineness in collecting data			Total
	data reception only	localization		6 hours	6-24 hours	24 hours	
Hydrology	18			2	10	16	18
Biology		39	1 km	10	8	31	49
Geology	29			15	14		29
Agriculture	1				1		
Glaciology	23	83	1-5 km	65	15	26	106
Oceanography	7	560	1 km	363	64	140	567
Meteorology	70	160	1-5 km	185	18	27	230
Total:	148	852		445	130	230	1000

Table 6

Characteristics of Geostationary Meteorological Satellites

Satellite	Subsatellite point	Collected data	Restoration time GMT *	Latitude zone	Longitude zone	Horizontal resolution, km	Remarks
GEOS-East	75° W	Оперативные данные о ветре (НСОС) A)	00.00 12.00 18.00	45° N —45° S	150—25° W	250	1) ГСОС-восток и запад охватывают диапазон 175° в. д.—90° з. д.
		Данные о ветре в тропиках (ЦИКИ) B)	17.00	15° N —15° S	130—20° W	100—200	
GEOS-West	135° W	Оперативные данные о ветре (НСОС) A)	00.00 12.00 18.00	45° N —45° S	175° E —85° W	250	
GEOS-West	135° W	Данные о ветре в тропиках (ЦИКИ) B)	21.00	15° N —15° S	170° E —90° W	100—200	
GMS "Himawari"	140° E	ЯМА, оперативные данные о ветре [2] C)	00.00 12.00	50° N —50° S	90° E —170° W		2) ЯМА получает также данные по ТПО
"Meteosa·"	0°	Оперативные данные о ветре (ЕКА) D)	00.00[3] 12.00	50° N —50° S	50° W —50° E	200	3) Иногда производится обработка данных за 18.00 СГВ
GEOS-Indian Ocean	60° E	Данные о ветре для Индийского океана (ЦИКИ) [4] B)	10.00 22.00	55° N —55° S	5—115° E	250—500	4) В период отказа ИК датчика только одна серия данных в сутки
		Данные о ветре для Индийского океана с высоким разрешением (ЦИКИ) [5] B)	08.30 20.45	35° N —20° S	30—110° E	200—300	5) Только в период 1 мая—8 августа 1979 г.
GEOS-Indian Ocean	60° E	Данные о ветре (ЛДМ)[6] E)	16.00	30—35° N	30—90° E		6) Только за периоды 17—18 января, 1—10 февраля и 16 мая—30 июня
		Данные о ветре (АКИ)[7] F)	08.30 20.30	20° N —20° S	30—110° E		7) Только за период 5 января—5 марта

* Greenwich Mean Time

KEY TO TABLE 6

A) EPA, operational data on wind
B) Center for Engineering and Space Research at University of Wisconsin
C) Japanese Meteorological Agency, operational data on wind
D) European Space Agency, operational data on wind
E) Wind data, French Laboratory of Dynamic Meteorology
F) Wind data, West German Aerospace Institute

1) GEOS-East and West take in range 175°E-90°W
2) The Japanese Meteorological Agency also receives data on ocean surface temperature
3) Data for 1800 GMT are sometimes processed
4) During the period of failure of the IR sensor only one series of data per day
5) Only during period 1 May-8 August 1979
6) Only during periods 17-18 January, 1-10 February and 16 May-30 June
7) Only during period 5 January-5 March

Table 7

Comparison of "Navaid" System and Ordinary Aerological Soundings

Ship	Position of ship	Comparison station	ΔR km	Δt min	Standard deviations A	B	C	D
"Pariso"	Vancouver	"Quadra" research ship	45	29	73	1.5	17	3.7
"Vilex"	Singapore	48694	17	52	27	1.3	5	5.7
"TTRS-9"	Hankow	59287	57	1	89	2.0	7	2.3
"Spratley"	Sydney	94767	35	0	36	1.6	24	2.2

A) altitude, m
B) temperature, °C
C) humidity, %
D) wind, m/sec

Table 8

Modified Submasses of Level IIb FGGE Data

Submass and type of data	Number of magnetic tapes	Number of days/tapes
All data except for satellite soundings and radiation	61	6
1. Vertical profiles of meteorological elements (including limb scanning data)	19	20
2. Horizontal sounding data (aircraft, constant-level balloons, etc.)	7	60
3. Characteristics of land surface	25	15
4. Sea data (ships, buoys, etc. including sea surface temperature from satellite data)	13	30

numerical forecasts with the additional use of buoy data. The regional prognostic centers of the southern states of Australia could more reliably identify the features of weather-forming systems over the oceans situated to the south of the Australian continent, which ensured a considerable improvement in regional forecasts. It became clear, in particular, that many of the high-latitude cyclones are considerably more intense and westerly transport is stronger than was assumed earlier.

Information from drifting buoys has already revealed some significant gaps in modern concepts concerning climate in the southern hemisphere. A possible contribution of this information to increasing the reliability of data on climate involves the following directions: 1) structure of the field of ocean surface temperature; 2) surface currents; 3) surface pressure field; 4) wind field at the surface (determined both from the pressure field and from the drift of buoys); 5) parameters of the free atmosphere, reconstructed on the basis of the surface pressure field (geopotential, thermal wind); 6) evaluations of humidity, cloud cover and other characteristics.

A major contribution to the mass of FGGE data was made by observations within the framework of the program of the system of ships for wind observations in the tropics. More than 40 ships (Table 1) carried out 3,004 (SOP-1) and 3,938 (SOP-2) soundings of wind, temperature, humidity and pressure. As noted by E. Yatila (WMO), more than half of the entire volume of wind observational data was obtained using a method based on the tracking of radiosondes using the existing international navigation system "Omega," which is intended for the servicing of ships and aircraft. The principle for functioning of this system involves the use of a coordinate system for the geographic tie-in of radiosondes consisting of the hyperbolic isolines of the phase difference of two radio transmitters: A and B (these isolines are geographically stationary). Data for a third transmitter are used in generating the isolines A and C. The presence of two pairs of stations in the "Omega" system ensures a precise determination of the position of a point on a plane. The rising radiosonde receives and transmits signals of the transmitter in the "Omega" system to a corresponding shipboard or land station where this information is processed for the purpose of tracking the horizontal coordinates of the radiosonde, whose altitude is determined from measurements of the temperature and pressure values. Applicable to the tasks of the FGGE program this method has been given the name "Navaid" sounding system.

The international comparisons of the "Navaid" system and ordinary aerological soundings revealed the standard deviations given in Table 7. Here ΔR and Δt are the spatial and temporal discrepancies of soundings (the first could favor an appreciable increase in the standard deviation).

The accuracy in wind determination is dependent on the quality of transmitter signals in the "Omega" system. If this quality is good, averaging of the signals over a time of about one minute is adequate for ensuring an accuracy of about 2 m/sec. In the case of a lower quality it is necessary to increase the averaging interval. Statistical data for the FGGE period indicate that for 98.5% of the soundings the wind velocity standard deviation was less than 1.6 m/sec. In 75% of the cases the averaging time interval corresponded to a thickness of the layer equal to 1,100 m or less. In 90% of the cases the thickness of the layer was less than 1,600 m.

Probes dropped from aircraft (Table 1) were used for 5,091 soundings of temperature, humidity and wind in the tropical zones of the Atlantic, Pacific and Indian Oceans. During SOP-1 a total of 153 constant-level balloons were launched from Easter and Canton Islands. The duration of functioning of 38% of the balloons was less than 10 days; more than half the balloons drifted in the southern hemisphere. A total of 160 balloons were launched during SOP-2 (launchings were also made from the Marianas); once again a considerable number drifted in the southern hemisphere. A great volume of data was obtained as a result of the installation of automatic meteorological stations on wide-bodied commercial aircraft. Equipment for the relay transmission of data via geostationary meteorological satellites was used on 17 aircraft.

The problem of processing and analyzing the gigantic volume of FGGE data is of great importance. In this connection an American data processing team (W. McGovern) prepared and is carrying out an FGGE program for modifying the structure and compression of the level-IIb data mass, the intention being to make them more convenient for the use of users interested in an analysis of only a small part (or a combination of different parts) of the entire data mass. The modification of the structure involves the formation of a chronological sequence of the most important level-IIb data, which makes it more convenient to use data in numerical modeling. However, for many users it is better to have data grouped by observational subsystems and definite geographical regions. In accordance with these requirements, the data mass will consist of four submasses at level-IIb containing all the results of observations, except satellite sounding data and outgoing radiation data for a cloudless sky (Table 8). The forming of this data mass, accomplished in cooperation with the United State Climate Center, should be completed in the autumn of 1980. The data will be stored in World Data Center A. Both the complete and modified data masses are global. Since even the use of the modified data mass can be difficult for some users, and also for the purposes of excluding parallelism between the data processing team and the National Climate Center, the possibility of a corresponding servicing of users is being considered.

By the time of beginning of the FGGE program it was clear that it was necessary to monitor the quality of satellite sounding data, but it was already too late to introduce a correction into the method for operational processing of data. Accordingly, provision is made for subsequent "editing" of all data for American satellites with respect to temperature and wind. This was begun in late 1979. By late 1981 the reworking of data for both SOP should be completed. Its objective is not the rejection of data, but an evaluation of their quality (for example, "reliable," "probably reliable," "probably unreliable," "unreliable"). The criteria for evaluation of the quality of the data are spatial-temporal consistency, correspondence to other data and synoptic consistency.

For the analysis of local weather-forming phenomena in active zones (storms, typhoons) work will continue on processing of ordinary and satellite information with assurance of a considerably higher spatial (horizontal) resolution (for example, in the case of thermal sounding -- up to 30 km instead of 250 km in routine processing). The "Macidas" interactive system created at the University of Wisconsin is used for this processing.

The United States Navy Oceanographic Computation Center, in cooperation with the data processing team, is preparing level-IIIb oceanographic and meteorological data in FGGE formats for the northern hemisphere with a grid of 61 x 6 points, similar to the grid of a polar stereographic projection having an interval of 381 km. A finer grid is used for the regions of the Gulf Stream and Mediterranean Sea. In the atmosphere 11 levels (layer 100-925 gPa) have been adopted; the wind is also examined in a boundary layer reduced to a height of 19.5 m. For the ocean temperature is determined at the surface and at depths of 30, 60, 90, 120, 180, 240 and 360 m, and also depth of the mixing layer, temperature at the thermocline level and thermocline tendency. In addition, information on the field of waves (direction, period and height) is included. The compilation of the entire data mass should be completed by late 1980.

Very interesting work on evaluating the informational contribution of data from satellite remote sounding to numerical weather forecasting has been done by specialists of the European Intermediate-Range Forecasting Center (L. Bengtsson and P. Kalberg). The global data mass obtained as a result of implementation of the FGGE program is especially important for an analysis of weather-forming processes in the tropics and in the southern hemisphere. Even an initial analysis has revealed that general circulation of the atmosphere in 1979 was considerably more intense than in the preceding years. This can be attributed only in part to the usual climatological variability. Without question, a major contribution was made by the unique completeness of observations, especially the data from the network of sea buoys, which made possible the detection of intensive weather-forming systems of lesser scales and also synoptic analysis in earlier uncovered regions. An examination of the data revealed an unexpectedly strong variability of the tropical atmosphere at synoptic scales, intensive exchange of momentum, heat and moisture at least in some regions of the equatorial zone. These results confirm the soundness of the conclusions drawn during recent years from numerical modeling, especially the conclusion that the exclusion of the southern hemisphere leads to a considerable deterioration of the reliability of a forecast of superlong waves in the northern hemisphere.

The new FGGE observational systems differ fundamentally from those existing earlier in that almost all the observational data are asynoptic and nonuniformly distributed in three-dimensional space. Information on the fields of mass and wind proves to be independent and frequently inconsistent in space and time. The new observational systems characterize several different scales of general circulation of the atmosphere and spatial correlation of errors in both horizontal and vertical directions is typical for some of them. All this determines the fundamentally great importance of use of improved methods of four-dimensional assimilation, as well as models of general circulation of the atmosphere with a high resolution capable of correct description of the principal physical processes at global scales.

There has been discussion of the results of numerical forecasts obtained in such a way that a forecast for a different time in advance is computed with the exclusion of certain data (and the complete data mass) for evaluating the informational contribution of different components of the observational system. The basis for the complete data mass was level-IIIb FGGE data prepared by the European Intermediate-Range Forecasting Center (global fields of meteorological elements interpolated at a point in a regular grid for three months for four times a day). Methods for assimilation, prediction and monitoring the quality of data have been described in detail.

The assimilation method developed at the European Intermediate-Range Forecasting Center is based on geostrophic balancing of the covariations of forecasting errors for geopotential and wind. A 15-level model of the atmosphere (10-1000 gPa) with a grid having an interval of 1.875° in latitude (longitude) is used.

The checking of the quality of objective analysis is accomplished in three stages: 1) an initial "estimated evaluation; 2) a comparison with near-lying observational data; 3) a comparison with the results of the preliminary analysis. The great discrepancies between the results of IR and microwave thermal sounding (up to 10°C) in the initial stage caused the rejection of use of microwave data, but after 10 February these data began to be taken into account with the exception of all data from microwave sounding: over the land, in the tropical zone (latitudes less than 20°) or regions of the ocean with heavy precipitation. With respect to the space observation system it is assumed that it will consist of the following components: 1) pressure measurements at the level of the underlying surface; 2) wind observations in the free atmosphere (constant-level balloons and aircraft); 3) satellite thermal sounding; 4) the wind field, reconstructed on the basis of the movement of clouds.

The results of numerical experiments indicate a considerable informational contribution of the space observational system used during the FGGE period. Even with exclusion of all the data from usual observations of the surface network, except for data on pressure at the level of the underlying surface, the remaining data are capable of ensuring information on the initial fields of meteorological elements which is adequate for predictions of a satisfactory quality for several days in advance for the entire earth. It is important that the data from the space observation system with surprising reliability reveal the macroscale characteristics of atmospheric energy. Nevertheless, it is unquestionable that radiosonde observations considerably improve the quality of forecasting for the northern hemisphere and substantially increase the useful advance time of the forecast.

The results indicate that the exchange between hemispheres was more intensive than expected. There is every basis for assuming that the tropics can exert an influence on processes in the middle and high latitudes more rapidly and more significantly than was assumed earlier. It therefore follows that it is categorically necessary to make regular observations in the tropics in order to ensure a forecast for 4-5 days and in investigations of climate.

In the planning of a global observation system ensuring the needs of weather forecasting and the study of climate it is important to take the following circumstances into account: first, numerical experiments have demonstrated the fundamentally great importance of satellite observations of the wind field in the tropics, which is evidence of the need for achieving the highest possible accuracy in reconstructing fields (the main difficulty in processing FGGE data was the relatively low accuracy in vertical tie-in of wind fields); second, further efforts on improvement in methods for reconstructing the vertical temperature profile and four-dimensional assimilation are extremely important; third, a global system constructed on a combination of data from ordinary and satellite observations is important.

In conclusion it must be emphasized that the COSPAR symposium on FGGE results revealed success (on the whole) in implementation of the FGGE observational program. It revealed the great efforts which now must be applied for the processing and analysis of the global mass of data and made clear the prospects for further development of the global system of meteorological observations.

REVIEW OF MONOGRAPH BY I. F. KARASEV: 'RIVER HYDROMETRY AND INVENTORYING OF WATER RESOURCES' (LENINGRAD, GIDROMETEOIZDAT, 1980)

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 p 122

[Review by N. B. Baryshnikov, doctor of geographical sciences]

[Text] A monograph by I. F. Karasev, entitled RECHNAYA GIDROMETRIYA I UCHET VODNYKH RESURSOV (River Hydrometry and Inventorying of Water Resources), with a volume of about 20 printer's sheets, prepared by the Gidrometeoizdat, has now been published.

In presenting different aspects of hydrometry, its author as a rule avoids a repetition of well-known subject matter and emphasizes the poorly studied points or stresses the theoretical validation of the methodological recommendations used in practical work.

In the monograph the author devotes much attention to evaluation of the accuracy in measuring elements of the water regime, employing for this purpose both his own findings and the methods used in related disciplines, especially in meteorology. In the book more than a little importance is also placed on problems involved in optimization of observations, new measurement methods and instruments which can be used in the hydrological network of different departments.

The book consists of an introduction, nine chapters and a bibliography of Soviet and foreign literature which includes about 400 items.

The introduction gives a concise outline of the development of the system for hydrometric observations in our country and briefly summarizes the book. There is a diagram which illustrates the dynamics of development of the number of hydrological posts in the Soviet Union, United States and Canada (p 4).

Chapter 1 is evidently fundamental in the book. Each of its sections is devoted to a problem which is independent and important for hydrometry. After an exposition of a list of standard observations made at various stations and posts of the Hydrometeorological Service network, the author proceeds to an analysis of the accuracy of observations. In presenting his theme he classifies all measurement errors as random and systematic and cites criteria for determining their limiting values. In this same chapter he examines some aspects of mathematical statistics as applicable to a description of hydrological fields on the basis of data from discrete measurements. Subsequent sections are devoted to the principles of optimization of observations and the possibilities of their use in optimizing the layout of the network of points for making observations of hydrological parameters. Without giving a detailed analysis of this section, it must be noted that the principles for formulation of the problem are correct and entirely timely.

Next the author sets forth the principal aspects of the method and the techniques for measuring the principal elements of the water regime: water levels (Chapter 2), water sections and channel relief (Chapter 3), current velocities in river channels and on river floodplains (Chapter 4) and water discharges (Chapter 5).

Chapters 6 and 7 are devoted to the method for determining runoff as the problem of constructing a continuous hydrograph on the basis of data from discrete measurements of water discharge. The author establishes the difference between and the relative order of operational and regime determination of runoff and proposes mathematical models for this purpose which have a measurement-hydraulic basis. In describing methods for the extrapolation of measured discharges he gives an original interpretation of the "kinematic wave" equation. A scale of roughness coefficients for river channels and floodplains proposed by the author is of great interest. It is based on data in the literature which have been systematized with allowance for possible errors in evaluating hydraulic resistance.

Chapter 8 is devoted to the hydrometric aspects of inventorying and use of water resources. It gives the scientific-methodological principles for a national inventory of waters and the corresponding methodological aspects are given in the chapter which follows. This chapter takes note of the interesting (although not put to practical use) structure of a checking-calibration system which is intended for the metrological support of hydrological observations.

The content of the monograph is based on investigations of recent years. The studies of both Soviet and foreign authors are fully taken into account, as is indicated by the extesive bibliography of exploited literature.

The results of the methodological investigations carried out at the State Hydrological Institute have been reflected in the hydrological publications INSTRUCTIONS FOR HYDROMETEOROLOGICAL STATIONS AND POSTS. The validation of these highly important methodological documents, presented in the monograph, will ensure the effective use of the instructions which they contain in the optimizing of observations on rivers.

Unfortunately, the monograph contains regrettable misprints and inaccuracies which must be eliminated with more careful editing of the second edition.

This book by I. F. Karasev on the whole is a very timely publication. The debatable nature of a number of the author's points of view favors the further progress of hydrometry. It is already used for teaching purposes at hydrometeorological institutes and universities in the training of hydrological engineers and will become a valuable aid for specialists working in the system of the State Committee on Hydrometeorology and Environmental Monitoring and other departments.

A more detailed analysis of all the points in the monograph, especially the debatable points, will require considerable time and evidently will be repeatedly reviewed by specialists.

SIXTIETH BIRTHDAY OF NATAL'YA LEONT'YEVNA BYZOVA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 p 123

[Article by specialists of the Institute of Experimental Meteorology]

Natal'ya Leont'yevna Byzova, a well-known scientist in the field of the physics of the atmospheric boundary layer, on 19 March 1981 marked her 60th birthday and the 35th anniversary of her scientific and public activity.

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The scientific research work of N. L. Byzova began in the Black Sea Division of the Marine Hydrophysical Institute, USSR Academy of Sciences, in 1946, after graduation from the Physics Faculty of Moscow State University. She successfully defended her candidate's dissertation in 1953.

Between 1957 and the present time N. L. Byzova has worked at the Institute of Experimental Meteorology of the USSR State Committee on Hydrometeorology and Environmental Monitoring (in the past an affiliate of the Institute of Applied Geophysics), where she soon advanced into the ranks of the leading specialists. Since 1968 she has headed the Scientific Division of Physics of the Atmospheric Boundary Layer.

Under the direction of N. L. Byzova a major research group was formed at the Institute of Experimental Meteorology whose work on study of turbulence in the atmospheric boundary layer and diffusion of impurities in the atmosphere, carried out using a 300-m meteorological mast, received universal recognition.

The field of scientific interests of N. L. Byzova was closely related to the timely problem of monitoring contamination of the air medium. Natal'ya Leont'yevna invested much work and creative initiative in the development of studies for investigation of the diffusion of impurities in the atmosphere. Under her direction and with her direct participation these investigations were carried out over a number of years. The results of many years of scientific investigations were generalized in the doctoral dissertation of N. L. Byzova in 1973. She is the author of almost 100 scientific studies, including the monograph RASSEYANIYE PRIMESI V POGRANICHNOM SLOYE ATMOSFERY (Scattering of an Impurity in the Atmospheric Boundary Layer).

Natal'ya Leont'yevna devotes much attention to the editing and review of scientific studies, the direction of young specialists and graduate students. She is always ready to come to assistance and generously shares her rich experience and knowledge.

N. L. Byzova has repeatedly represented Soviet meteorological science at international conferences and meetings.

The scientific research work of Natal'ya Leont'yevna is successfully combined with public activity. She is a permanent lecturer of the "Znaniye" ("Knowledge") Society and is a propagandist in the political education network.

For her self-sacrificing work and successes in the development of meteorology N. L. Byzova has been awarded the Order of the Red Banner of Labor, the anniversary medal "For Illustrious Work in Commemoration of the Hundredth Anniversary of the Birth of V. I. Lenin" and the Honorary Lenin Diploma.

In congratulating Natal'ya Leont'yevna on her noteworthy anniversary, we wish her good health, creative successes and joy in life.

EVENTS AT THE USSR STATE COMMITTEE ON HYDROMETEOROLOGY AND ENVIRONMENTAL MONITORING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 pp 123-124

[Article by V. N. Zakharov]

[Text] An expanded session of the Board of the USSR State Committee on Hydrometeorology and Environmental Monitoring was held on 23 March 1981 at the Central House of Writers.

The Chairman of the State Committee on Hydrometeorology and Environmental Monitoring, Yu. A. Izrael, Corresponding Member USSR Academy of Sciences, presented a report at the session entitled "Results of the Work of the State Committee on Hydrometeorology and Environmental Monitoring During the Tenth Five-Year Plan and the Tasks of the Eleventh Five-Year Plan Following From the Resolutions of the 26th CPSU Congress, the Positions and Conclusions of the Report of Comrade L. I. Brezhnev, General Secretary of the Central Committee CPSU, at the Congress."

In the introductory part of his report Yu. A. Izrael stated that the session of the Board was taking place in an atmosphere of political and work ascendancy as a result of the recently transpiring 26th CPSU Congress.

The speaker stated that the large body of personnel of the State Committee on Hydrometeorology and Environmental Monitoring unanimously approves the resolutions of the 26th CPSU Congress, the positions and tasks set forth in the report of Comrade L. I. Brezhnev, and accepts them as fixed goals.

In discussing the hydrometeorological support of the national economy, the speaker noted that in three of five years of the report period there were unfavorable hydrometeorological conditions. In this section he mentioned the great work which was done by the USSR Hydrometeorological Center, the Institute of Applied Geophysics, the Estonian Administration of the Hydrometeorological Service and the Central Volga Hydrometeorological Observatory in the hydrometeorological support of the 22d Olympic Games. The probable success of short-range weather forecasts and warnings of the occurrence of dangerous phenomena was increased by 1-3%. There was an increase in the area of agricultural crops protected against hailfalls and at the present time it is 6.4 million hectares. At the same time, the report also mentioned a number of shortcomings in work on the hydrometeorological support of the national economy.

At the present time the scientific research and experimental design work at the State Committee on Hydrometeorology is being carried on by 21 scientific research institutes and the Central Design Bureau of Hydrometeorological Instrument Making.

The plan for scientific research and experimental design work for 1976-1980 for the most part has been carried out and a number of results of great scientific and practical importance have been obtained. It was possible to achieve new results in the improvement of methods for making weather forecasts for short and intermediate advance times. Much work was carried out in the field of agrometeorological and hydrological forecasts. Investigations were made in the field of formulating a theory of climate and developing methods for the prediction of climate. Complex predictions of the state of the environment were developed, as well as methods for computing different hydrological characteristics. Scientific investigations were made for developing new and improving existing methods for the artificial modification of meteorological processes. Major investigations of the world ocean and investigations in the Arctic and in Antarctica were carried out, etc.

During the Eleventh Five-Year Plan work will be carried out on five programs approved by the State Committee on Science and Technology, USSR Gosplan and USSR Academy of Sciences, for which the State Committee on Hydrometeorology and Environmental Monitoring is the key department, and also a number of other programs for which the State Committee on Hydrometeorology and Environmental Monitoring will be a co-administrator. In addition, at the present time eight purposeful complex programs have been developed by the State Committee on Hydrometeorology and Environmental Monitoring along the lines of its activity in which there is reflection of both scientific and production aspects.

The speaker also discussed existing shortcomings in the organization and implementation of scientific research.

The following problems were also discussed: study and monitoring of environmental contamination; development of a national system for observations and monitoring of the state of the environment and climate; international cooperation; administrative activity and material-financial support; work with personnel; work conditions and work safety; socialist competition.

In conclusion the speaker expressed the assurance that the 100,000 workers of the State Committee on Hydrometeorology and Environmental Monitoring will honorably cope with the tasks assigned them.

Participating in discussions of the report were the heads of the Administrations of Hydrometeorology and Environmental Monitoring, directors of institutes and representatives of the central headquarters of the State Committee on Hydrometeorology and Environmental Monitoring and the Central Committee of the Trade Union of Aviation Workers.

The assemblage unanimously adopted a petition to the Central Committee CPSU, Presidium of the USSR Supreme Soviet, USSR Council of Ministers and Comrade L. I. Brezhnev, General Secretary of the Central Committee CPSU, Chairman of the Presidium USSR Supreme Soviet.

The session was attended by the Deputy Chairman of the USSR Council of Ministers, Comrade Z. N. Nuriyev, responsible workers of the Central Committee CPSU, and also the USSR Gosplan, USSR State Committee on Science and Technology, USSR Academy of Sciences, other ministries and departments.

CONFERENCES, MEETINGS AND SEMINARS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 pp 124-128

[Article by Yu. G. Slatinskiy and N. A. Zaytseva]

[Text] A regular session of the basin section "Indian Ocean and Southern Seas" of the Scientific Council on the Problem "Study of the Oceans and Seas and Use of Their Resources" of the USSR State Committee on Science and Technology was held during the period 20-21 November 1980 at Sevastopol'. The session was attended by 67 persons from 15 scientific research, planning and other organizations whose activity is related to the sea. From the State Committee on Hydrometeorology the session was attended by representatives of the Arctic, Antarctic and Marine Administration, the Odessa and Sevastopol' Divisions of the State Oceanographic Institute. A total of 28 scientific reports were presented. These summarized the results of studies by members of the basin section in the field of hydrology, hydrochemistry and hydrobiology of the Black and Mediterranean Seas and the Indian Ocean.

In discussing the preliminary results of oceanographic investigations in the Indian Ocean under the "Kiprio" project, V. A. Kosnyrev (Marine Hydrophysical Institute) noted that in a large-scale survey in the western part of the ocean it was possible to discover more than 10 weak eddy formations. Their lifetime was approximately 2-5 times less than in the Atlantic; on the other hand, the velocity of movement was rather great, up to 9 miles per day. The low eddy activity in combination with the pronounced stratification of water masses (vertically) was also tied in to the reduced background of biological productivity in the ocean.

L. A. Koveshnikov (Marine Hydrophysical Institute) reported on the results of study of the thermohaline structure of waters in the equatorial zone of the Indian Ocean during the period of the summer monsoon. The investigations were made in three polygons situated in different parts of the ocean. The penetration of subantarctic waters into the northern hemisphere to 2°N was noted. A frontal zone with great horizontal salinity gradients, separating the waters of the Arabian Sea from the remaining part of the ocean, was detected.

V. A. Bryantsev (Sea of Azov and Black Sea Scientific Research Institute of Fishing and Oceanography) told about the search for the most productive zones in the Indian Ocean. It is noted that the horizontal advection of antarctic waters, favoring the inflow of biogenous substances, is observed only to the south of 40°S. In the remaining part of the ocean a constant inflow of biogenous substances occurs only in zones of upwelling on the continental shelf and in zones of current divergence.

V. I. Mel'nik (Institute of Geological Sciences, Ukrainian Academy of Sciences) reported on the results of investigations of bottom deposits in the northern part of the ocean. It was possible to make a more precise determination of the composition and conditions of formation of bedrock and the most recent deposits and establish the dependence of the distribution of ferromanganese nodules on the nature of bottom relief and tectonic conditions.

Several reports were devoted to the fish resources of the ocean. E. Z. Samyshev (Sea of Azov and Black Sea Scientific Research Institute of Fishing and Oceanography) reported on investigations of the biological productivity of waters in the open part of the Arabian Sea. L. V. Kuz'menko, G. V. Barinov and A. D. Gordina (Institute of Biology of the Southern Seas) discussed some problems involved in study of primary production and ichthyoplankton in the equatorial zone of the ocean.

I. M. Ovchinnikov (Southern Division, Institute of Oceanology, USSR Academy of Sciences) in his report analyzed the results and prospects for study of the Mediterranean Sea basin during the Tenth Five-Year Plan. A number of major expeditions were carried out with the occupation of about 2,500 deep-water stations. A particularly great volume of work was carried out in the winter of 1977 when in a synchronous survey it was possible to cover virtually the entire surface of the Mediterranean Sea. The research materials were used in publishing the monograph entitled GIDROLOGIYA SREDZEMNOGO MORYA (Hydrology of the Mediterranean Sea) and several specialized collections of articles, an atlas of currents in the Mediterranean Sea is being prepared for publication and work has developed for creating a specialized data bank which already includes more than 21,000 stations.

V. A. Zhorov (Marine Hydrophysical Institute) reported on the results of investigations in the basin of the Black Sea under the "SKOICh" project. A detailed study was made of the process of formation of deep waters and it was possible to trace the propagation of the highly saline waters of the Sea of Marmara in the Bosphorus region. On the basis of a great volume of experimental data it was possible to construct seasonal charts of the quasistationary currents. A number of mathematical models were used in computing possible changes in physical fields and the intensity of vertical exchange in connection with the withdrawal of part of the river runoff. A generalization of data on the spatial-temporal variability of the oxygen and hydrogen sulfide fields was initiated. The research data were used in publishing two specialized collections of articles.

V. V. Belyavskaya and L. F. Yermakova (Sevastopol' Division of the State Oceanographic Institute) reported on the results of hydrochemical and hydrobiological investigations carried out in the open sea and individual regions of the coastal zone. During the past five-year period more than 60 expeditions were carried out during which 5,400 abyssal stations were occupied. A detailed study was made of the statistical characteristics of the hydrogen sulfide fields. Regions of anomalies in the salinity field were detected and long-term data on the content of dissolved oxygen were generalized. Intensive studies were made for optimizing the network of stations in the open sea and choice of the most representative regions of observations. Work proceeded on the development of methods for determining some trace elements in sea water and work was initiated on the generalization of long-term data on the hydrochemical regime of the mouth regions of rivers.

I. F. Gertman (Sevastopol' Division, State Oceanographic Institute) gave a detailed discussion of some problems involved in the forming of a regional bank of deep-water hydrological information for the basin of the Black Sea and Sea of Azov. It is noted in the report that during the last two decades about 60,000 abyssal stations have been accumulated in the archives of members of the basin section. In order to make effective use of information in the interests of the national economy a centralized data mass on technical carriers has been created and a set of programs is being developed in order to ensure the spatial-temporal sorting and statistical processing of data. All the mathematical support of the bank was prepared in ALGOL-60 language. The materials in the bank have already been used in computing the mean long-term monthly and seasonal norms for the temperature and salinity fields in the Black Sea, evaluation of their variability and analysis of the mean annual values of the heat and salt supplies in the sea and the role of the anthropogenic factor in their changes.

A resolution which was adopted defined a number of leading tasks for the further development of investigations in the basin of the southern seas and the Indian Ocean. In particular, it was recommended that further work on study of the Indian Ocean be tied in with the specific multisided programs of the USSR Fish Industry Ministry ("Kril'," "Kal'mar" and others). It was deemed desirable that work be continued on the multisided study of the Mediterranean Sea under both departmental and international programs. In the Black Sea it is recommended that work be broadened in the western part and in the region near the Bosphorus. Plans call for concentrating efforts on clarification of the factors responsible for freeze-ups in the northwestern part of the sea.

The participants in the session approved the work of the Sevastopol' Division of the State Oceanographic Institute on the organization of a regional bank of hydrometeorological information. It was recommended that all institutes in the basin cooperate in this work in order to bring about the maximum broadening of the data base. The resolution called on the State Committee on Hydrometeorology to assign to the Sevastopol' Division of the State Oceanographic Institute the functions of a regional center for oceanographic information for the Black Sea and the Sea of Azov.

Yu. G. Slatinskiy

A scheduled international symposium on radiation was held during the period 10-15 August 1980. It was organized by the Radiation Commission of the International Association of Meteorology and Atmospheric Physics with the support of the WMO, COSPAR and the American Meteorological Society (such symposia are usually called each four years). The symposium was held at the University of Colorado (Fort Collins, Colorado) with the participation of 340 representatives from 26 countries. The USSR delegation consisted of four persons.

The symposium program included six sessions devoted to the principal directions in study of atmospheric optics and radiation:

1 -- radiation in the middle atmosphere;

2 -- the latest results of radiometric sounding of the atmosphere (indirect methods);

3 -- atmospheric optics and spectroscopy;
4 -- radiation and modeling of climate and weather and forecasting;
5 -- the earth's radiation balance;
6 -- scattering and absorption of radiation in the cloudy and turbulent atmosphere.

Session 7, devoted to methods and instruments, was carried out in the form of a stand presentation of reports during the entire period of the symposium. At the same time there was an exhibit of instruments and equipment of several American measurement laboratories. In addition to oral presentations the program included stand sessions. A total of about 210 reports were read and presented at the stands.

There were neither review nor solicited reports at the symposium. All speakers without exception were given 10 minutes for reading of the report and 5 minutes for questions and all speakers were required to supply three-page expanded summaries of their reports. A collection of expanded summaries was published before the beginning of the symposium and was handed to participants at the time of registry.

Session 1 was devoted to the theory of and observations of the interaction between radiation and dynamic factors, radiation and composition of the stratosphere and the above-lying layers. G. London and H. H. Barson (United States) examined the absorption of UV and visible solar radiation by atmospheric ozone and also minor gases (CO_2 and H_2O). A number of reports were devoted to measurements from aircraft and satellites: UV radiation (in reports of American specialists from Virginia) and the parameters of stratospheric aerosol (Boulder, California). NASA is carrying out a program for investigation of the climatic effects of aerosol from satellites and aircraft. Several reports gave the preliminary results. Specialists from Wyoming have made measurements of the vertical profiles of the concentration of aerosol, ozone and NO_2 by indirect methods from an artificial earth satellite using a three-channel solar photometer (0.43, 0.6 and 1.0 μm). They also presented the results of 5-year investigations of the optical density of aerosol in the middle latitudes, carried out using balloons. Specialists from Boulder (United States) presented reports devoted to the results of the LIMS experiment (Limb IR Stratosphere Monitor), carried out on the NIMBUS-7 artificial earth satellite. The experiment made use of a 6-channel radiometer which measures the IR radiation of atmospheric gases during scanning across the earth's limb. Preliminary data have been obtained on the content of CO_2 and nitric acid and temperature profiles were reconstructed. Comparison of the latter with radiosonde and aircraft measurements reveals an agreement in the range 1-2°C.

Session 2 included the results of experiments carried out from satellite, aircraft and surface platforms. The experiments are carried out using spectrometers and narrow-band radiometers carried aboard artificial earth satellites and aircraft. Using remote methods it is possible to reconstruct the temperature and pressure fields, profile and total content of ozone, CO_2 and NO_2 (the reports were accompanied by profiles of these parameters, and also maps). G. Ohring and B. Neeman (Israel) compared several methods for determining the thermal wind on the basis of satellite radiation measurements. L. M. MacMillin (United States) proposed an improved operational technique for excluding cloud effects from temperature sounding from satellites, based on a comparative analysis of radiation from cloudy and cloudless sectors. Several reports by American specialists gave the results of radiometric measurements carried out from aircraft during a number of FGGE experiments, including during MONEX. These experiments were carried out for the purpose of perfecting methods for remote sounding, as well as for the correction of satellite data. A number of reports were presented on cloud cover: determination of the optical thicknesses of clouds, the upper boundaries of clouds, water content in clouds and the temperature profiles in the cloudy atmosphere.

At session 3 there was a discussion of new observations and theories related to lidar and other methods for remote sounding and also the fine structure of spectral absorption properties of different components of atmospheric composition. Reports were presented which were devoted to study of the fine structure of spectra of the atmosphere and contaminating impurities, investigations of atmospheric aerosol, optical properties of thin clouds of the Ci type, radiation transfer in haze layers, and also Sahara dust and its influence on climate, measurements of the intensity of sky glow at the zenith, etc. The principal methods are: photometry, spectrometry, aureole measurements, lidars, etc.

At session 4 there was a discussion of the types and contribution of different radiation components to numerical models. A large number of reports was devoted to an examination of cloud-climate relationships; in different numerical models estimates are made of the energy contribution of cloud cover (Australia, United States, Israel); the possibilities of parameterization of radiation transfer processes applicable to prediction models (West Germany, England, United States) are examined; estimates are made of the sensitivity of climate to changes in the solar constant (United States), the CO_2 content, etc. A report by R. Venerald and S. Manabe (United States) demonstrated the possibility of reconstructing the cloud cover using a model of global general circulation of the atmosphere. The consequences of the effect of anthropogenic factors on changes in atmospheric transparency, albedo of urban and rural regions, etc. are discussed. A report by O. Toon and J. Pollack (United States) gave an evaluation of the greenhouse effect of CO_2 in the example of the Venusian atmosphere. A report by E. Rashke, et al. (West Germany) described an adaptive and economical two-flow radiation model intended for use in models of general circulation and in prognostic models.

Session 5 included the results of measurements and special computations of the radiation balance of the earth-atmosphere system at all scales. Aboard several satellites ("TIROS-N", NOAA-F, NOAA-G, "NIMBUS-6 and -7") a complex experiment was organized for the first time for determining the earth's radiation balance; a number of reports gave preliminary results. T. Vonder-Haar (United States) examined the possibilities of an investigation of climate based on satellite measurements of the annual cycle of the earth's radiation balance. Radiation data from the GEOS satellite afford a possibility for investigating the temporal and spatial variability of the cloud cover. The problems of calibration of satellite radiometers are discussed separately. The reports of American specialists describe the technique for radiation measurements made using satellite wide-angle radiometers.

The reports in session 6 examined experimental and theoretical data on cloud albedo, radiation transfer in clouds, radiation properties of clouds of different forms, light scattering and attenuation in clouds. A series of reports was devoted to the study of cirrus clouds, their optical properties, liquid-water content, distribution of crystals in clouds and their role in climate. Several American reports examined the possibility of remote determination of the index of aerosol absorption, the intensity and degree of polarization, etc. Measurements of solar UV radiation and its attenuation by clouds and haze were discussed. Data were obtained on the spectral attenuation of the solar flux by ozone, Rayleigh scattering and aerosol and the dependence of the optical density of aerosol on wavelength. T. Mackey, et al. (United States) carried out a laboratory and field checking of the Monte Carlo model on the basis of scattering in restricted clouds. R. Welch and W. Zdunkowsky (West Germany) computed a series of radiation characteristics of the fields of cumulus clouds. N. Grassy, et al. (West Germany), also by computations, examined radiation transfer in vertically inhomogeneous multicomponent clouds in comparison with restricted clouds. R. Ellingson and E. Kolchinsky (Maryland) carried out computations of IR heating in an atmosphere with cumulus clouds and constructed diagrams of the rate of heating and cooling separately for the layer under the cloud and for the troposphere (0-15 km) with clouds in dependence on the quantity of clouds and their thickness.

The symposium defined the most timely modern directions in the study of radiation. Studies related to the formulation of numerous experiments on artificial earth satellites are being vigorously pursued. In these experiments measurements are made of the components of the radiation balance, temperature of the underlying surface and air density; the vertical profiles of temperature, ozone and water vapor are reconstructed; components of atmospheric composition at great altitudes are determined. In addition to satellites, abroad extensive use is being made of aircraft and complex experiments are being organized with the simultaneous participation of satellites and aircraft. During recent years considerable successes have been attained in investigations of aerosols; data have been obtained on the global distribution, chemical composition, and optical properties of aerosols, etc. In the field of investigation of the interaction between radiation and clouds increased attention has been given to high clouds and their role in climate. The results of radiation-dynamic investigations have clarified the role of radiation in the formation of climate. Different parameterization schemes have been created, intended for including radiation in a model of circulation and climate. Ways to use radiation in forecasting are being developed.

NOTES FROM ABROAD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 6, Jun 81 p 128

[Article by B. I. Silkin]

[Text] It is reported in the NEW SCIENTIST, Vol 89, No 1237, 1981 that the United States Council on Environmental Quality has presented the government with its 11th annual report containing a prediction of the state of the environment in the next few decades.

Within the United States, in addition to some indications of improvement in the state of the atmosphere and waters, there are negative tendencies. For example, during recent years it was necessary to ban the use of a large number of water sources for drinking purposes because they were contaminated by toxic substances. The most common among these were benzene, carbon tetrachloride, perchloroethylene and vinyl chloride.

The United States Environmental Protection Agency pointed out that contamination of ground water serving as a source of drinking water is observed in at least 34 states. The principal reasons for this include inadequate safety measures in the mining, petroleum and gas industries, leakage from containers of harmful substances, effluent from sewer systems and points for the collection of urban wastes and the improper storage of chemicals.

The spreading of deserts, it has been discovered, is occurring not only in the developing countries with their slash-and-burn agriculture. In the United States about 92 million hectares have undergone this process during recent years. In these areas there are active processes of erosion and salinization of the upper layer of soils and surface waters and the destruction of local vegetation.

This is attributable to incorrect irrigation methods, poor drainage, ground water exhaustion, excess grazing of domestic animals or the unprecedented growth of major populated places. The plans for a marked increase in coal production in the combustible shales in the western United States and increased lumbering there constitute a danger.

The authors of the report do not propose specific measures for contending with such tendencies.

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