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BASIC PROBLEMS OF THE HYDROMETEOROLOGICAL SERVICE

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Organization of Observations

Systematic observations of the atmosphere, seas, and rivers are made by a network of hydrometeorological stations spread irregularly over the USSR. The various offices which previously maintained the stations set them up arbitrarily without any unified plan. When the entire network was unified, the Hydrometeorological Service still did not know how many stations would be necessary.

A network of 10,000 stations and 20,000 posts is required in the USSR to obtain data on climatic and hydrological elements and local processes. At present, the network consists of 3,000 stations and 4,000 posts, nonuniformly distributed. The network is thick enough in industrial and populated regions, but quite insufficient in the north and northeast and in the Central Asia deserts.

After determining the required number of stations, plans were drawn up for their efficient allocation in the USSR. These plans were put into effect by making the network more efficient in populated and industrial regions; unnecessary stations were closed and the remaining stations were put in order. The war interrupted this work.

The Germans destroyed 3,500 stations and posts with all their equipment. Upon liberation, these stations were rapidly rebuilt so that at present almost all stations and most posts are in operation.

During the new Stalin Five-Year Plan, 500 stations, mostly in isolated regions, will be constructed.

No matter how thick the network of stations, aerological reports are still necessary to obtain the correct picture of atmospheric processes. In aerological studies, we are not keeping pace with the increasing requirements of our aviation with respect to the number of points producing atmospheric soundings, height of ascents, and quality of measurements. Measures are being taken to eliminate these defects this year. The main tool for obtaining aerological data is the

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radiosonde. We are increasing the number of points and the ceiling of radio-sounding. The aerograph is also used for aerological measurements. This year we are replacing outmoded aircraft which reached only 3-4 kilometers by some which reach 7 kilometers.

During the war, air weather reconaissance was used in our own and foreign armies. Specially-equipped planes were sent behind enemy lines to obtain weather data. We now use this method for regions without developed networks of stations and for sea areas.

The barrage balloon and radar are now used in aerology. The captive balloon permits one to follow time variations in meteorological elements at a certain height. It is comparatively cheap and simple to use, and is now being made available to use, and is now being made available to several stations.

Radar permits one to determine high-altitude winds under all conditions. Wires or other targets are attached to a small balloon so that radar can accurately determine the position of the balloon to 30 kilometers away.

Radar undoubtedly can determine the position of cloud masses and other atmospheric formations at great distances. Centimeter waves are reflected from such surfaces, thus making possible their detection.

This is the status and potentialities of typical methods for obtaining aerological data. The development of these methods and their use and study are the task of the Central Aerological Observatory, the youngest of Soviet scientific-research institutes. In addition, the observatory conducts systematic aerological investigations of various atmospheric processes with the help of free balloons (study of the structure of atmospheric fronts, for example) and assists other institutes and the Academy of Sciences USSR in the organization of special aerostat flights.

Observations made "in passing" on the open sea are conducted by military and commercial vessels and by the various expeditions which cover the seas of the USSR every year. At present, such data is very scanty and in no way satisfies the needs of the Service. At the same time, systematic hydrological and meteorological observations on the open seas are very important. We must know the sea -- its properties, state, temperature, transparency, and currents -- as an area of fleet and fishing operations. The state of the sea gives us important characteristics of large-scale hydrometeorological processes. For example, careful measurements of water temperature and other hydrological elements in the Barents Sea up to the meridian of the Kola Peninsula, which were repeated yearly up to the war, permitted us to follow the thermal state of the northern loop of the Gulf Stream, and the latter was taken into consideration in drawing up long-range ice forecasts for the Arctic. In the coming years, we must ensure the broad development of systematic oceanographic works and expeditions and acquire specially equipped ships for this purpose.

The development of new instruments is naturally important in the organization of observations. Recently, our scientific-research institutions and, especially, the Central Construction Bureau of the Main Administration of the Hydrometeorological Service have designed many new instruments which will shortly be used in actual practice. Sometimes these are simple instruments designed for mass production, for example, the Tret'yakov anemometer, an instrument which was used by the army in World War II and produced by the tens of thousands. In addition, there are the gas barometer and a new type of rain gage, which is free from the eternal defect of all rain gages, i.e., distortion of winter precipitation because snow is blown out by the wind.

The first series of automatic weather stations (designed in the Central Construction Bureau) have been set up as samples in various regions of the USSR, e.g., in the Arctic, Pamirs, Yakutsk taiga, and shores of the Sea of Okhotsk. The automatic stations report their observations by radio to distances of several hundred kilometers and operate many months without supervision. The inventors (Gorileychenko, Surazhskiy, Mal'tsev and others) were awarded a Stalin prize.

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Study of Climate and Hydrological States; Calculations and Processing

Observational data is used to determine normal averages and most probable values of meteorological and hydrological elements at various points of the country, to compile reports on the present weather and hydrological states, and to forecast these states for certain definite times.

It is quite clear that climate and hydrological states must be known in planning various constructions or economic measures. It would be impossible, for example, to use the same construction norms for buildings in Odessa and Yakutsk. However, planners sometimes forget such phenomena as debacle and floods in designing a bridge or do not consider how much water a river can supply before planning a plant or city on it. Such grave oversights are infrequent, of course. Usually, the planner takes the most unfavorable set of hydrometeorological elements into consideration and provides a more than sufficient safety factor of strength or size in designing constructions. It is much more difficult, however, to select safety factors actually needed to provide economical construction along with required strength. For example, if a roadbed crosses a valley, a drain sufficient for passage of spring and flash floods must be made in the fill. Careful investigations of maximum runoff, made under the direction of Prof D. L. Sokolovskiy (Laureate of the Stalin prize) in the State Hydrological Institute, have considerably reduced the safety factors previously used in constructions of this type, thus making possible enormous savings. Various hydrological and meteorological calculations are required in planning dams and bridges, radio towers, transmission lines, irrigation systems, and port constructions. Sometimes these calcualtions are made by the builders themselves with the Hydrometeorological Service providing the required handbook data; sometimes the calculations are made by organizations of the Hydrometeorological Service.

Much has been done to prepare the necessary handbook data on the climate and hydrology of our country. Climatic handbooks for the entire USSR have recently been completed by the Main Geophysics Observatory. The Great Climatic Atlas of the Soviet Union will consummate this work.

In the same period, the State Hydrological Institute summarized basic hydrological data in the Inventory of Water Resources of the USSR. Most of this data has already been published.

Soviet scientific institutes, without awaiting completion of these major handbooks, are producing much different descriptive material designed for definite consumers. Much of this material was produced during World War II for the army and navy and includes hydrometeorological manuals, special climatic maps for aviation, hydrometeorological characteristics of seas, and monthly navigation charts.

The production of basic handbook data on USSR climate and hydrology from available material is the primary problem of the Hydrometeorological Service and is still not completed.

The second problem is determining indirectly the hydrometeorological elements for regions without observation stations. The utilization of small rivers is an example of this need: Construction of small hydroelectric power plants requires hydrological calculations and observational data. However, we cannot have, and do not intend to have, even one hydrological station on each of the 25,000 small rivers which are of interest from the power standpoint. Consequently, we must open stations on small representative rivers. Thus, by making single reconnaissance inspections of other rivers, we can compare them with the representative rivers.

In the same way, we can study local climatic characteristics which are important for farm crops. We now have observation stations studying nearby rivers or climate in addition to making systematic observations at the station itself.

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The third important problem is to study the vast influences of climate and its variation upon hydrometeorological behavior. At present, for example, there is the general warming of the Arctic and the severe variations in the level of the Caspian Sea. We must understand climatic variations and how disturbances in normal behavior of any element influences the rest to be able to calculate the effect of artificial operations, such as the construction of large reservoirs and drainage of vast swamp regions, upon climate and the hydrometeorological regime. An example of such calculations in Professor Zubov's recent work in the State Oceanographic Institute on the possible consequences of separating the Azov from the Black Sea by a dam crossing Kerchenskiy Strait.

Processing of observational results is of extreme importance for climatic studies. About ten million individual measurements of meteorological and hydrological elements enter the Hydrometeorological Service each year. Even standard treatment of this data to clarify observational errors and to reduce them to definite initial values is quite difficult and requires a staff of technical workers. Haphazard processing will not satisfy our future needs and will retard the development of scientific studies.

Although our handbooks show that probability of winds of various intensities in a region of certain air temperatures, of ice storms, etc., it is extremely difficult to determine the compound probability of certain combinations of elements, for example, strong wind with icing, although such combinations are often the most interesting.

The only way out of this situation, i.e., the only method of transforming clumsy observational archives into flexible semifinished calculations, is through mechanization; i.e., the introduction of machines and present-day methods of analysis and computations for hydrometeorological data. This problem is being attacked vigorously by a special institution, the Central Scientific Research Hydrometeorological Archives, organized in 1943 to study various methods of mechanizing typical calculations and to index on cards the main observational archives. Since that time, the Archives has done considerable work in mechanizing many calculations and in indexing meteorological observational data.

Forecasts

Various forecasts, e.g., weather forecasts for periods from several hours to several months, short- and long-range forecasts of rivers and seas, etc., are produced. The easiest are short-range forecasts of river levels (95-98 percent correct) while the most difficult are long-range weather forecasts (65-70 percent correct).

Long-range forecasts, using a method devised more than 20 years ago by Mul'tanovskiy are given for one or 3 months in advance. The method perfected by Mul'tanovskiy's followers, headed by Pagava, establishes empirically certain laws governing gross synoptic processes over prolonged time intervals. The basic principles of the method are: the hypothesis of centers of action in the atmosphere, unique nidi whose activity determines shifts in pressure formations and air masses; the hypothesis of a natural synoptic period, a time interval in which position of main pressure fields and direction of processes are maintained; and the hypothesis of 5 and 3-month periods.

Some of these principles have now been proven by independent methods (the existence of a natural synoptic period is now unquestioned), while others remain problematical. There are three basic elements in long-range forecast, namely: prediction of deviations from norms of average-monthly values; prediction of synoptic processes, i.e., movement of air masses and pressure formations; and finally the weather forecast, i.e., descriptions of the weather for various parts of the country.

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Systematic verification of long-range weather forecasts shows that the correctness is 6.5-7.0 on a scale of ten (for comparision, daily forecasts are 8.0-9.0) which is very low and naturally cannot satisfy the economy, but for the interim no better method exists. The method of long-range forecasting used is not only the most successful, but is the most developed and scientific in comparison with others. Long-range forecasts, for all their imperfection, still orient the economy more correctly than if only climatic norms were used. Although long-range forecasts are produced only by Mul'tanovskiy's method, research work in finding other methods is pushing forward. Interesting results are promised by the work of Blinova, based upon methods of dynamic meteorology, and the work of Belinskiy. Important results have been obtained recently by Pagava in devising forecasting methods based upon two natural synoptic periods, a sort of average between long-range and short-range forecasts.

Short-range forecasts are very common. In the USSR, there are about 2,000 weather bureaus or stations which produce forecasts, both general and special; e.g., for military and commercial aviation, the fleet, and railroads. Short-range weather forecasts by synoptic maps have existed for 80 years. One important transition in methods took place 25 years ago and another is occurring now. The first was frontological analysis, which replaced pressure and temperature fields by state and motion of air masses and atmospheric fronts. Since that time, Soviet and foreign scientists have perfected this method particularly in giving the analysis a three-dimensional character. Advective-dynamic analysis devised by Pogosyan and Taborovskiy is an example. The second transition is due to a school of dynamic meteorology founded by Fridman 20 years ago in the Main Geophysics Observatory and carried on by Kochin, and now headed by Kibel', a Stalin Prize winner.

In 1939, Kibel' predetermined some elements of future weather by hydrodynamic equations. In England in the 1920's Richardson had set up a system of equations which theoretically could be used to determine the next day's weather, but he himself said that the calculations would take a year. Kibel' and his students found a theoretically possible and practical method by clever use of frontal conditions and simplifications.

Predeterminations of temperature and pressure give results almost equal to the normal synoptic method. Much more accurate results will be obtained when the quality of the initial data is improved, particularly the number and quality of radiosonde observations, and also when calculation methods are improved. Great interest is therefore attached to the numerous works of Kibel''s collaborators in the Division of Dynamic Meteorology, the Central Forecasting Institute, and the Main Geophysics Observatory.

One important characteristic stands out in long-range forecasts of activities of rivers and seas, devised by Bregman, Vangengeym, L'vovich, Belinskiy, etc., namely, the phenomenom to be forecast depends upon hydrometeorological development and past factors. For example, in forecasting spring floods (debacle and high-water), these known factors are ice thickness, the amount of snow cover in the basin, the nature of atmospheric circulation, the predominance of latitudinal or meridional transfer of air masses, and the state of the underlying surface (surface temperature of the Atlantic Ocean) in the zones of the air masses' formation, i.e., in the final analysis, a calculation of the amount of heat to be transferred to the USSR from the Atlantic in spring.

Naturally, future hydrometeorological behavior is predicted with the same accuracy (although by other methods) as long-range weather forecasts, but hydrological forecasts have a slight advantage due to the influence of actual known background. In practice, hydrological forecasts are more often correct and in some cases may be given far in advance; for example, the forecast of the level of the Caspian Sea is given in March a year in advance and is correct within several centimeters or 15 percent of level variation. This is possible because of factors known when the forecast is drawn up. The main factor here is the stores of water in the snow cover of the Volga River basin. This water is about 70 percent of the entire discharge of the Volga for one year, and the discharge of the Volga produces 80 percent of the entire influx into the Caspian.

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The influence of known factors is still more significant for short-range river forecasts. Thus, if rain falls up river, it is easy to establish when and how a flood will appear in its lower course if the river regime is known. However, we do not infer that the problem of the influence of these known factors is simple and practically solved. It is easy to calculate how much water will be obtained as a result of snow thawing in a glass tank on a laboratory desk, but it is quite another matter to make this calculation for snow lying on millions of square kilometers of the Volga River basin. We still know little of the laws of discharge and flood formation.

Forecasting is the most difficult work of the Hydrometeorological Service. The Central Forecasting Institute directs scientific research institutions in this field and concentrates on the development of all important forecasts, e.g., weather, river and sea, long and short range.

Terrestrial Magnetism; The Ionosphere

For the time being, magnetic investigations stand slightly apart in the Hydrometeorological Service because no obvious connection has been established as yet between meteorological phenomena in the lower levels (up to 20-30 kilometers), the ionosphere, and various electromagnetic phenomena.

However, it is felt that such a connection undoubtedly exists. Its discovery will be of real importance to the Hydrometeorological Service. This will permit a spanning of the gap between solar activity and meteorological processes and consequently will aid forecasters.

At present, the main task of the Scientific-Research Institute of Terrestrial Magnetism and magnetic observatories of our service is the study of the geomagnetic field and ionosphere. The institute has done much work on a general magnetic survey of the USSR and actively assists geologists in geophysical prospecting for mineral resources. Recently, the institute organized a regular ionospheric service for systematic sounding of the ionosphere at several points. This service provides pertinent information and forecasts on conditions for radio-wave propagation.

The institute suffered greatly from the German occupation, and its members work under very difficult conditions at present.

The Problem of Actively Influencing the Weather; Trends of Future Studies

Influencing the weather is not far off. We have already interfered with the weather on a small scale. In 1938, one of our institutes experimented in creating artificial fog to protect plantings. The institute conducting the experiment employed a special type of smoke whose particles served as good condensation nuclei and caused the formation of a fog which protected the seeds from radiation cooling. Calculations showed that this fog was cheaper than direct heating of air.

Construction of large reservoirs and drainage of vast swamp areas undoubtedly casue small but marked climatic changes, but more serious enterprises in this direction are not far off. Atomic energy will give us power of the order necessary foi such attempts.

Our scientists consider three main trends to be followed in attempting to influence the weather. The first is the creation of weather conditions desired in a certain restricted area under any conditions. This might include the dispersal of fog and clouds up to a certain height near an airfield. Considering the enormous energy which such measures will require, they will be profitable in only few cases.

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The second is interference during unstable states, where comparatively small operations can turn a process in the direction desired; for example, the direction of motion of air masses might be changed by using atomic energy to heat the air greatly in a certain region of an ocean.

The third is climatic changes over considerable areas by major interference in the existing atmospheric circulation or sea currents. This requires enormous constructions, which in turn will produce a major effect for decades and centuries.

We now consider some important trends of future investigations. To obtain reliable weather forecasts and to be able to analyze hydrometeorological behavior, we must clarify the physicomechanical aspects of the phenomena involved. This, rather than pure description and recording of meteorological processes, is now the primary and most difficult goal of our investigations. For example, the qualitative side of the hydrological cycle is well-known to laymen and scientists, but there are great quantitative difficulties; for example, we do not know all details of evaporation from sea and land surfaces and from swamps and forests and we do not know why a polar maritime air mass took precisely the route it did yesterday, nor what the conditions in a cloud must be for rain, nor what part of precipitated rain runs off into a river bed, nor what part goes into the soil.

To analyze all these problems we want first to be able to express gross hydrometeorological processes through quantitative physical laws. Secondly, we will study carefully and in detail structure and behavior of cloud particles, water movement in soils, evaporation from sea surfaces, etc. To do this we must make accurate physical measurements under natural conditions, in clouds and under water; we must use flying laboratories and instruments for work in the depths of the sea. Finally, we must be able to reproduce, artificially, phenomena on their proper scale. For example, if we want to calculate accurately how a river freezes and its ice thaws, we must reproduce this process, and thus our laboratory must have water of various temperatures, flowing with various velocities, and have over this water air with various velocities, all on a scale of 1:100 to 1:200, rather than 1:10,000, where the similarity will be broken. We must have large-scale installations to study bedding and runoff and must be able to subject the atmosphere to various powerful irradiations effective to hundreds and thousands of meters. All this is very difficult and frequently costly, but we cannot understand the physical essence of hydrometeorological phenomena without sufficiently broad experiments.

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