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27 October 1958

SCIENTIFIC WORK IN METEOROLOGY

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Soobshcheniye o Nauchnykh
Rabotakh po Meteorologii
/Report on Scientific Work
in Meteorology/
Submitted to the International Association
on Meteorology for the 11th General Assembly
of the International Geodetical and Geophysical
Union, Moscow, 1957
51-page pamphlet

Academy of Sciences
of the USSR
Committee on Geodesy
and Geophysics

INTRODUCTION

pg 3 The present report embodies the results of scientific investigations carried out in the USSR during 1950 - 1955 in the following branches of meteorology: climatology; synoptic meteorology; dynamic meteorology; actinometry, atmospheric optics; physics of clouds and precipitations; physics of the ground surface layer and atmospheric turbulence.

Together with the bibliography, which is listed by branches, it was deemed expedient to furnish a short list of textbooks and manuals on meteorology, as well as comprehensive monographs on specific problems of meteorology, published during the period indicated above.

1. Kurs meteorologii /Course in Meteorology/ (physics of the atmosphere), edited by P. N. Tverskoy (1951, 878 pp.) - For hydrometeorological institutes and universities.

2. Osnovy dinamicheskoy meteorologii /Basic Principles of Dynamic Meteorology/, edited by D. L. Laykhtman and M. I. Yudin (1955, 647 pp.). A manual for students and scientific workers.

3. Meteorologicheskiye pribory /Meteorological Instruments/, by V. N. Kedrolivanskiy and M. S. Sternzat (3rd edition, 1953, 540 pp.) - Contains a description and the theory of modern instruments used in observatories, as well as of instruments for the measurement of radiation, optical and electrical properties, etc.

4. Fizika atmosfery /Physics of the Atmosphere/, by A. Kh. Khrgian (1953, 456 pp.), - For universities and hydrometeorological institutes; contains a relatively detailed physical and mathematical treatment of certain problems in meteorology.

5. Osnovy aviatsionnoy meteorologii /Principles of Aviation Meteorology/, by L. T. Matveyev and P. L. Smirnov (1955, 353 pp.) - Describes in condensed form modern principles of general and synoptic meteorology and methods for their practical application, with particular reference to weather forecasting.

6. Kurs klimatologii /Course in Climatology/, by B. P. Alisov, O. A. Drozdov, and E. S. Rubinshtein. (Parts I, II - General climatology and methods of climatological processing, 1952, 487 pp; part III - Climates of the Earth, 1954, 320 pp.) - An extensive manual for universities and specialists engaged in climatological research.

7. Klimatologiya /Climatology/, by S. I. Kostin and T. V. Pokrovskaya (1953, 425 pp.) - A textbook for agricultural institutes and agronomic specialists; a comparatively large portion of the text is devoted to problems of climatological processing.

8. Rukovodstvo po Kratkosrochnym prognozam pogody /Guide for Short Range Weather Forecasting/, published by the Central Institute for Weather Forecasting (parts I, II, 1954 - 1955) - Summarizes the results of modern methods for synoptic weather forecasting in a brief and convenient form for practical purposes, and includes numerous examples and diagrams.

pg 4 9. Dinamicheskaya meteorologiya /Dynamic Meteorology/, by K. T. Logvinov (1952, 150 pp.) - A concise and comparatively elementary practical exposition of the principles of modern dynamic meteorology.

The following extensive reviews dealing with basic problems in meteorology should be mentioned:

1. Luchistaya energiya Solntsa /Radiant Energy of the Sun/, by K. Ya. Kondrat'yev (1954, 600 pp.) This book, together with the latest book by the same author "Atmospheric Radiant Heat Exchange" (1956, 420 pp.), is the world's most comprehensive review of radiation processes in the atmosphere, reflecting the present status of Soviet and non-Soviet science in this field.

2. Atmosfernyy ozon /Atmospheric Ozone/, by I. A. Prokof'yeva (1951, 231 pp.) - A condensed, but very full summary of scientific work in the field of atmospheric ozone.

3. Oblaka, osadki i grozovoye elektrichestvo /Clouds, Precipitation, and Thunderstorm Electricity/, by N. S. Shishkin (1954, 280 pp.) - Devoted primarily to physical processes occurring in clouds and to their mathematical treatment, and also to processes leading to formation of precipitation (particularly in convective clouds).

4. Atmosfernyy led /Atmospheric Ice/, by A. D. Zamorskiy (1955, 377 pp.). - The most comprehensive description of various forms of solid precipitation, their growth and destruction, their statistics, conditions for their observation and settling, etc.

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I. CLIMATOLOGY

General Problems, Instruction Manuals and Courses. In 1951-54, a number of articles, discussing the present status of climatology and its development trends, were published. /1 - 35./

An extensive discussion of the above problems took place during a conference on climatology, organized in June 1953, by the Main Administration of the Hydrometeorological Service. The data reviewed at the conference were published in the form of a symposium entitled: "The Contemporary Status of Climatological Investigations and Their Development Trends," edited by M. I. Budyko, and published in 1954.

Climatic Radiation Factors. In recent years, numerous investigations of the problem of climatic radiation factors were conducted, a considerable part of which was related to the study of radiation and heat balances. Charts showing components of radiation and heat balances for a number of territories were drawn up for the first time by members of the Main Geophysical Observatory Imeni A. I. Voyeykov. (41) - (50), (52), (57), (58), (60).

This cycle of articles culminated in the publication of an "Atlas of Heat Balance" (40), containing 66 world charts of average annual and monthly values of radiation and heat balance components of the earth's surface.

Many studies were devoted to the investigation of radiation and heat balances in individual regions with the aid of especially organized observations. Work performed by members of the Tashkent Geophysical Observatory (36) - (39), (51), (53) - (56), (59), (61) - (63) forms an important part of these observations. In particular, the problem concerning differences in the heat balance of various types of basement surfaces, effect of irrigation, etc. was studied in detail.

Circulation Factors of Climate; Humidity Cycle. In recent years, research on circulation factors of climate was conducted both on the scale of the Northern Hemisphere (64), (65), (73), (74), (80), (83), (89), (100) - (104), (107) - (111), (113), (114), (120), (122), as well as along the line of study of separate regions or phenomena (66) - (69), (75), (76), (88), (92), (96) - (99), (105), (119), (121).

The first group included a study of synoptic macro-processes in large areas of the globe and their connection with circulation indices, and an investigation of the role which these processes play in the formation of climate. The second group describes circulation factors which are responsible for general climate characteristics in various areas of the Soviet Union, and also discusses the development of certain processes or phenomena (for example, dry winds) or certain weather and climatic conditions (for example, precipitation in south eastern portions of the European territory of the Soviet Union.

A great deal of attention was devoted to investigation of the humidity cycle, specifically having in mind the reckoning of its
pg 6 possible modification in connection with work done on the climate transformation (70), (72), (77) - (79), (86), (87), (90), (91), (93) - (95), (103), (106), (112), (115) - (118), (123) - (126), (128).

A large meeting, devoted to these problems, was held at the Institute of Geography of the USSR Academy of Sciences, and the data discussed at this meeting were published in the press (181).

Theory of Climate. Changes and Variations in Climate. Research on the theory of atmospheric circulation was continued in the work dealing with the theory of climate (134), (142), (149), (150), (155). Proceeding from fundamental principles of hydrodynamics, a theoretical explanation of temperature distribution in the earth's atmosphere, of pressure and wind distribution, etc. was obtained. At the same time, it was possible to evaluate the role played by various basement surfaces, albedo, effect of evaporation and condensation, etc.

Numerous investigations were devoted to climatic changes during historical time and preceding epochs. Published works (129) - (133), (135) - (141), (143) - (148), (151) - (154), (156) gives data on brief variations and prolonged changes in the thermal regime and humidification conditions of various territories. The progress of general climate warming during the past decade and the problem dealing with the start of a new period of climatic changes were studied in particular detail. Some of the studies listed make use of solar activity data in explaining the observed climatic changes (157) - (159).

Climatic Factors of Natural Processes. The most of these works devoted to the study of climatic factors of natural processes examined the relationship between climatic conditions and the indices of hydrological processes: evaporation, drainage, intensity

of snow melting, and others (161) - (164), (166), (167), (169) - (181).

The relation between soil zones and climate was investigated in a monograph (165), published in 1953.

The connection existing between climatic conditions and overall geographical zonality was examined in studies (160), (168).

Melioration of Climate. Investigation of Local Climate. A considerable number of climatologists in our country participated, in recent years, in a study of the hydrometeorological efficiency of meliorative measures. Specifically, numerous investigations were conducted aimed at the study of the effects of irrigation upon the climate of the ground air layer. The following factors were examined: the effect of irrigation upon the radiation balance, various stages of thermal balance under different conditions of vegetation, soil temperatures, conditions in the ground air layer, early light frosts, duration of the growing season, etc., (182), (183), (188) - (191), (194), (196), (197), (200) - (203), (205), (208), (211) - (214), (217) - (219), (224) -(230), (235), (238), (239), (241) - (244), (249), (251) - (258), (265) - (268), (271), (272), (274), (275), (277), (285), (288), (289), (293), (294), (298) - (300), (302) - (304), (307) - (309). A number of studies investigated the effect of forest shelter belts upon the meteorological regime, turbulence and air circulation, characteristics of thermal balance, snow cover and soil temperature, duration of the growing season (184), (185), (187), (192), (193), (195), (198), (199), (204), (209), (215), (220), (222), (223), (225), (226), (228), (231), (233), (234), (236), (237), (240), (245), (246), (248), (250), (259) - (264), (269), (270), (273), (276), (279) - (281), (283), (284), (286), (290) - (292), (295), (296), (301), (305), (306).

Several investigations were devoted to the study of climatic changes occurring during drainage of marshy regions (186), (210), (221), (227), (278), (282).

The above studies, as far as the method of investigation is concerned, are rather closely related to the study of the peculiarities of local climate in different geographical areas. A considerable
pg 7 portion of such research was devoted to the study of local climates of areas where meliorative measures are being carried out.

Agroclimatology. Phenology. The scientific work conducted in these fields has clearly expressed practical objectives in view. All the studies concentrate from different directions on the problem of

improving the development of agricultural crops and raising crop capacity.

The topics studied included the connection existing between hydrometeorological and climatic conditions and individual crops, their crop capacity, areas of distribution, the effect of certain adverse weather conditions on plant development, and general laws governing the interaction between climate and agricultural crops. Problems concerned with the effect of irrigated cultivated lands upon the climates of large regions, for instance in Central Asia, have been studied. (311) - (376).

Investigations related to the rayon development of mineral-bearing and virgin lands in the oblasts of the USSR should be particularly noted. Extensive data on agroclimatic and water resources of rayons where virgin and mineral-bearing lands are under development have been processed.

Climatography. Soviet climatographic studies covered many sections of the globe, including the Antarctic. Various rayons of the USSR were studied in particular detail. Numerous climatic handbooks were published, containing digests of actual data. Detailed monographs or articles dealing with the climate of numerous sections of the USSR have been published. A study was made of the formation conditions of individual climatic and weather phenomena (377) - (425).

Methods Used in Digesting and Generalizing Observation Data. Problems connected with the thermal balance and its separate components occupy a prominent place among these investigations. The development of climatological computation methods for calculating thermal balance components is of particular importance. Methods for climatographic processing of data are reflected in studies related to problems of complex climatology and mechanical data processing (426) - (449).

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The Atlas contains the following series of charts:

A - Total solar radiation - annual and monthly values for the surface of the earth.

B - Radiation balance - annual and monthly values for the surface of the earth.

C - Consumption of heat for evaporation - annual values for the surface of the earth and monthly values for ocean surfaces.

D - Heat, gained or lost by ocean surfaces as a result of the action of sea currents - annual values.

E - Evaporation - annual values for the surface of the earth and monthly values for ocean surfaces.

In addition to charts showing consumption of heat for evaporation and turbulent heat exchange, the Atlas contains graphs showing the annual progress of these values for various climatic land areas.

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II SYNOPTIC METEOROLOGY

The results of a large number of investigations on synoptic meteorology by Soviet authors, as well as the results of many years of practical experience by synoptic researchers of the USSR Hydrometeorological Service, particularly of synoptic researchers working at the Central Institute of Forecasts, engaged in the compilation of various types of weather forecasts, are summarized in a collective work (1) published under the title: "Guide for Short-Range Weather Forecasts." This is the first time that such a summary, which includes results of investigations on problems of synoptic meteorology published in the USSR and in foreign countries, has been compiled. The "Guide" consists of two parts and contains a sufficiently complete and systematic exposition of contemporary synoptic methods used for short-range weather forecasts. More detailed information on subjects listed in this guide can be found in the studies listed below, which were carried out during the period 1951-56.

General problems of great significance to modern science, such as problems of cyclone and anticyclone formation, theory of local variations in atmospheric pressure, temperature and humidity, are examined in studies (2) - (29).

Studies (30) - (37) give formulas for computing regulated vertical velocities in the field of pressure or wind.

The experimental synoptic investigations (37) - (76) describe the spatial structure of baric formations, the conditions resulting in their evolution and displacement, and also the changes caused by these formations and other factors in the fields of pressure and temperature at various levels of the troposphere and under various physical and geographical conditions in the USSR.

Studies (77) - (88) examine theoretical systems of front-formation, the spatial structure of atmospheric fronts and their cloud systems, data on microstructure of clouds, and results of studies of inner mass cloudiness, its origin and structure.

The calculation of regulated vertical movements formed the basis for analyzing formation conditions and for establishing a method used in the quantitative forecast of continuous and heavy (cloud burst) precipitation.

Other problems studied included the theory used in calculating factors leading to formation of cloud bursts and vertical velocities in frontal zones, as well as the results of corresponding experimental

investigations. Summaries of these investigations, as well as results of studies of specific weather phenomena (cloudiness, fog, early frosts, snowstorms, etc.), and corresponding forecasting methods are described in studies (89) - (150).

A large number of experimental investigations related to synoptic meteorology were carried out in connection with the development of a synoptic long-range weather forecasting method. Studies (151) - (167), in which data from aerological observations were utilized, expounded individual aspects of B. M. Mul'tanovskiy's method (concerning natural synoptic periods and seasons, extreme seasons, etc.). Problems related to methods used for long-range weather forecasting based on data of general atmospheric circulation, and their relation to the action of basement surface and solar activity, are described in studies (168) - (182). Other possible methods for long-range forecasting, and certain problems related to this aspect of synoptic meteorology, are described in studies (183) - (194).

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Basic facts related to the macrocirculation method for making long-range weather forecasts in the Arctic Region over a protracted period lasting for 4 to 6 months, which is indispensable in making forecasts of ice formations well in advance, were successfully worked out at the Arctic Scientific-Research Institute (195) (196).

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III. DYNAMIC METEOROLOGY

A review of the principal investigations carried out in dynamic meteorology (up to the end of 1953) is given in a textbook (1), which also contains a number of new results and methodical generalizations.

In recent years, serious attention was given to the problem of general atmospheric circulation and to the related problem of computing the average distribution of temperature in the atmosphere. The development and application of theories of general circulation, proposed by N. Ye. Kochin (2) and (3), and by Ye. N. Blinova (7), are described in studies (5), (8), (15), (18), (45), (56) - (59), (81), (90) and (91). Study (60) is devoted to the application of the same ideas to monsoon circulation. The problem of modeling atmospheric circulations is discussed in study (26). An analysis of the annual course of the Earth's rotation speed and its connection with atmospheric circulation is given in studies (64) and (65). Problems of horizontal mixing with the scope of general circulation are examined in studies (48), (49) and (71). Various aspects of the theory concerned with temperature distribution in the atmosphere are described in studies (9), (42), (43), (46), (61), (66), (86), (87) and (96). A combined computation of temperature distribution and heat currents has been performed (67).

In studies (29), (36) and (54), it has been proposed to investigate an important problem concerning orographic influences upon air currents, based on fundamental work performed in the 1930's by N. Ye. Kochin and A. A. Dorodnitsyn. The theory of convective movements in the atmosphere, and specifically the theory of breezy and mountain and valley winds, has been further developed in studies (4), (12), (23) - (25), (98), and others.

The theory concerned with the transformation of air masses and its applications is covered in a series of studies. The work performed by M. Ye. Shvets (93) shows that the approximate method devised by the author for solving equations of the parabolic type can be successfully used in problems related to boundary layers and, specifically, in problems concerning the transformation of air masses. The monograph by M. Ye. Berlyand (6) presents a generalization of the investigations carried out by the author over a long period of years in the field of the theory of thermal transformation of air, daily courses of meteorological elements and applications of theoretical results in weather forecasting and active influence upon the meteorological regime of the ground surface layer. For further information on this problem, attention is directed to studies (13), (19), (30), (35) and (89).

The problem of the effect exerted by the non-gradient nature of winds in the free atmosphere upon winds in the atmospheric boundary layer was examined from various aspects in studies (50), (55), and (70). A number of studies is devoted to the development of methods for computing vertical velocities, i.e., (52), (63), (74) and others, specifically, in the boundary layer [(40), (44), (47)] and in a front area [(28), (31), (41)]. The effect of vertical currents on evaporation and condensation of water vapors was investigated in studies (94), (95), (97) and others. Individual principles of atmospheric thermodynamics have been defined with greater precision in studies (76), (78) - (80), (83), (88) and others.

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Investigation and interpretation of the method for forecasting temperature and pressure, proposed by I. A. Kibel' in (10), (37), (53), (72), and (82), were continued in the early 1950's. In 1949, A. M. Obukhov used the vortex equation for analyzing non-stationary atmospheric processes. Since 1952, the vortex equation has been utilized as the principal relation, together with the heat inflow equation, for studies in the field of weather forecasting by means of dynamic meteorological methods. The investigations performed in this field examine various factors which exert an effect upon pressure changes in the middle troposphere, including the effect exerted by orography and the presence of fronts. A method has been developed for computing local changes in pressure, which takes into account the initial field of wind (17), (84) and (86). In studies (20), (32) and (75), certain new aspects of the problem concerning wind deviation from gradient wind are examined. A very general interpretation of the laws governing non-stationary atmospheric processes is given in study (38), and the concepts, presented in study (62), concerning adjustment of the pressure field to the wind field, are further developed. The transformation of coordinates, which defines more precisely those equations which are used in numerical forecasting, is suggested in study (99).

Problems related to the structure of meteorological fields in which large-scale movements occur, and problems connected with characteristic values of space and time "derivatives," are discussed in studies (11), (74), (90), (100) and (101).

The results obtained in study (101) are utilized in estimating the accuracy of various simplified equations of atmospheric dynamics (including vortex and divergence equations), while the results obtained in study (90) are used for the construction of empirical "influence functions," for the purpose of utilizing these functions in numerical prognosis. Specific problems of atmospheric dynamics

were investigated in studies (21), (22), (27), (33), (39), (68), (69) and others. Many studies, which have both a dynamic-meteorological and synoptic significance, are listed in the "Synoptic Meteorology" Section.

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IV. ATMOSPHERIC OPTICS AND ACTINOMETRY

The present chapter summarizes briefly the principal results of investigations in the fields atmospheric optics and actinometry, which have been conducted in the USSR since 1950. This summary is limited to a discussion of purely optical problems, leaving aside certain applications (in the heat balance, and others).

Optical Properties of the Elements in the Atmosphere. Molecules. Laboratory investigations were performed on absorption by water vapor in the near infra-red region. Considerable deviations from Buger-Ber's law were found to exist in the region of partial pressures ranging from 10 to 100 millibars (1).

In view of the fact that Buger-Ber's law is not fulfilled in the atmosphere, a method was developed for computing radiation absorption by H_2O and CO_2 molecules based on experimental transmission functions (2), (5). The reverse problem was also investigated, namely determination of the water vapor content in the atmosphere by the spectroscopic method (3).

Aerosol and Cloud Particles. The theory of light dispersion by small particles in the atmosphere was elaborated along the following lines: elimination of various unclarified points in the theory, development of approximate methods for computation of large spherical and non-spherical particles, and tabulation of accurate formulas. A general review of the results obtained and a systematic discussion of the problem are given in a book (3), while a more detailed discussion of separate items is given in studies (7), (8) and (10) - (14). Among the individual results obtained, one should note the clarification of the paradoxical doubling of the attenuation factor on large particles (6), caused by diffraction peculiarities of particle dispersion. Curious resonance phenomena during light dispersion on small particles were discovered (9). Detailed computations of the dispersion and polarization indicatrix on a

maximum large-size water droplet in the visible range were carried out (7), followed later by examination of the ultra-violet and infra-red regions (20). The theoretical transition from precise diffraction formulas to geometrical optical formulas was investigated (10), and the indicatrix of light dispersion by a cloud drop was computed (9). Dispersion on large transparent particles of spherical or arbitrary shape was investigated experimentally (4). It was found that indicatrices of non-spherical particles were much less elongated. Peculiarities of the heat radiation of small particles were theoretically investigated (9), as well as heat radiation of water drops, in connection with the problem concerned with the effect of fog on the radiation balance of the Earth's surface (13). An approximate method yielding simple formulas even for non-spherical particles (ellipsoids) was developed in study (8).

Conditions under which dispersion of light by individual particles in a volume may be considered as incoherent are investigated in study (12). A theory on light dispersion by arbitrary double layer particles was established (15), and detailed computations were made in (16) of radiation properties of cloud drops in the infra-red region
pg 36 (up to λ <117 u) (16). The effective diameter of small particles for a 90° angle dispersion was investigated (17). The reverse problem was solved, namely the utilization of an experimentally measured dispersion indicatrix for determining the distribution curve of sol particles according to their sizes. This problem is closely connected with the problem regarding conditions under which the so-called "coronas" may be observed (18), (19).

Theory of Radiation Transfer in a Cloudless Atmosphere. The theory of radiant transfer in the atmosphere has been developed along the following lines:

a. Transfer of heat radiation, as applied to problems of atmospheric thermodynamics and dynamic meteorology.

b. Dispersion of short-wave radiation in a cloudless atmosphere, as applied to problems of atmospheric optics, visibility, and aerial photography.

A general review of the results obtained is given in studies (26) and (27), and, in connection with the problem of thermal regime in the ground surface layer (21). Some of the most important results will now be examined.

Transfer of Thermal Radiation. Distribution of solar infra-red radiation in the atmosphere and heat inflow caused by its absorption,

have been calculated (32), (35). The problem of radiant equilibrium of a gas sheath surrounding a totally black sphere has been solved (30). New designs and patterns of absorption spectra of the principal absorbing substances have been obtained (27). Methods which take into account selective absorption in heat exchange problems have been developed (27), (51), and temperature distribution according to altitude, accounting for all the principal types of heat exchange, has been computed. Vertical temperature distribution, with a schematic account for selectivity of absorption, has been investigated (33), (34), (48).

Dispersion of Short-Wave Radiation. Serious efforts have been made to develop mathematical methods for solving transfer equations (24), (25), (31), (47). Computations were carried out on the intensity of dispersed light in the atmosphere, and on smoke content factors in case of spherical elongation, also various degrees of elongation of non-spherical dispersion indicatrices (28), (29), (46). Accurate methods have been developed for determining the intensity of radiation emitted by a medium (23), (43). An accurate method for determining the light regime inside a medium is given in study (17). Statistical methods for solving problems related to the theory of light dispersion have been developed (42), (44), (45). Methods for the approximate accounting of multiple dispersion during determination of the brightness of the sky in daytime have been developed, which make results of observations free from the effect of higher-order dispersion (23), (38), (29), (40), (43), (49), (50). In this connection, a number of studies take into consideration the spherical nature of the Earth (40), (49), (50). One must point out investigations concerned with light propagation in the atmosphere, which take polarization into account (41), as well as investigations aimed at the mathematical foundation of the radiation transfer theory (22).

Transparency, Brightness and Polarization in a Cloudless Atmosphere. The mechanism governing the inflow of solar radiation on the Earth's surface was studied on the basis of observations and calculations (52), (60), (64), (73). Certain data related to the problem of the daily course of spectral factors of atmospheric transparency were also obtained (65).

Total absorption of solar radiation in different layers of the atmosphere was investigated by means of pyranometric observations made in several locations from airplanes and balloons (54), (57), (62), (63), (74), (75). It was found that this total absorption is 1.5 times greater than the absorption calculated by the well-known formula of Meller.

Several studies were devoted to investigation of the distribution of power and visual brightness of the firmament (56), (59), (78). The dispersion indicatrix of the entire atmosphere was investigated, and a simple method for its determination, based on observations of the sky's brightness, was developed (66) - (72). Optical properties of the atmosphere prevailing in mountain conditions were investigated separately (73). It was found that the
pg 37 results of measurement of the effective radiation at the Earth's surface were in good agreement with theoretical calculations, whereby the advantages displayed by the new radiation nomogram were particularly conspicuous (58), (76). Balloon measurements performed up to 8 kms. altitude confirmed the fact that the effective water vapor density is proportional to the square root of pressure (77). Investigations of the distribution of back radiation in a clear firmament allowed the experimental determination of the multiplier accounting for the diffusivity, which was equal to 1.68 ± 0.05, and also permitted to determine the integral absorption function (55). The long-wave radiation of the Earth's surface was successfully used in experiments aimed at determining the mean temperature of this surface (53), (61).

Optics of Clouds and Fogs. A general analysis of the problem is given in a book (92). Studies on radiation transfer in clouds were conducted along the following lines:

a. Investigations primarily concerned with microphysics of absorption and dispersion processes of radiant energy on drop-thin water. The results obtained are used in developing a theory of radiation processes in clouds, based on the solution of Schwartzschild's approximate equations (92) - (96).

b. Investigations based on the solution of precise radiation transfer equations, with simplified assumptions on absorption and dispersion properties of clouds (85), (87) - (90). The experimental investigation of multiple light dispersion in turbid media yielded interesting results (86).

c. Measurements of cloud transparency in mountain conditions (Elbrus) agreed in a satisfactory manner with theoretical expectations. An optical method, which permits to study separately the liquid and vapor phase in a cloud, was successfully developed (82). Direct airplane measurements of long-wave radiation currents in clouds agreed with theoretical calculations. (84). Detailed investigations were conducted on the reflection, penetration, and absorption of solar radiation by clouds of various shapes (91).

Reflecting Capacity of a Natural Surface. Investigations were conducted both on the ground and from aircraft. A general review of these investigations is given in (109) and (111).

Ground Measurements. The mechanism of spectral and angular variations of albedo in various soils, vegetation types, snow, and ice were studied (93) - (96), (97) - (102), (106), (112), (113), (115), (118), (120). As a rule, albedo diminishes with increasing Sun altitude, which is due to a change in the angle of incidence of Sun rays and in the spectral composition of light (105), (108), (112). It was found that the albedo of water basins is influenced by water turbidity and agitation (26), (107), (110), (118). New and perfected computations of terrestrial albedo were performed, and it was discovered that the meteorological method for determining the albedo of the Earth coincides as a whole with the photometric method (96), (103), (117). It was established that the radiation current reflected by the Earth's surface possesses a considerable anisotropic character (101). In the infra-red region of the solar spectrum the albedo of a number of natural soil covers was found to amount to 30 - 40% (121). The spectral reflecting capacity of a barite paper standard was investigated (102).

Aerial Measurements. The albedo of certain surfaces was determined from an aircraft (99), (113) and from a balloon (116). It was discovered that changes in albedo with altitude sometimes result in higher, sometimes in lower, albedo values (119). The effect of pressure (i.e. flight altitude) on recordings of pyranometers was established (104).

Actinometry. Instruments and Recording Methods. Together with theoretical studies, methods and techniques of actinometric observations have been improved. While before the war, actinometry
pg 38 was primarily directed toward investigations of atmospheric transparency and calculations of Sun and sky short-wave radiations, as macroclimatic radiation characteristics, instruments have been transferred in recent years from observatory towers to meteorological sites and the observation periods have been coordinated with climatological periods (15).

The principal activity of observation stations include measurement of residual (balance) radiation, both total and short-wave (0.3 - 4u) radiation, by means of actinometers, pyranometers and balancemeters. Separate investigations in the vicinity of the station furnish information on the radiation regime of the principal ground surface types in the station area. The albedo of the earth

is investigated by means of an inverted pyranometer. Time intervals between direct observations amount to 3 hours in daytime and 6 hours at nighttime.

Former stations were equipped with several point galvanographs for recording actinometer readings, the shaded pyranometer, and in some stations, of the balancemeter. New stations are equipped with a three-position recorder, which is used primarily for recording total radiation. The actinometer, pyranometer, and balancemeter are also connected with this recorder. Photorecorders, electronic and mechanical self-recording potentiometers used in individual stations. New models of mechanical galvanographs are being developed for stations deprived of alternating current. Development of integrator actinographs has just started.

A thermoelectric type of actinometer, designed by Savinov, is used in the USSR network. It has an increased sensitivity and a 10° angle of aperture, the aperture being twice as large as the receiver. The same angle is utilized in the shading of pyranometers and balancemeters. The sensitivity of actinometers is approximately 7 mkv /microvolts/ per 1 cal/sq. cm. min, with a 15 ohm resistance. The inertia is equal to 20 seconds.

Pyranometers (153) under a semi-spherical glass hood are equipped with square, black and white thermobatteries having a sensitivity of 8 - 11 mkv and an inertia of 30 seconds. The relation between sensitivity and angle of incidence is established for each instrument, and this relation is considerable in view of the use of convex glasshoods. This relation is taken into account during processing of data. The selectivity of parameters and its effect upon measurements of dispersed radiation are being studied at the present time.

Balancemeters having a high frame heat conductivity and equipped with 340 constantan - silver thermocouples, have a 7 mkv. sensitivity (at a 600 hm resistance) which is reduced by 2 - 2.7% when wind velocity increases by 1 m/sec. Wind is determined by simultaneous wind meter recordings. Artificial blowing is not performed during calm weather. The selectivity of the receiver has been studied. The effect of the air current structure on balancemeter recordings is being studied. Savinov's pyrgeometer of new design is used in some stations.

A general needle-type GSA-1 galvanometer equipped with stretchers and encased in a white cast frame, allowing to conduct operations under field conditions in the sun, is used with all four instruments.

Pyranometers and balancemeters, their parameters of which are being adapted to galvanometers, have recently been improved. Radial-symmetrical pyranometers with a standard sensitivity of 5.7 mkv, a 19 ohm resistance and 10 sec. inertia, which errors caused by batteries have been reduced, are being introduced, as well as low ohm balancemeters equipped with a copper - constantan battery having the same sensitivity and resistance.

A metal rack for installing instruments at the station has been designed, which permits a rapid grading of the instrument and which always exposes the pyranometers and balancemeters from the same side to the sun.

Observations with the aid of pyranometers and balancemeters are accompanied by simultaneous observations with an actinometer equipped
pg 39 with a separate galvanometer, thus permitting to control the results of observations of albedo and of residual radiation intensity under variable sunshine.

A thermoelectric actinometer or a bimetal Mikhelson's actinometer, and in some stations a pyrheliometer, are used as control instruments for checking pyranometers and balancemeters. In addition to Angstrem-type and Soviet pyrheliometers, modified instruments proposed by Voloshin are used which have a circular receiving aperture and which are equipped with thermobatteries of higher sensitivity.

Bolometric pyrheliometers with a round aperture, proposed in Saratov by V'yushkov and Sklyarov, deserve consideration. The aperture angles of these instruments are the same as in actinometers.

The number of stations measuring illumination (or light exposure) has been reduced to 6 at present, but will be increased again during the International Geophysical Year. Recorders of ultra-violet radiation are undergoing tests.

Methods used in actinometric observations are described in special "Directives," published in 1947, part of which have become somewhat obsolescent and which have been supplemented by methodical instructions (151). An expanded handbook guide is in the press, which contains a description of methods for recording actinometric data.

Checking guides describe methods for checking actinometers and pyrheliometers and instruments recording artificial radiation sources. Modern instruments are described in a new edition of V. N. Kedroli-vanskiy's book.

The Problem of Visibility. Visual thresholds and other characteristics of vision were studied in detail in connection with the problem of visibility range of distant objects and lights (122), (124), (127), (128), (129), (131), (143).

A large amount of work was devoted to improving methods for measuring visibility. A new instrument for measuring visibility, known as a contrastmeter, was developed at the Main Geophysical Observatory, which is based on the principle of extinguishing the field of vision with increased brightness (133) - (138). A standard method for visual determination of the visibility range, based on contrasts of distant objects, has been developed (123) - (125), (129) - (132), (140), (143). The visibility range of real objects and lights under normal conditions was investigated (124) - (126), (129), (130) - (142), (144).

Atmospheric Ozone. Investigations were conducted which were concerned both with theoretical foundations (145), as well as with the practical development (149) of methods for the determination of atmospheric ozone, based on absorption in several sections of the ultra-violet spectrum range. Some results of ozone observations are described in articles (146) - (148) and in a review monograph (150).

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V. PHYSICS OF CLOUDS AND PRECIPITATION

Investigations of the physics of clouds and precipitation were conducted in the USSR during the period of 1950 - 1956, mainly along the following lines: development of equipment and of methods for studying the structure of clouds and precipitation, such as cloud elements, water content, hydrometeors, chemical composition of cloud elements and precipitation, intensity of precipitation, etc.

A large amount of data on the microstructure of clouds and precipitation was obtained in the course of special flights through clouds and by means of captive balloons, as well as on the surface of the Earth in mountain relief conditions. A large number of laboratory studies of evaporation processes, of condensation and coagulation of drops, and of the effect exerted by the solid phase upon these processes, etc., were conducted. Laws governing distribution of cloud elements and precipitation and their coagulation

and transformation were discovered, as well as the mechanism leading to formation of various types of precipitation. Results of these investigations are described in studies (1) - (48).

Investigations were performed on the distribution pattern of certain meteorological elements in clouds. Methods and equipment for studying convective movements in the free atmosphere, specifically in cumulus clouds, were developed. Certain laws governing the mechanism leading to formation of internal massy stratus and cumulus cloud formations in flat and mountainous country were investigated (49) - (70).

Internal massy and frontal cloud formations and the changes occurring in these systems as a result of synoptic conditions were investigated. Studies were made of the spacial structure of frontal clouds and of its evolution as a result of large-scale atmospheric processes. Certain relations between microstructure of clouds and the conditions causing their growth and destruction were discovered. A study was made of characteristic altitude values of the lower border and thickness of certain types of clouds and cloud systems, and their relation to physical and geographical conditions (71) - (78).

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pg 48 ## VI. PHYSICS OF THE ATMOSPHERIC GROUND LAYER AND ATMOSPHERIC TURBULENCE

Investigations of the physics of atmospheric ground layer are related closely to the study of atmospheric turbulence. A large number of studies in the field of atmospheric turbulence are based on investigations of the theory of local and isotropic turbulence carried out by A. M. Kolmogorov and A. M. Obukhov, and published in 1949. A review of this theory and its further development may be found in study (46). The problem connected with the structure of the temperature field in a turbulent current was theoretically discussed in studies (47) and (69). The results obtained from a study of the structure of wind velocity and temperature fields were checked experimentally with the aid of special equipment (32), (48), (49), and agreed well with the data obtained by measurements. Basic concepts of the theory of local and isotropic turbulence were also

applied in the study of the macrostructure of meteorological fields (66) and in the theory of instruments for measuring wind velocity (70).

Concepts of the semi-experimental turbulence theory were also widely used in practical calculations and in the analysis of processes occurring in the boundary layer. A series of formulas based on this theory was proposed for computing the factor of turbulent exchange on the basis of data of vertical temperature distribution and wind velocity in the ground layer at various stratifications (8), (9), (34). Recent studies (41), (26), have analyzed the problem concerning the influence of stratification on turbulent exchange from the standpoint of the similitude theory. Studies (1), (14), (27) and (33) examined methods for direct measurement of heat currents and amount of motion in the atmosphere, based on straight measurements of micropulsations in meteorological elements.

A great deal of attention was devoted to experimental and theoretical studies aimed at the investigation of vertical distribution and time changes of basic meteorological elements. The data obtained on vertical profiles of wind, temperature and humidity in stationary conditions (51) and by means of several expeditions (14), (15), (27), (40), (52) were analyzed from the standpoint of developed theories of turbulent exchange (8), (9), (34), (41).

The problem of wind vertical profile, up to the grade of gradient wind, is examined in (3) from the standpoint of contemporary concepts of the relation existing between the exchange factor and altitude, and of the turbulent energy balance. A theory of non-periodical and periodical temporary temperature and humidity variations in lower atmospheric layers and in upper soil layers has been developed (4), (19), (35), (67), as well as a similar theory of temporary wind variations (5), (74). On the basis of these studies, computation methods have been proposed for forecasting daily temperature and humidity fluctuations (4), (19), (34), (35), (67), minimum night temperatures (20), (65), (71), degree of dew intensity (4), and the presence of fog and its basic characteristics (4), (25). The results obtained agree with experimental data. Investigations were carried out on temperature and humidity variations in the lower air layer over a water surface, and a method of computing evaporation mists has been suggested (17), (59) - (61).

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A large series of studies (4), (18), (21) - (24), (36), (57), (64) is devoted to the study of the transformation of air masses under the influence of the basement surface. These studies examine stationary and non-stationary variations in the temperature and

humidity of a moving air mass. The formulas derived in those studies are used for advance forecasting of temperature and humidity over a 24 hour period.

The theory of certain methods for controling the meteorological regime of the ground layer, which have found practical applications, has been developed on the basis of established results concerning temporary variations of meteorological elements and the transformation of air masses. This category includes studies concerned with the meteorological efficiency of combating frosts by such means as smoke and open heat (4), (6), (7), irrigation (4), (11), (12), (38), (62), (72), and wind protection belts (13), (16), (53), (57).

An important application of the turbulence theory is the problem concerned with distribution of admixtures in the atmosphere. Solution of this problem is attempted by means of source function formulas obtained in solving problems concerned with transformation of air masses (4), (36), (42). The theory of diffusion of heavy particles has been improved (14). Ultimate speeds of particle propagation are considered in studies (39), (43). Studies on the diffusion theory (44), (45) are based on the known relationship between the exchange factor and the scale of the phenomenon.

Studies (28), (50), (54) - (56), (63) are concerned with investigations of the effect exerted by turbulence upon the characteristics of sound and electromagnetic waves which are propagated in the atmosphere. These studies also consider the influence of effects and the results obtained are in good agreement with experimental data (29) - (31), (68).

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