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SOVIET CLOUD PHYSICS RESEARCH AND WEATHER MODIFICATION ACTIVITIES

OSI-Z-SR/60-42
31 August 1960

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

SOVIET CLOUD PHYSICS RESEARCH AND WEATHER MODIFICATION ACTIVITIES

NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive scientific intelligence research and represent the final and considered views of the Office of Scientific Intelligence.

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CLASSIFIED REFERENCES

The classified source references supporting this paper are identified in a list published separately. Copies of the list are available to authorized personnel and may be obtained from the originating office through regular channels. Requests for the classified list of references should include the publication number and date of this report.

PREFACE

The potential value of weather control or cloud modification has been recognized for well over a decade. Military requirements exist for weather control techniques to support a variety of missions. The capability to disperse supercooled stratiform clouds and fog could be used, for example, to improve terminal weather for aircraft landing and take off, to provide close support of ground operations, and to enable optical tracking of missiles. "Rainmaking" over airfields and battle fields conceivably could cause low visibility and be used as a method of warfare.

Successful weather modification promises tremendous economic as well as military benefits. If clouds can be stimulated to produce rain at times critical for crop growth and if damaging hail storms can be suppressed, crops can benefit. Furthermore, the propaganda value of well-supported claims that techniques had been developed to control the weather are obvious.

The popular press has given much publicity to weather control experiments, usually indicating a degree of success not supported by fact. At the present time no nation can produce evidence that they can control weather to any large degree, but certain successes have been achieved on a small scale in limited circumstances. Supercooled clouds and fog have been dissipated and precipitation probably has been increased somewhat from certain types of clouds. Considerable controversy still exists among competent scientists concerning the future of weather control. One group believes there is little likelihood that man will be able to control weather effectively within the foreseeable future. Another group believes that the advances in the relevant sciences in the past two decades have been so startling and rapid that it may be a mistake to assume successful weather control will not take place or to assume that it could occur only in the far distant future. Both groups agree that until scientists understand more completely the physics of clouds, precipitation mechanisms, and the larger scale energy processes of the atmosphere and ocean, the feasibility of controlling weather will remain in doubt.

The status of Soviet research in cloud physics and weather control is stressed in this report, with most emphasis being placed on radar meteorology, the latter field supports both cloud physics research and the control or modification of weather. Climate control * has not been covered. The intelligence presented herein is based primarily upon an external contract

* Climate control is the term applied to schemes for artificially altering or controlling the climate of a region. Weather control is the term applied to controlling day-to-day weather in contrast to changing the average weather over a long period of time.

study by the Office of Scientific Intelligence, but earlier reports have also been brought up to date and the intelligence incorporated in this report where essential. All pertinent information available through 1 June 1960 has been considered in writing the report.

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PROBLEM

To assess Soviet cloud physics research and weather modification activities.

CONCLUSIONS

1. The USSR is engaged in a large and comprehensive cloud physics and weather control program, surpassing in size the program of the United States but slightly inferior in quality. Soviet scientists recognize the lack of basic knowledge in many important aspects of cloud physics and weather control and are aggressively working toward the solution of these problems.

2. The Soviets have developed a routine operational technology for dispersal of certain types of low-level clouds and fogs by cloud seeding at airports to facilitate flights by civil and military aircraft. They are conducting experiments to increase rainfall and suppress hailstorms for the benefit of agriculture. It is not likely that the Soviet Union has advanced beyond the West in this area of weather control. On the other hand the Soviets have classified much of the research in these fields and probably have done more work than they have reported.

3. In the supporting field of radar meteorology, the Soviet Union is believed to lag behind the West, but will probably overcome this deficiency within the next few years.

4. The large size of the expanding Soviet cloud physics and weather modification research program and the large number of competent Soviet scientists available presage advances such that the USSR will catch up with the West in the capability to modify weather within 5 years. Based on their plans and their estimated capability to achieve them, it is believed that Soviet scientists during the next 5 years will conduct their first experiments designed to control large-scale meteorological processes, but their advances will be insufficient for them to control large-scale weather processes in an operational sense during this period.

SUMMARY

More than 30 Soviet institutes and organizations with more than 200 scientists are engaged in cloud physics and weather modification research. An analysis of Soviet manpower in this field indicates that the magnitude of the program is considerably larger than that of any Western country. Research in all areas of cloud physics is being pursued actively in the Soviet Union and plans include: (1) the strengthening of work in troposphere synoptics, microphysics of clouds and fog and their modification, cloud electrification and instrumentation for experiments; (2) the expansion of studies of large-scale weather systems through the use of aircraft soundings to high altitudes, (3) the broadening of atmospheric chemistry research; (4) the broadening of theoretical generalization of experimental work; (5) the developing of new instruments for atmospheric studies and the perfecting of rockets for use in studying high clouds; and (6) the establishing of a new periodical "Clouds and Precipitation," as well as semiannual seminars. Plans also are under way for an "All-Union Cloud Year" in 1962 to obtain detailed observations that will provide basic information to advance weather modification techniques. These plans suggest experiments to influence large-scale weather processes.

Soviet cloud physics and weather modification research has been along lines similar to those pursued in other parts of the world with only minor differences in the level of achievement. Recently, the Soviets emphasized studies of atmospheric electricity and the development of better instruments for cloud physics measurements. Only a few Soviet papers have shown an advanced approach to the use of radar for meteorological problems, and this lack of positive evidence leads to the conclusion that the Soviet Union trails the West in applying the techniques of radar meteorology to cloud physics and weather modification research, even though the Soviets are highly capable in the field of radar and have air defense radar of excellent quality. For cloud physics research, they still use the ancient "Kobal't" radar that has characteristics long surpassed by weather-radar developments in the West. The Soviets apparently classify some of their weather-radar research, for a number of papers have withheld from publication for several years and there are gaps in their literature that must be known to the Soviets from studying foreign journals. Any lag is likely to be eliminated in the next few years with the expanding Soviet research programs in cloud physics and weather modification.

Cloud seeding research is also evidently classified, for details are withheld from the scientific journals. Nevertheless, it is known that experiments with dry ice to dissipate low clouds and fog began in the USSR around 1950. Continued work in the area led to the USSR becoming in 1958 the first country to establish a routine procedure to clear airports of fog and low clouds by seeding techniques. The Soviets are continuing to use a variety of reagents and seeding techniques. In addition to dry ice, other reagents, such as silver iodide and lead iodide, have been used in weather modification experiments. Aircraft, rockets, balloons, and tracer bullets have been used to carry the seeding reagent into the clouds. Many of these techniques have been used in the hail prevention program in southern USSR and the Caucasus.

The Soviets have made a scientifically sound proposal that large amounts of silver iodide introduced in a cloud will prevent damaging hail, but have not demonstrated that they can accomplish this "overseeding" effectively.

The Soviets have concluded that rainfall can be increased by seeding, but they have not reported the efficacy of their seeding. It is difficult to believe that they have not undertaken the necessary statistical tests to determine the effectiveness of their seeding experiments; or that, as the gaps in the literature would indicate, they are not seeding winter storms or stratified orographic clouds, which provide promise of increasing rainfall. Probably such experiments have been conducted but the results are classified and not available.

DISCUSSION

ORGANIZATIONS AND PERSONNEL ENGAGED IN CLOUD PHYSICS AND WEATHER MODIFICATION RESEARCH

The senior organization in the USSR charged with coordinating Soviet cloud physics and weather modification research is the Coordinating Council on the Problem of Physics of Clouds and Precipitation. This organization was established in 1955 by the Presidium of the Academy of Sciences, USSR, and is a part of the Department of Physico-Mathematical Sciences. Ye. K. Fedorov, Corresponding Member of the Academy of Sciences and director of the Institute of Applied Geophysics, is chairman of the Coordinating Council. A number of research institutes and organizations operate under the general coordinating efforts of the council. The Council organizes interdepartmental conferences on cloud physics and weather control research at irregular intervals six conferences having been held to date. Besides sponsoring scientific conferences, the Coordinating Council reports to the appropriate Soviet research organizations on cloud physics and weather modification work done in the Soviet Union and abroad. Members of the June 1959 conference resolved that the Council should intensify the work of reporting on the research done in the Soviet Union and abroad to improve its coordinating work.[1] More than 30 Soviet institutes and organizations engaged in cloud physics and weather modification research have been identified (appendix A). These include institutes of the Academy of Sciences, USSR, and the Academies of Sciences in certain of the Soviet republics, the universities, the weather service, and the armed forces.[2] Three of the Soviet organizations have very large cloud physics and weather modification research programs, namely, the Institute of Applied Geophysics, the Main Geophysical Observatory, and the Central Aerological Observatory. These 3 organizations are estimated to have 32, 69, and 30 scientists respectively (a total of 131) engaged in research on cloud physics and weather modification. A conservative estimate, based on the authorship of publications, is that 218 scientific research personnel are active in the Soviet program; the actual number working at the present time probably is larger. (The leading Soviet personnel are listed in appendix B.) No country in the West has so many scientists working in the cloud physics and weather modification field. For example, the United States has approximately 75 scientists engaged in similar research.[3]

CLOUD PHYSICS RESEARCH ACTIVITIES

The Soviets have been making impressive progress in their cloud physics research and the program is active and expanding. (See biblography, appendix C.) Most of the pertinent Soviet scientific literature that is available deals with basic cloud physics research, although an increasing amount of information is becoming available on weather control.

All areas of cloud physics research are being pursued actively in the Soviet Union. A measure of the scope of the program is the Sixth All-Union Cloud Conference, held at the Institute of Applied Geophysics of the Academy of Sciences, USSR, from 15 to 20 June 1959, which was attended by 44 Soviet representatives of nearly as many different types of scientific institutions of the USSR, as well as representatives from Communist China.[1] The meeting was called by the Coordinating Council of Problems of the Physics of Clouds and Precipitation of the Department of Physical Mathematical Sciences of the Academy of Sciences, USSR. The overall effort evidently has an interdisciplinary character. Articles pertinent to cloud physics have been written by members of the Institute of Physical Chemistry and other organizations, such as the Institute of Power Engineering and Hydraulics of the Academy of Sciences, Armenian SSR.

The Sixth Cloud Conference was called to review the progress made since the previous

conference in 1956 and to encourage an expansion of research in cloud physics. Resolutions were adopted: (1) to strengthen work in troposphere synoptics, microphysics of clouds and fog and their modification, cloud electrification, and instrumentation for field and laboratory experiments; (2) to expand studies of large-scale weather systems through the use of aircraft soundings to high altitudes, with special attention to clouds extending to very high altitudes; (3) to broaden work in atmospheric chemistry; (4) to broaden theoretical generalizations of experimental work; (5) to develop new instruments for atmospheric studies and perfect the use of rockets for studying clouds in the upper layers of atmosphere; (6) to organize an All-Union Cloud Year (VOG) in 1962; (7) to publish through the Academy of Sciences, USSR, a new periodical entitled "Clouds and Precipitation," and to hold seminars on given problems twice a year; (8) to increase informative work by the Coordinating Council on domestic and foreign investigations; and (9) to hold the next conference in 1961 before the VOG begins.[1]

The establishment of a special physics journal, the decision to hold seminars at 6-month intervals, and the plan to have an "All-Union Cloud Year," as well as the other decisions, all indicate a large expansion of an already substantial program. The aims spelled out in the series of resolutions have also been recognized as being important by other countries, and many have instituted modest programs. The Soviets have apparently seen the important implications of greater knowledge of cloud and precipitation processes and control and have dictated that emphasis will be placed on this type of research.

Of particular interest is the Soviets declaration that a more daring approach must be directed to studies influencing large-scale weather processes and climate.[1] This indicates that the Soviets recognize the potential of this type of research but that relatively little has been done to date in the area of large-scale weather modification. Evidently, increased efforts and experiments will be directed toward this goal in the future and it is believed that during the next 5 years the Soviets will conduct their first experiments designed to control large-scale meteorological processes.

Soviet research has been along lines similar to those pursued in other parts of the world, with only minor differences in level of achievement. Research in the USSR and the United States appears to be on about the same level in the study of ice crystals and snowflakes, cloud formation and structure, atmospheric electricity, and cloud physics instruments. In the USSR, more progress has been made in the study of the microstructure of clouds, whereas in the United States more progress has been made in the study of raindrop spectra and precipitation processes. Research in these areas of cloud physics is basic to an understanding of the natural mechanisms of precipitation and such understanding is a prerequisite for effective control of the weather.

Recently, some emphasis has been placed on studies of atmospheric electricity and on the development of better instruments for cloud physics measurements. One of the most productive scientists in these areas has been I. M. Imyanitov. He has written a large number of articles on various aspects of atmospheric electricity and recently published a book.[4]

RADAR METEOROLOGY

Radar is capable of detecting the presence of hydrometeors, especially large water and ice particles, and has been used extensively and beneficially in cloud physics research programs throughout the Western world. Radar has furnished valuable data on fundamental problems regarding the formation of precipitation in convective clouds. It has been useful for studying the growth of convective clouds and the precipitation-generating levels in clouds. The ability of radar to detect large water and ice particles has made it a valuable tool for assessing the results of cloud-seeding experiments. To date, it has been used primarily for the detection of formation of precipitation in cumuliform clouds, but it is reasonable to expect in the near future it will be used to supplement rain-gage networks, in order to obtain a better estimate of the total rainfall over the seeded area.

Radar Equipment

The standard radar set used by Soviet meteorologists is the so-called Kobal't radar. This equipment operates at a wave length of 3.2 centimeters, peak output power of 50 kilowatts, utilizes an antenna diameter of 0.736 meter and records on a plan-position indicator (PPI) scope.* All articles involving radar observations of clouds and precipitation have stated that the Kobal't radar or a modification thereof was employed. The Kobal't has been used both on the ground and in airplanes.[5] [6]

The characteristics of the Kobal't radar are similar in many respects to those of the AN/APQ–13, a U.S. airborne radar set developed in the early 1940's for bombing and navigation and widely used by the U.S. Air Weather Service from 1945 to 1954. An improved U.S. radar set, the AN/CPS–9, which was specifically designed for weather observations, has been used operationally since about 1954.

Several Soviet papers have been written about techniques to increase the sensitivity of the Kobal't. In 1958, V. D. Stepanenko carried out tests in which the 0.736-meter antenna reflector was replaced with a 2-meter reflector.[7] Another article in 1958 reports on a modified Kobal't radar with a fixed, 20-meter, vertically pointing antenna.[8] It is clear from these articles published in 1958, that the Soviet scientists were trying to improve an existing piece of equipment, whereas in the United States a specially designed radar had already been in operational use for about 4 years. The AN/CPS–9 is a much better weather radar than the modified Kobal't because the antenna scanning is flexible, the output power is higher, and in all probability the minimum detectable signal is lower. In addition, the U.S. Weather Bureau in 1959 began to install new weather-radar sets that are superior to the AN/CPS–9 in many respects.

It appears that the Soviets have a network of Kobal't radar sets for use at weather stations. A Soviet meteorologist, V. M. Muchnik, cites radar data obtained at Kiev during the period 1952 and 1956.[5] He also indicates that there was a Kobal't radar set in Moscow but does not give any dates. A. A. Federova analyzed data obtained at Rostov-on-Don.

V. V. Kostarev set out to use radar with a vertically pointing antenna for the detection of cloud layers. Recognizing that it would be necessary to increase the sensitivity of the Kobal't radar, he chose to increase the antenna diameter to 20 meters. This was done by the construction of a steel reinforced concrete paraboloid that was sprayed with a metallic paint (figure 1). He discovered that the antenna gain (the increase or amplification of the signal) varied with range, out to a distance of about 25 kilometers. Over 12 kilometers, the altitude range of interest, there was a breakdown of the usual relationship between echo strength and distance. After considerable effort, Kostarev finally stated that exact quantitative measurements were difficult.[8]

In the West the aims of Kostarev's research, the detection of cloud layers, have been met in various ways. The first was to increase output power, and in this way, increase the signal-to-noise ratio. The most successful way to observe clouds with radar was to use radar sets at shorter wave lengths. As early as 1951, Western scientists were utilizing K-band radar sets (wave lengths 0.86, 1.25, and 1.87 centimeters) for cloud detection. Since that time they have been widely used both for research as well as for cloud-base and cloud-top indicators.

Theoretical Work in Radar Meteorology

In 1952, D. M. Vysokovskiy gave a detailed discussion of the use of radar for weather observations and the theory involved.[10] Recently A. B. Shupyatskiy has proposed that by measuring returned power and attenuation one should be able to obtain measurements of the mean drop sizes and the water content of heavy rainstorms.[11] The article gives a fairly detailed discussion of the relevant scattering theory and develops equations for calculating the variables of interest. Although

* A type of radarscope on which the range and azimuth of a target are displayed in polar coordinates.

the ideas expressed by these Soviet authors were not new, their articles showed that they were acquainted with the electromagnetic theory involved. Most of the relevant references were derived from journals published outside the Soviet Union.

A paper published in 1958 has dealt with the problem of estimating turbulence in clouds by measuring the fluctuations of radar signal strength.[12] This article does not reference U.S. and Canadian work on this subject, which has been quite extensive since 1950, but it demonstrates a more advanced approach to the use of radar for meteorological problems than most of the other Soviet articles found to date.

Application of Radar to Meteorology

A number of articles have been found that refer to radar as a tool for detecting the presence or absence of precipitation.[7 13] Some studies have been made of the characteristics of radar echoes as they apply to cloud physics. A. P. Chuvayev (1956) investigated the vertical extent of convective clouds and the existence of a precipitation echo.[14] Similar work was published in the United States in 1951. V. M. Muchnik published statistics on the size of convective echoes and the fraction of the observed area covered by echoes.[6] Similar work was done by the U.S. "Thunderstorm Project" about 9 years earlier. Muchnik also made a study of the differences of the radar echoes from showers and thunderstorms.[5] The author used a rain intensity of 24 millimeters per hour to discriminate between the two phenomena. He listed various rules involving vertical echo extent and range of detections that would permit a separation of showers from thunderstorms. This empirical approach is not particularly useful.

A paper written in 1953 but published 4 years later, stated that thunderstorms can be circumnavigated by airplanes if the airplanes are equipped with suitable electric field measuring equipment. It points out that the arguments against radar for airborne use are (1) weight, (2) high cost and (3) inability to distinguish between showers and thunderstorms. In a later section, the authors state that it would be worthwhile to combine a field meter with radar.[15] Muchnik concluded that aircraft should be equipped with radar and thunderstorm detectors to improve safety and comfort.[6] In the United States the recommendation to install radar in commercial aircraft was made by various agencies in about 1949, and was put into practice in about 1954.

Sokolov, who in 1958 claimed that he was entrusted by the "Military Scientific Society" with the study of weather observations by means of radar, has discussed various aspects of weather-radar observations and suggested ways to improve the observations. Many of his statements are overgeneralizations and either incorrect or misleading and do not demonstrate an expert knowledge of the practical limitations of radar equipment.[9]

Status of Soviet Radar Meteorology

If the articles in the open literature cited above represented the latest thinking of Soviet experts in radar meteorology at the time they were published, it would have to be concluded that the Soviets trail far behind U.S. scientists. To date, all the articles found deal with the use of the low-powered X-band Kobal't. Azimuthal scanning and vertically pointing antennas have been employed but nothing has been reported about vertically scanning equipment. The use of K-band equipment has not been mentioned. V. Sokolov pointed out the value of large peak power but there is no evidence that anything but the Kobal't radar has been used for weather work.[9]

Only one article has been found dealing with the use of radar for quantitative measurements of rainfall intensity although a few articles have mentioned this possibility. Many other aspects of radar meteorology have been barely touched upon or not mentioned in the Soviet literature. Some examples are the following: (1) the "bright-band";* (2) nonspherical particles; (3) melting particles; (4) depolarization; (5) isoecho contour mapping. Most of the published Soviet studies have

* The enhanced radar echo of snow as it melts to rain.

been of a qualitative exploratory nature of the type published in the United States 5 to 10 years ago. It would appear on the basis of this literature that Soviet radar meteorology lags that of the United States by at least 5 years.

On the other hand, this assessment does not take into account radar equipment and investigations that are classified, and there are strong suggestions of classification in this area. For example, one of the articles cited above was written 4 years before it was published. The long delay suggests official suppression of publications. Soviet air defense radars are known to be of excellent quality and are equal to the best of the Western systems. There is little doubt, therefore, that the Soviets have the capability to develop high quality weather-radar. It is likely that some developments have been classified and it is possible that any lag in radar-meteorology may be more apparent than real; nevertheless, from a conservative point of view, the Soviets would have to be judged as trailing in the specialized field of radar-meteorology. Also, it doesn't seem reasonable that if improved radar were available they would continue to use and publish on the Kobalt. It is quite likely that if improved weather radars are available, it is a recent development and they are therefore definitely behind in terms of use of, and result from, such radars. With the expanding Soviet research programs in cloud physics and weather modification, it is believed that more and better weather-radar will become available within the next few years.

CLOUD SEEDING AND WEATHER MODIFICATION RESEARCH

Soviet cloud seeding work reported in the scientific literature has been scanty indeed, although the Soviet press and radio have reported on weather modification activities from time to time since 1947. During 1959–60 a number of fairly substantial articles have appeared concerning research done in the period before 1957. It has become clear that considerably more research in the area of weather modification has been in progress than has been indicated by earlier literature. In 1958, a foreign meteorologist who visited the USSR reported that the staff of a Soviet institute engaged in weather modification was reluctant to discuss their work because it was classified; however, he was given the impression that the work was in the process of being declassified.[16] Quite evidently there has been a relaxation of government classification, but it does not appear that the relaxation has been complete. The large lag in time between completion of the work and publication indicates that details of work completed during the last 3 or 4 years still are being withheld from the scientific journals.

There are several interesting sidelights concerning Soviet classification of weather control research and activities. Several issues of *Trudy, Main Geophysical Observatory,* which bear unusual numbers, namely, 09, 013, 020, have been cited in the literature undoubtedly by oversight. No other Trudy series have numbers which begin with a zero. Every effort to obtain these has failed. Recently, a direct attempt to obtain them in Moscow was turned away with the statement that these were state papers and were unavailable. When members of Kozlov's party were asked about Soviet weather control during their visit in the United States, all claimed they had never heard of any Soviet capability in this field and treated it as a joke.[17]

Cloud and Fog Dispersal

The earliest available Soviet scientific reference to research applicable to cloud and fog dispersal by dry ice (solid CO_2) is dated 1951.[19] As early as 1952, the Soviets attempted, with questionable success, to dissipate the low clouds by seeding techniques over Red Square in Moscow during a big parade.[20] The successful use of dry ice seeding for dissipating stratiform clouds has been reported in a number of popular and scientific papers dated 1955 through 1957.[21–23] In 1958, Federov stated, "The problem of the dispersal of supercooled clouds can be considered solved in principle. At present, in the USSR, a distinct technology designated for opening airports in winter is being completed and introduced into practice. Successful dis-

persal is being accomplished over expenses of 10 to 15 kilometers." [24] A popular article reiterates and substantiates this statement later in 1958 and another brief article published in 1960 describes a demonstration of carbon dioxide seeding of a fog bank to clear an airport.[25] [26] The scientific feasibility of dissipating subcooled clouds by dry ice seeding was established in the United States by the Signal Corps Engineering Laboratories during the period 1952–55.[27] The USSR, however, was the first country to establish a routine operational program for dispersing such clouds and fog.

Seeding Reagents

Although Soviet scientists showed they were aware of the possible value of various types of seeding reagents, virtually all field experiments described in the scientific literature available a year or so ago made use of seeding with dry ice from aircraft.[28] Articles that have appeared recently have shown that the Soviets have used and will continue to use a variety of seeding techniques and reagents.

G. Ya. Myakishev (1958) in a nontechnical article has discussed the use of calcium chloride particles for seeding so-called "warm clouds." He also indicated that experiments were conducted with water spray from aircraft which "gave positive results in separate cases only. Work in the given direction is continuing." [29] This popular article did not contain much substance, but it does show that investigation of techniques of modifying warm clouds is in progress. It is also known that the Soviets purchased a number of small rockets (maximum altitude 1,500 meters) from an Italian manufacturer (figure 2). The Italians have proposed that these rockets could be used for seeding with sodium chloride and have employed them for this purpose in Africa. The Soviets probably have used them for this purpose also. A group of Soviet scientists have concluded that experiments on burning red phosphorus directly in the clouds showed that research on hygroscopic substances must be carried further with the object of modifying the warm parts of clouds.[30]

An increasing number of articles deal with the use of silver iodide. The particles have been dispersed in a number of ways. Shtal' and Morachevskiy have discussed various aspects of cloud seeding techniques.[31] [32] They mention that silver iodide has been placed in clouds by firing tracer bullets containing silver iodide as a component of the combustible mixture. The firing was done from the ground. These articles are of a non-technical nature and do not give enough detail to evaluate the feasibility or value of this seeding scheme. The authors also mention the use of lead iodide and report on the dispersion of silver iodide from an airplane. Other authors have also mentioned airborne silver iodide seeding. A non-technical article states that anti-hail rockets have been developed to seed with silver iodide. These rockets undoubtedly are similar to the rockets purchased from the Italians.[33] A group of authors have discussed the use of silver iodide for hail suppression and state that continuous crystallization would require four to 10 kilograms in a cloud, but they suggest using 8 to 30 kilograms of the reagent to take into account unknown factors.[34] The use of 8 to 30 kilograms of silver iodide in a cloud as suggested by the Soviets is a much larger quantity than has ever been used in the West. If this amount of silver iodide crystals can be put into a cloud, hail probably would be prevented. It is not clear how this can be done effectively and there is no evidence of it being done in the USSR.

An extensive program was carried out in 1956 to test the possibility of modifying individual cumulus congestus clouds by introducing silver iodide or lead iodide into the subcooled part of the cloud. The seeding crystals were produced at the ground by a new technique of condensation after vaporization of a mixture with red phosphorus. The latter served as a fuel for the vaporization. One part of silver iodide was mixed with two parts of red phosphorus. Two kilograms were used to seed one cubic kilometer of cloud. The efficacy of the mixture of silver iodide and red phosphorus is unknown and was not stated in the article. The experimenters, however, demonstrated they were aware of

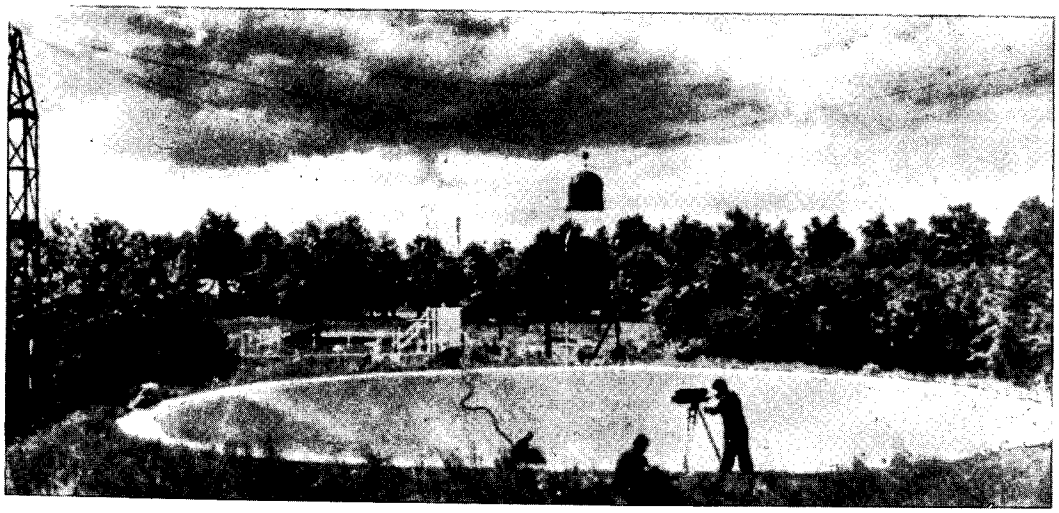

Figure 1. Kobal't Radar with 20-meter antenna.

Figure 2. Italian anti-hail rockets being prepared for shipment to USSR.

Figure 3. Soviet cloud physics research instruments mounted on aircraft.

the difficulties of using silver iodide particles in their discussions of various relevant factors such as photo-deactivation.[30]

Balloons have been employed for dispersing silver iodide and dry ice.[30] Dry ice seeding also has been carried out by hanging a basket of dry ice from a cable below an airplane.[35] The use of silver iodide for dissipating low cloud and fog was mentioned for the first time in a scientific article published in 1959.[36]

Increasing Rainfall by Cloud Seeding

A number of recently available Soviet reports have concluded that a rainfall increase could be caused by cloud seeding. One group concluded that silver particles released from the ground would increase precipitation if meteorological conditions were correct.[30] G. Ya. Myakishev reported that water spray sometimes produced rain from warm clouds.[29] I. M. Imyanitov et al., reported precipitation echoes always appeared on the radar from cumulus congestus clouds after dry ice seeding.[13] A. P. Chuvayev also reported precipitation was caused to form in convective clouds by seeding with dry ice in quantities of less than 1 kilogram per kilometer.[37] Previously evaluated Soviet articles dealing with "rainmaking" also concluded that rainfall could be increased by seeding. There still are no Soviet reports of a systematic, carefully designed and executed program of cloud seeding that would permit statistical tests of the efficacy of cloud seeding. In most cases the behavior of a seeded cloud has been compared with that of other clouds. The possibilities of bias make this technique of questionable value.

Seeding of Convective Clouds

In the past year it has become clear that the Soviets are engaged in an extensive program involving the study of convective clouds and thunderstorms. A large research program is in progress in the southern USSR and the Caucasus. One lengthy article describes studies of thunderstorms in these regions.[18] The investigations have involved the use of specially instrumented aircraft and radar. The aircraft, IL–12 number L–1784, was equipped by the Scientific Research Institute of the Civil Air Fleet with a Kobal't radar, a "complex of apparatus for recording the parameters characterizing the flight of an aircraft through a turbulent medium, an installation for measuring the atmospheric electric field strength" and apparatus for atmospheric soundings (meteorograph for recording altitude, temperature and humidity, microphotographic equipment for observing cloud droplets and water content instrument). This aircraft is equipped well for cloud physics observations * (figure 3). In another article, written 4 years before publication, the same authors describe experiments in which cumulus congestus clouds were seeded with 2 to 7 kilgrams of dry ice in an effort to modify the electric state of the clouds.[13] They concluded that dry ice seeding could lead to large increases in the electric field intensity, "and probably, in favorable conditions can also prevent the development of hail." The conclusion about modification of the electric state of the clouds was a reaffirmation of the same conclusion drawn in a paper by I. M. Imyanitov and A. P. Chuvayev written in 1956 and is similar to one arrived at by MacCready in the United States. The validity of the conclusion in both cases, however, is open to question because of uncertainties about the experimental techniques. In any event, the Soviet paper does not present hail observations and without them the conclusion must be regarded as hypothetical.

Silver iodide seeding from the ground has been used in an attempt to modify convective clouds in the Caucasus for the purpose of preventing hail.[30] From radar observations, the experimenters concluded that in seeded clouds the "echo zones created artificially" were 1.5 to 2 kilometers lower than natural echoes. Also, they stated that "modification of cumulus congestus clouds to prevent hail is possible only where the cloud has developed up to the negative temperature regions (—5 to —10°C)." Since they were using silver iodide particles, which are not effective until

* Soviet scientists started making detailed microphysical studies of clouds with well instrumented aircraft several years before such studies were made in the United States.

these temperatures are reached, this statement is certainly valid. Nevertheless, the implication that something can be done about hail suppression is not proven. They do not present any data on hail. Although there have been a number of statements about the use of seeding to prevent damaging hail, floods, etc., no articles have been found yet which relate seeding activities directly to that phenomena.

The emphasis placed on the study of thunderstorms and hail and their control through cloud modification techniques is clearly shown by the fact that the research in the southern USSR is a cooperative effort of several organizations. For example, the Academy of Sciences of Armenia and Georgia are working with other institutes of the USSR.

Status and Trends of Soviet Weather Modification

During the past year, the Soviet literature has contained more information than previously about cloud modification studies. Soviet scientists are believed to have accomplished much more research in this area than has found its way into the open literature. The map (figure 4) shows the areas in which cloud seeding operations are known to have been carried out, the organizations, and the dates involved. Some of the results of the work at locations A, B, and C (see map), have been reported, but the results of the project D have been very sketchy. It should be noted that all of these programs have been concerned with the modification of convective clouds. In all of these operations, one of the prime objectives has been to develop techniques to suppress damaging hail.

One of the potentially important applications of cloud modification techniques is that of increasing rainfall. No reports have been found of experiments to obtain quantitative estimates of rainfall increases following seeding. In many other countries such "rainmaking" activities have been in practice for many years. The results of most of these tests have not been conclusive. In order to make quantitative analyses of the effects of the seeding, it is necessary to measure rainfall at the ground or flow of water out of a watershed. The analysis involves statistical techniques. Good experiments also incorporate sound statistical principles in the design of the experiments. No Soviet research of this type has been found yet. In view of the great practical value of this kind of work, it is difficult to believe that this area has been overlooked or neglected.

It may be significant that the Soviet reports say virtually nothing about seeding winter storms or stratified orographic clouds for the purpose of increasing rainfall. It seems inconsistent that such a well-known technique of cloud modification has not been tried. Many Western scientists believe that these types of clouds are most suitable for increasing rainfall. The Soviets very probably have been conducting experiments in this promising area for weather modification, but the results are classified and not available.

An examination of figure 4 indicates that the reported cloud seeding activity is concentrated in the western Soviet Union. A well-balanced program would call for activity also in the eastern sections because there are geographical differences in cloud types and cloud properties. It is likely that work has been done in the eastern sections but not reported and that it will continue in the future. It is stated that the "All-Union Cloud Year" is intended to obtain detailed cloud observations over the entire Soviet Union. The observations are to be used to improve cloud forecasts and later to modify the clouds "in the interest of aviation, agriculture, transport, and other fields of the People's Economy." [1]

The actions taken by Soviet scientists during the past year show that they recognize the lack of knowledge of many important aspects of cloud physics. They also demonstrate an aggressive attitude towards the solution of many of the problems. The magnitude of their program is impressive indeed. It has been expanding rapidly. Without doubt the development of successful techniques to modify clouds, to suppress damaging hail and lightning, prevent flash floods

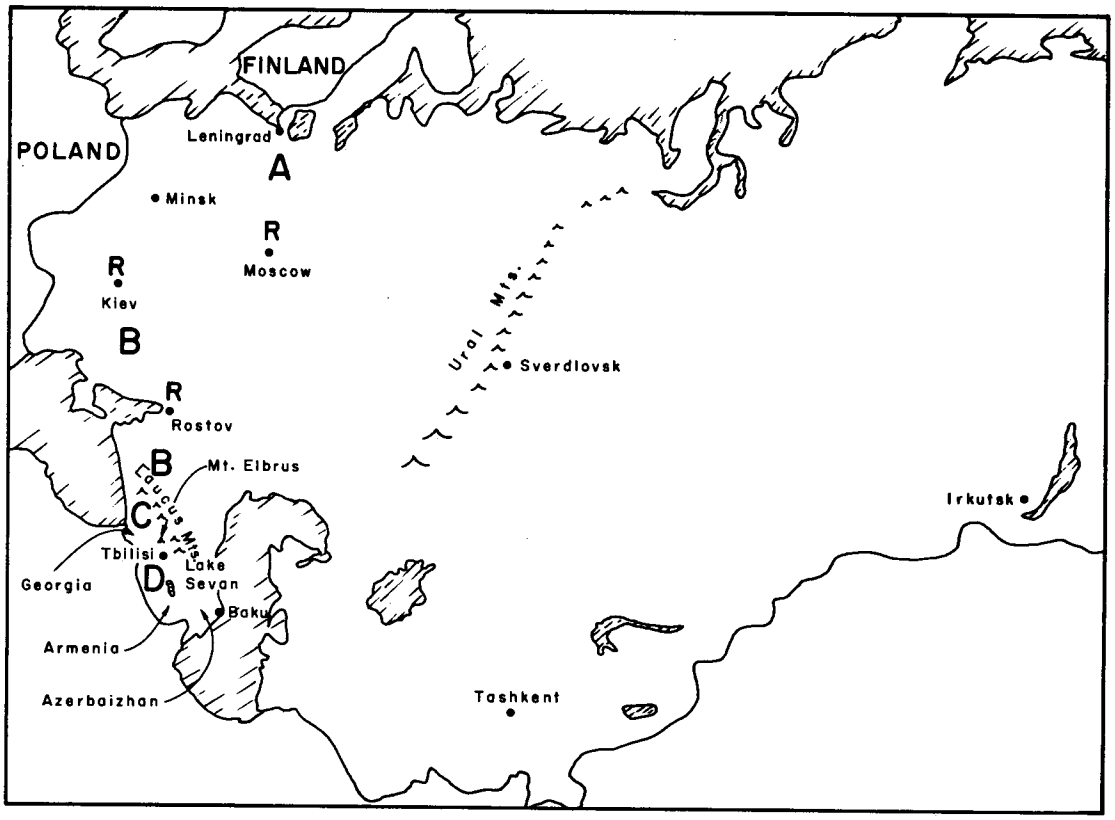

Figure 4. Areas of Soviet cloud seeding activity.

KEY	INSTITUTE PERFORMING EXPERIMENT	DATE OF EXPERIMENT
A Convective clouds, thunderstorms, hail – dry ice	Main Geophys. Obs.	1951–1952
B Convective clouds, thunderstorms, hail – dry ice	Main Geophys. Obs. Scientific Res. Inst., Civil Air Lines	July 1953
C Convective clouds, thunderstorms, hail – seeding	Inst. of Geophys., Acad. Sci. Georgia SSR	1952 to 1956
C Convective clouds, thunderstorms, hail – Agl from ground	Inst. of Geophys., Acad. Sci. Georgia SSR Inst. of Applied Geophys., Acad. Sci., SSR Georgian Admin. of Hydrometeor. Service Tbilisi Sci. Res. Hydrometeor. Inst. Dept. Atmos. Phys., Lenin State Univ.	May to July, 1956 Probably to present
D Convective clouds, thunderstorms, hail – dry ice	Main Geofiz. Obs. Inst. Power Eng. & Hydraulics, Acad. Sci., Armenia	1958–1959
R Locations of radar sets.		

and increase rainfall would be of tremendous economic value. At present, neither the Soviets nor any other group can convincingly claim that they can do these things successfully. Quite obviously, the "propaganda" value of well-supported claims that techniques have been developed to control weather would be enormous. In recent years the most spectacular scientific advances have had military overtones. A development of such tremendous peacetime value as artificial rainmaking or hail suppression probably would have great impact.

It is estimated that the USSR will overtake the West in the fields of cloud physics and weather control research in 5 years if the resolutions of the "Sixth All Union Cloud Conference" are carried out while the programs of the West continue at their present, and likely future, rate. The Soviets are in a strong position to mount an expanded research program since they have ample trained personnel to carry it out effectively. There is little reason to doubt that the Soviet government will continue to support the expanding program in weather modification.

GLOSSARY

Convective clouds Clouds that owe their vertical development, and possibly their origin, to vertical motions in the atmosphere.

Cumuliform clouds Clouds in which the principal characteristic is vertical development in the form of rising mounds, domes, or towers.

Cumulus congestus clouds Strongly developing cumuliform clouds with generally sharp outlines and sometimes with a great vertical development; they are characterized by a cauliflower or tower aspect of large size.

Hydrometeor Any product of condensation or sublimation of atmospheric water vapor.

Orographic clouds Clouds whose form and extent are determined by the disturbing effects of the topographical features of the earth's surface upon the passing flow of air.

Stratiform clouds Clouds with extensive horizontal development as opposed to vertical development.

Supercooled clouds Clouds that contain liquid water droplets at temperatures below freezing.

Troposphere synoptics The qualitative study of the development, movement, and behavior of weather phenomena in the lower 10 to 20 kilometers of the atmosphere.

APPENDIX A

ORGANIZATIONS AND PERSONNEL ENGAGED IN CLOUD PHYSICS RESEARCH

The scientists listed either are presently or were in the last 10 years at the particular establishment. In some instances, the association of a particular individual with a particular establishment is based on weak evidence, but it was felt desirable to do this rather than to indicate the affiliation as "unknown." After each individual's name is a list of the dates by year of articles published or reported at a conference by that individual. When more than one paper was published in 1 year, letters a, b, etc., are used to designate each article. The symbols SA and CA indicate that the author in question was either a senior or coauthor respectively of a paper having more than one author. The symbol P indicates the research was reported at a conference but a published form of the paper has not been located.

ACADEMY OF SCIENCES, USSR

Coordinating Council on Problems of Physics of Clouds and Precipitation, Moscow

Institute of Applied Geophysics, Moscow

All types of cloud physics research including cloud seeding.

Alekandrov, E. L.: 1959
Balabanova, V. N.: 1959 a,b.
Belyayeva, I. I.: 1957 (SA)
Bibilashvili, N. Sh.: 1959 (SA)
Bocharov, Ye. I.: 1958 a,b.
Bolsheverov, B. M.: 1952
Bonchkovskiy, V. F.: 1954
Borishanskiy, L. S.: 1952 (SA)
Chudaykin, A. V.: 1956 (P)
Fedorov, Ye. K. (Corresponding member of Academy of Sciences; Director of Institute of Applied Geophysics): 1958; 1957 (CA); 1956; 1951; 1950.
Krasnogorskaya, N. V.: 1958; 1956; 1955; 1952
Krechmer, S. I.: 1954
Laktionov, A. G.: 1958
Levin, L. M.: 1959; 1958 a,b; 1957 a,b; 1956; 1956 (CA); 1954 a,b; 1953; 1953 (SA).
Litvinov, I. V.: 1959; 1958 a,b; 1957; 1956 a,b,c,d; 1955
Mamina, E. F.: 1957 (SA)
Merzhanov, K. M.: 1956 (SA)
Mikirov, A. Ye.: 1959; 1957 a,b,c; 1957 (CA)
Novikov, Ye. A.: 1957 a,b.
Ordzhonikidze, A. A.: 1959 (CA)
Peterimov, N. I.: 1956 (CA)
Pshenay-Severin, S. V.: 1959; 1958; 1957
Pudovkina, I. B.: 1956 (P)
Sergiyeva, A. P.: 1959; 1958
Shaposhnikova, I. I.: 1954 (CA)
Shchelokov, V. V.: 1956
Skatskiy, V. I.: 1956
Smirnov, N. S.: 1957 (CA); 1956; 1956 a,b (CA); 1954 (SA); 1950
Starostina, R. E.: 1956 (P); 1953 (CA)

Sulakvelidze, G. K.: 1959;
1959 a,b (CA)
Tantsova, N. N.: 1954 (CA)
Teverovskiy, Ye. N.: 1956 (P);
1952 (CA)
Vul'fson, N. I.: 1958; 1957 a,b;
1956 a,b; 1956 (SA); 1954, 1953
Zaytseva, A. M.: 1959 (CA)

Institute of Physical Chemistry, Moscow

Nuclei, Growth of water drops

Batova, G. A.: 1956 (P)
Churakov, V. N.: 1956 (P)
Deryagin, B. V. (Corresponding member of Academy of Sciences); 1957 (SA); 1957 (CA); 1956 (SA); 1951 (CA); 1949 (SA); 1948 a,b (SA)
Dukhin, S. S.: 1957 (SA); 1957 (CA); 1957 (CA)
Izmaylova, G. I.: 1956 (P)
Kudryavtseva, N. M.: 1956 (P)
Leonov, L. F.: 1956 (P); 1952 (CA); 1951 (CA)
Nikol'skiy, A. P.: 1956 (P)
Petryanov, I.: 1948 (SA)
Prokhorov, P. S.: 1956 (P); 1952 (SA); 1951 (SA); 1949; 1949 (CA); 1947 (SA)
Rosenblum, N.: 1948 (CA)
Starozhilova, A. I.: 1956 (P)
Todes, O. M.: 1948 (CA)
Valesenko, G. Ye.: 1956 (P); 1948 (CA)
Yashin, V. N.: 1947 (CA)

Institute of Physics of the Atmosphere, Moscow

Theoretical studies of convection, convective clouds

Driving, A. Ya.: 1958 a,b (SA)
Feigel'son, Ye. M.: 1959; 1954 a,b; 1951
Gutman, L. N.: 1958 (CA); 1957 a,b
Polozova, M. N.: 1958 (CA)
Smirnova, A. I.: 1958 a,b (CA)
Tsvang, L. R.: 1958 (SA); 1956
Zolotavina, N. Y.: 1958 (CA)

Institute of Oceanology, Moscow

Atmospheric salt

Blinov, L. K.: 1950

Institute of Physical Problems imeni S. I. Vavilov

Ball lightning

Kapitsa, P. L. (Member of Academy of Sciences): 1955

Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Near Moscow

Lightning

Kashprovskiy, V. Ye.: 1956 (P)

ACADEMY OF SCIENCES, ARMENIAN SSR

Institute of Power Engineering and Hydraulics

Artificial precipitation

ACADEMY OF SCIENCES, GEORGIAN SSR

Thunderstorms, hail, cloud modification

Institute of Geophysics, Tbilisi

Bukhikashvilli, A. V.: 1958 (Director)
Kurdiani, I. G.
Kartsivadze, A. I.
Okudzhava, A. M.

ACADEMY OF SCIENCES, KAZAKH SSR

Chemical composition of water

Baktorov, A. B.: 1958

CHIEF DIRECTORATE OF THE HYDROMETEOROLOGICAL SERVICE

Main Geophysical Observatory, Leningrad

All types of cloud physics research with emphasis on convective clouds; cloud modification studies

Ashkipova, E. P.: 1957
Bashkirova, G. M.: 1957 (SA); 1953 (SA)
Braxilevich, V. V.: 1950 (SA)
Budilova, Ye. P.: 1954 (CA)
Chestnaya, I. I.: 1955 a,b; 1951; 1948
Chikirova, G. A.: 1956 (CA)
Chukanin, K. I.: 1959 (CA)
Churinova, M. P.: 1955; 1951
Chuvayev, A. P.: 1957 a,b,c,d,e; 1957 (SA); 1957 a,b,c,d (CA); 1956 (C) a,b; 1955 (CA); 1954 (SA); 1953 a,b,c; 1953 a,b,c (CA); 1950 (CA)
Dergach, A. L.: 1959 a,b,c
Dianov, I. M.: 1959 (CA)
Drozdov, O. A.: 1955
Dubov, A. S.: 1949
Dvali, Ye. R.: 1956
Frenkel, Ya. I.: 1953; 1950; 1946 (SA)
Gaevskiy, V. L.: 1955
Gigineyshvili, V. M.: 1953 (SA)
Gordon, I. Z.: 1951
Imyanitov, I. M.: 1958 (SA); 1957; 1957 a,b,c,d (SA); 1956 a,b; 1956 a,b,c,d (SA); 1952 a,b; 1950; 1949 a,b
Khimach, M. A.: 1956, 1954 (CA)
Kolokolov, V. P.: 1957; 1956 (SA); 1956 (CA)
Krasikov, P. N.: 1959 (SA); 1957 (SA); 1957 (CA); 1956 (SA); 1953; 1953 (CA)
Krasil'shchikov, L. B.: 1956 (P)
Kryukova, G. T.: 1954 (CA)
Kulik, M. M.: 1957 a,b,c (CA)
Ledokhovich, A. A.: 1959 (SA); 1959 a,b (CA) 1956 (SA); 1956 (CA)
Loch, B. F.: 1956 a,b
Makhotkin, L. G.: 1959; 1958 (SA)
Mamontov, N. V.: 1957 (CA)
Matveyev, L. T.: 1959 a,b; 1956 (SA)
Mikhailovskaya, V. V.: 1958 (CA); 1956 (CA)
Minin, I. K.: 1956 (P)
Morachevskiy, V. G.: 1959 (SA); 1959 a,b (CA); 1958 a,b (CA); 1957 (CA)
Morozyanskiy, A. L.: 1956 (P)
Myvkhyurya, V. I.: 1956 (P)
Nikandrov, G. T.: 1957 (CA); 1957 a,b (SA); 1956 a,b (SA)
Nikandrov, V. Ya.: (Vice Director): 1959 (SA); 1959 (CA); 1957 a,b; 1957 (CA); 1956 a,b; 1953; 1953 a,b (SA); 1953 (CA); 1951; 1950 (SA); 1950 (CA)
Ogorodnov, D. Ye.: 1956 (CA)
Osipova, G. I.: 1957
Pastukh, V. P.: 1957 (SA)
Pershina, T. A.: 1956 (CA)
Pinegin, G. N.: 1954 (CA)
Piotrovich, V. V.: 1958; 1956; 1949
Polyakova, Ye. A.: 1956; 1953 (SA)
Rabinovich, B. I.: 1957 (CA)
Reynet, Ya. Yu.: 1956
Sal'man, E. M.: 1957
Selezneva, Ye. S.: 1956; 1953; 1950; 1948 a,b; 1946
Sereyev, O. D.: 1953 (CA)
Shifrin, K. S.: 1958; 1957 (SA); 1955 a,b; 1953 (CA); 1951 a,b

Shishkin, N. S.: 1957 a,b; 1956 a,b; 1955 a,b; 1954 a,b,c,d; 1954 a,b (SA); 1953 a,b; 1952 a,b; 1951 a,b, c,d,e,f; 1949; 1948; 1946; 1946 (CA)
Shtal', V.: 1958 a,b (SA)
Shvets, M. Ye.: 1955; 1951 a,b; 1948 (CA)
Selitskaya, V. I.: 1959 (CA)
Solov'yev, A. D.: 1958 (CA); 1956 a,b.
Sokhrina: 1957 (CA)
Strel'tsova, M. B.: 1956 (CA)
Tarasov, A. V.: 1957 (CA)
Timofeev, M. P.: 1955; 1948 (CA); 1948 (SA)
Vasil'chenko, I. V.: 1958
Vinograd, P. L.: 1956
Vorontsov, P. A.: 1959 (SA); 1956; 1955; 1954 (SA)
Voskana, A. I.: 1957 (SA)
Voskresenkiy, A. I.: 1959; 1959 a,b, c, (SA); 1957 (SA)
Zabrodskiy, G. M.: 1959 (SA)
Zamorskiy, A. I.: 1956; 1955 a,b; 1953; 1952; 1951 a,b; 1950 a,b; 1948 a,b,c,d,e
Zaytsev, V. A.: 1959 (SA); 1959 (CA); 1956 (SA); 1956 (CA); 1950; 1948 a, b, c,d.
Ziganov, N. P.: 1956 (CA)
Zykova, V. V.: 1956

Central Aerological Observatory, Dolgoprudnaya, near Moscow

All types of cloud physics research with emphasis on stratiform clouds, cloud modification.

Bergun, K. I.: 1953
Borovikov, A. M.: 1953; 1952; 1952 (CA); 1948
Britayev, A. A.: 1959 (SA); 1956
Buikovskaya, S. N.: 1958 (CA)
Chernikov, A. A.: 1958 (CA)
Federova, A. A.: 1956
Gayvoronsky, I. I.: 1949
Gorelik, A. G.: 1958 (SA)
Khrgian, A. Kh.: 1956 (SA); 1953 (SA); 1953; 1952; 1952 (SA)
Kimdrat'yev, N. N.: 1959
Korneyev, A. N.: 1959 (SA); 1959 (CA)
Kostarev, V. V.: 1958 (CA)
Kotov, N. F.: 1958
Krutskaya, L. I.: 1958
Malkina, A. D.: 1958; 1957; 1952 (SA)
Marfenko, O. V.: 1952 (CA)
Mazin, I. P.: 1958 (CA); 1956 (CA); 1953 (CA); 1952;1952 (CA)

Minervin, V. Ye.: 1958 (SA); 1956
Pinus, N. Z.: 1957; 1956; 1953
Reshchikov, A. A.: 1952 (SA)
Reshetov, V. D.: 1959 a,b.
Seregin, Ya. A.: 1958
Shmeter, S. M.: 1957 (SA); 1952
Shupyatskiy, A. B.: 1959 a,b;
1958; 1957
Shur, G. N.: 1957; 1957 (CA)
Stepanenko, V. D.: 1958
Tonkova, Z. V.: 1952 (CA)
Trubnikov, B. N.: 1959 (CA)
Tsitovich, T. A.: 1959
Zak, Ye. G.: 1952 (SA) a,b; 1952 (CA);
1949

Odessa Scientific Research Geophysical Observatory

Structure of fog

Akinov, M. N.: 1957

Scientific Research Institute of Hydrometeorological Instrument Construction, Moscow

Instrument development

Nepomnyashchiy, S. I.: 1959; 1958

State Hydrological Institute, Leningrad

Chemical composition of precipitation

Voronkov, P. P.: 1954

Sverdlovsk Geophysical Observatory

Atmospheric electricity

Paramonov, N. A.: 1956; 1950 a,b.

Tashkent Scientific Research Geophysics Observatory, Tashkent

Atmospheric electricity

Chernyavskiy, E. A.: 1957; 1954; 1948
Kazakov, G. I.: 1954
Kulagin, D. I.: 1955 a,b; 1954; 1952; 1950

Tbilisi Scientific Research Hydrometeorological Institute, Tbilisi

Thunderstorms, hail, cloud modification

Bartishvili, I. T.: 1957
Gigineishvili, V. M.
Khmaladze, G. N.: 1959
Lominadze, V. P.

Ukrainian Scientific Research Hydrometeorological Institute, Kiev (including Kiev Geophysical Observatory)

Showers, thunderstorms, thunderstorm electricity, atmospheric electricity

Muchnik, V. M.: 1958 a,b,c; 1956 a,b,c,; 1956 (SA); 1955 a,b; 1955 (CA); 1954 a,b; 1953; 1952 a,b,c,d; 1949 a,b.

CHIEF DIRECTORATE OF THE CIVIL AIR FLEET

State Scientific Research Institute, Civil Air Fleet

Shelkovinokov, M. S.: 1957

CHIEF DIRECTORATE OF THE NORTHERN SEA ROUTE

Arctic and Antarctic Scientific Research Institute

Stratified clouds, cloud modification

MINISTRY OF THE CHEMICAL INDUSTRY

Scientific Institute of Fertilizers and Insecto-Fungicides, Moscow

Aerosols, fog formation

Amelin, A. G.: 1956 (SA); 1955 (SA); 1951
Belyakov, M. I.: 1955 (CA); 1955 (CA)
Fuks, N. A.: 1958 (SA); 1956 (SA)
Yankovskiy, S. S.: 1958 (CA)

MINISTRY OF DEFENSE

Air Engineering Academy imeni Mozhayskiy, Leningrad

Ledokhovic, H. A.: 1957 (CA)
Matveyev, L. T.: 1957 also identified with GGO
Zaytsev, V. A.: 1957 (SA) also identified with GGO

Department of Meteorological Service VVS (Airforce)

Prokhod'ko, M. P.: 1957
Snegerev, V. I.: 1957

MINISTRY OF ELECTRIC POWER STATIONS

All Union Scientific Research Institute of Hydraulic Engineering

Freezing bulk water

Bibikov, D. N.: 1956

MINISTRY OF HIGHER EDUCATION

Byelorussian State University imeni V. F. Lenina, Minsk
(Formerly Minsk State University)

Thunderstorm electricity

Arabadzhi, V. I.: 1959; 1957 a,b; 1956 a,b,c,d,e,f; 1955; 1953 a,b,c; 1952; 1950

Irkutsk State University imeni A. A. Zhdanov, Irkutsk

Chemical composition of precipitation.

Votintsev, K. K.: 1954

Leningrad Hydrometeorological Institute, Leningrad

Ice particles formation, precipitation, chemical composition of precipitation, Bowen theory on rainfall.

Aleshina, G. I.: 1956 (CA)
Belyashova, M. A.: 1956 (CA)
Chili, A. V.: 1958 (CA)
Dmitriyev, A. A.: 1958 (SA); 1958 (CA

Kachurin, L. G.: 1959; 1956 a,b; 1956 a,b (SA); 1953; 1951 a,b; 1950
Kudravtseva, V. I.: 1956 (CA)
Lomanov, S. I.: 1956 (CA)
Nestarova, M. I.: 1956 (CA)
Serebryakova, A. A.: 1956 (CA)
Seryakova, L. P.: 1956 (CA)
Tverskaya, N. P.: 1958; 1956 (SA); 1954; 1953 a,b; 1951; 1950; 1949
Yudina, N. P.: 1958 (CA)
Zaytseva, N. A.: 1956 (CA)
Zhavoronkina, T. K.: 1958 (SA)

Leningrad State University imeni A. A. Zhdanov, Leningrad

Atmospheric nuclei; chemical composition of precipitation; behavior of water and ice particles, convective clouds, hail, cloud modification.

Bayandina, F. I.: 1956 (P)
Breido, Ts. G.: 1956; 1955
Budyko, M. I.: 1957; 1946 (SA)
Grabovskiy, R. I.: 1956; 1955; 1954; 1952 a,b,c; 1951
Kiryukhin, B. V. (Prof.): 1959 (CA); 1956; 1956 (SA); 1951
Lyapin, E. S.: 1946 (CA)
Milin, V. B.: 1956 a,b (SA); 1954; 1953 (SA)
Pevzner, S. I.: 1956 (CA)
Tverskoy, P. N.: 1956 a,b (CA); 1954; 1949 a,b; 1948 (SA); 1947 a,b.

Moscow Engineering Physics Institute

Laboratory studies of convection cells.

Laipiderskiy, V. I.: 1956

Moscow State University imeni M. V. Lomonosov, Moscow

Freezing small water volumes; moisture transport and heat balance.

Belyayev, F. I.: 1958 (CA); 1956 a,b (CA); 1950 a,b
Kolesnikov, A. G.: 1958 (SA); 1956 a,b (SA)
Raunner, Yu. L.: 1956
Rusanov, V. I.: 1956

Rostov State University

Electrostatic precipitators

Litvinov, V. F.: 1955 (CA)
Litvinova, N. N.: 1955 (CA)

APPENDIX B

LEADING CONTRIBUTORS TO SOVIET CLOUD PHYSICS PROGRESS

On the basis of the available scientific literature it is possible to list Soviet scientists who have made important contributions to the various areas of research. Asterisks designate particularly productive scientists.

1. Atmospheric nuclei and precipitation chemistry

   S. A. Durov
   Ya. I. Frenkel
   *R. I. Grabovskiy (author of a book on this subject in 1956)
   N. S. Smirnov

2. Cloud droplet spectra and liquid-water contents in clouds.

   *A. Kh. Khrgian (author of book on physics of the atmosphere in 1953)
   I. P. Mazin
   Ye. S. Selezneva
   *Ye. B. Zak
   *V. A. Zaytsev

3. Raindrop spectra

   *I. V. Litvinov
   *N. V. Krasnogorskaya
   A. Ye. Mikirov

4. Ice crystals and snowflakes

   *Ye. B. Zak
   *A. D. Zamorskiy (author of book on subject in 1955)

5. Cloud formation and structure

   A. G. Amelin
   *A. P. Chuvayev
   N. I. Grishin
   *L. N. Gutman
   *N. V. Kolobkov (author of book on thunderstorms and squalls in 1951)
   V. S. Kozarin
   L. T. Matveyev
   K. S. Shifrin

*N. S. Shishkin (author of book on clouds, precipitation and thunderstorms in 1954)
M. P. Timofeev
*N. I. Vulf'son

6. Precipitation processes

B. V. Deryagin
*L. G. Kachurin
B. V. Kiryukhin
*L. M. Levin
*V. Ya. Nikandrov
P. S. Prokhorov
*N. S. Shishkin (author of book on clouds, precipitation and thunderstorms in 1954)
N. P. Tverskaya

7. Atmospheric electricity

V. I. Arabadzhi
Ts. G. Breydo
*A. P. Chuvayev
Ya. I. Frenkel
*I. M. Imyanitov (author of book on instruments and methods for studies of atmospheric electricity)
P. L. Kapitsa
N. V. Kolobkov
*L. M. Levin
*V. M. Muchnik
*N. S. Shishkin
*I. S. Stekol'nikov (author of several books on lightning)
P. N. Tverskoy

8. Instruments

I. M. Imyanitov
N. V. Krasnogorskaya
A. A. Ledokhovich
B. F. Loch
N. Z. Pinus
V. A. Zaytsev

9. Radar meteorology

M. P. Dolukhanov
A. G. Gorelik
V. V. Kostarev
*V. M. Muchnik

*A. B. Shupyatskiy
*D. M. Vysokovskiy

10. Cloud seeding ans weather control

*A. P. Chuvayev
*I. M. Imyanitov
*V. Ya. Nikandrov
P. N. Krasikov
V. G. Morachevskiy
V. V. Petrovich
A. D. Solov'yev
A. I. Voskresensky

APPENDIX C

BIBLIOGRAPHY OF ARTICLES REVIEWED MARCH 1959 TO FEBRUARY 1960

ALEKANDROV, E. L., 1959: Sixth All-Union Cloud Conference. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 10, 1526-1527.

ANON., 1951: Artificial rain. Nauk i Zhizn'. v. 23, no 5, p. 51.

BALABANOVA, V. N., N. Sh. BIBILASHVILI, A. I. KARTSIVADZE, B. V. KIRYUKHIN and G. K. SULAKVELIDZE, 1959: Experiments on the modification of cumulus clouds in the Alazani Valley. Izv. Akad. Nauk SSSR, Ser. Geofiz., no 2, 262-275.

BASHKIROVA, G. M., and T. A. PERSHINA, 1956: Some data from observations of the shapes of snowflakes. Trudy Glavnoy Geofiz. Obs., no 57 (119), 19-35.

BUKHIKASHVILI, A. V., 1958: Twenty-five years of the Institute of Geophysics, Academy of Sciences, Georgian SSR. Izv. Akad. Nauk SSSR, Ser. Geofiz., no 10, 1153-1161.

CHESTNAYA, I. I., 1955: Fluctuations of the lower limit of stratus clouds. Trudy Glavnoy Geofiz. Obs., no 54, 24-30.

CHUVAYEV, A. P., 1957a: An experiment in controlling the development of strongly convective clouds in northwestern European USSR. Trudy Glavnoy Geofiz. Obs., no 67 (129), 59-103.

_____, 1957b: Modern possibilities for preventing storms and hail. Trudy Glavnoy Geofiz. Obs., no 74, 71-102.

DERYAGIN, B. V. and S. S. DUKHIN, 1957: The influence of thermophoresis on the coagulation of droplets in clouds. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 779-784.

DMITRIYEV, A. A. and A. V. CHILI, 1958: On meteor showers and precipitation. Trudy Morskogo Gidrofiz, Inst., v. 12, 181-190.

DRIVING, A. Ia. and A. I. SMIRNOVA, 1958: Clouds in the stratosphere. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 337-346.

DVALI, Ye. R., 1956: The electric field of the atmosphere during precipitation. Trudy Glavnoy Geofiz. Obs., no 58 (120) 69-74.

FEDOROV, Ye. K., 1950: A word about atmospheric phenomena of electrical origin by Lomonosov and the present concept of atmospheric electricity. Izvest. Akad. Nauk SSSR, Ser. Geograf. i Geofiz., Moscow, v. 14, no 1, 25-36.

_____, 1958: Controlling weather and climate. Soviet Bloc International Geophysical Year Information, U.S. Department of Commerce. Office of Tech. Services, Aug. 15, 1958, p. 4-16.

FEIGEL'SON, Ye. M., 1951: Radiational properties of stratus clouds. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 4, 92-117.

GORELIK, A. G., V. V. KOSTAREV and A. A. CHERNIKOV, 1958: Radar measurement of turbulent motions in clouds. Meteor. i Gidrol., no 5, 12-19.

GRABOVSKIY, R. I., 1954: The formation of clouds and atmospheric precipitation. Priroda, no 10, 91-95

IMYANITOV, I. M., 1956: Methods of measuring the gradients of conductivity and ion concentration of the atmosphere. Trudy Glavnoy Geofiz. Obs., 58 (120), 3-7.

_____, M. M. KULIK and A. P. CHUVAYEV, 1957: Preliminary data on experiments for controlling the development and the change in the electrical state of strongly convective clouds in the southern regions of European USSR and in the Transcaucasus. Trudy Glavnoy Geofiz. Obs., no 67 (129), 33-58.

_____, and V. V. MIKHAYLOVSKAYA, 1958: Aircraft instrument for measuring charges of precipitation particles. Pribory i Tekh. Eks., no 2, 86-91.

_____, _____, N. P. ZIGANOV and M. B. STREL'TSOVA, 1956: Instrument for long-term measurements of intensity of the atmospheric electric field under complex meteorological conditions. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 1121-1127.

KHIMACH, M. A., 1956: The precipitation of ice from supercooled clouds and fog. Trudy Glavnoy Geofiz. Obs., no 27 (119), 44-49

KOSTAREV, V. V., 1958: Experience in radar troposphere sounding. Trudy Tsentral. Aero. Obs., no 20, 3-16.

KRASIKOV, P. N. and G. A. CHIKIROVA, 1956: The microphysical characteristics of local fogs. Trudy Glavnoy Geofiz. Obs., no 57 (119), 88-100.

_____, and N. V. MAMONTOV, 1957: Determining the sizes of particles isomorphous with ice used in experiments of the phase transformation of water. Trudy Glavnoy Geofiz. Obs., no 67 (129), 144-152.

KRASNOGORSKAYA, N. V., 1956: The results of measuring electric charges on precipitation particles in the free atmosphere. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 844-852.

LAKTIONOV, A. G., 1958: Distribution of aerosol particles in the free atmosphere. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 419-421.

LEBEDEVA, N. V., 1955: Consideration of the role of dynamic turbulence in the development of convection. Meteor. i. Gidrol., no 2, 21-26.

LEDOKOVICH, A. A. and V. A. ZAYTSEV, 1956: Remote measurement of air temperature and humidity from airplanes. Trudy Glavnoy Geofiz. Obs., no 63 (125), 177-183.

LEVIN, L. M. 1957: The intake of aerosol samples. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 87-101.

LITVINOV, I. V., 1957: The distribution function of liquid particles in rainfall. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 838-839

_____, 1958: The origin of multilayered hailstones. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 2, 277-279

LOCH, B. F., 1956a: Narrow-sector recording of atmospherics. Trudy Glavnoy Geofiz. Obs., 58 (120), 42-46

_____, 1956b: Experimental observations on the number of storm discharges. Trudy Glavnoy Geofiz. Obs., 58 (120), 47-52.

MAMINA, E. F. and Ye. K. FEDOROV, 1957: The water balance of a cloud system. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 658-663.

MIKIROV, A. E., 1957: Measurement of particle size distribution in clouds and fog. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 4, 512-515.

MINERVIN, V. Ye., 1956: Concerning measurements of moisture and ice in supercooled clouds and some errors in these measurements. Trudy Tsentral. Aero. Obs., no 17, 15-35.

MUCHNIK, V. M., 1952: Electrification in the collision of balls and drops in an electrical field. Trudy Glavnoy Geofiz. Obs., 35, no 97, 35-41.

_____, 1955: Relation of storm formation to the intensity of precipitations. Meteor. i Gidrol., no 9, 31-33.

_____, 1956a: The nature of the thunderstorm. Nauka i Zhizn', v. 23, no 6, 41-43

_____, 1956b: On possible electrification mechanism of hydrometeors in cumulus rain clouds. Trudy Glavnoy Geofiz. Obs., 58 (120), 53-57.

_____, 1958a: Detection of thunderstorm and rainstorms by the radar of a storm identification station. Trudy Tsentral. Aero. Obs., no 20, 73-80

_____, 1958b: Some radar characteristics of rainstorm and thunderstorm cells. Trudy Tsentral. Aero. Obs., no 20, 82-87.

MYAKISHEV, G. Ya., 1958: Artificial precipitation. Nauka i Zhizn', no 4, 77-78.

NEPOMNYASHCHIY, S. I., 1959: New airplane meteorograph for vertical sounding of the atmosphere. Meteor. i Gidrol., no 1, 51-54.

NIKANDROVA, G. T. and A. P. CHUVAYEV, 1957: Investigation of the transition in cloud microstructure under modification by solid carbon dioxide. Trudy Glavnoy Geofiz. Obs., no 67 (129), 104-113.

PARAMONOV, N. A., 1950: The unitary variation of atmospheric electrical potential. Dokl. Akad. Nauk SSSR, v. 90, no 1, 37-38.

PROKHOROV, P. S. and L. F. LEONOV, 1952: The effect of a saturation deficit on the process of collision and coalescence of water drops. Kolloid Zhur., 14, no 1, 66-72.

PSHENAY-SEVERIN, S. V., 1957: Effect of hydrodynamic interaction between small cloud drops upon their falling speed. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 8, 1945-1051.

PUZANOV, V. P. and V. I. AKKURATOV, 1952: The mechanism of formation of certain types of hailstones. Meteor. i Gidrol., no 2, 29-33.

REYNET, Ya. Yu., 1956: A combination meter for atmospheric ions. Trudy Glavnoy Geofiz. Obs., 58 (120), 23-30.

SALEZNEVA, Ya. S., 1953: Conditions that determine the quality of cumulus clouds. Meteor. i Gidrol., no 2, 8-14.

SERGIYEVA, A. P., 1958: The electric charges of cloud particles. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 347-357.

SHISHKIN, N. S., 1954: Dimensions of rain drops. Priroda, no 10, 90-92.

_____, 1955a: Effect of size distribution of cloud particles on the size of rain drops. Trudy Glavnoy Geofiz. Obs., no 54 (116) 78-80.

_____, 1955b: Using the layer method for forecasting the vertical force of convective clouds. Trudy Glavnoy Geofiz. Obs., no 54, 96-103.

_____, 1956a: Investigations of clouds yielding precipitation in the form of snow. Trudy Glavnoy Geofiz. Obs., no 57 (119), 11-112.

_____, 1956b: Some results of research on thunderclouds and cloudbursts. Trudy Glavnoy Geofiz. Obs., no 63 (125), 3-21.

SHTAL', V. and V. MORACHEVSKIY, 1958a: Is it possible to actively influence the weather: Sovetskaya Aviatsiya (a newspaper), Feb 8, p. 4.

_____, _____, 1958b: Active influence on the weather. Priroda, v. 47, no 9, 85-88.

SHUPYATSKIY, A. B., 1958: Radar measurements of the mean drop size and the water content in heavy rainstorms. Trudy Tsentral. Aero. Obs., no 20, 56-66.

SHVETS, M. E., 1955: Condensation of water vapor in the atmosphere. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 547-551.

SMIRNOV, N. S., 1956: The problem of the effect of an atomic explosion on the state of the atmospheric. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 10, 1227-1231.

SOKOLOV, V., 1958: Weather observations by radar. Sovetskaya Aviatsiya, no 274, Nov 22, p. 3.

SOLOV'YEV, V. A., 1956: On one method of measuring the charges and size of cloud (fog) droplets. Trudy Glavnoy Geofiz. Obs., 58 (120), 31-41.

STEPANENKO, V. D., 1958: Improving the meteorological target detection efficiency of the "Kobal't" radar. Trudy Tsentral. Aero. Obs., no 20, 67-72.

TSYGANOV, G. P., 1957: Experience of meteorological servicing of tower control area and utilization of radar station "RUPOR" at the air weather station of the Civil Air Fleet at Rostov-on-Don. Meteor. i Gidrol., no 6, 46-47.

TVERSKAYA, N. P., 1951: The temperature of evaporating drops. Izvest. Akad. Nauk SSSR, Ser. Geograf. i Geofiz., 15 (1), 74-81.

_____, 1953: Heat transfer and evaporation of a drop in a current. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 259-263.

VOSKANOV, A. I., I. M. IMYANITOV, M. M. KULIK and A. P. CHUVAYEV, 1957: The possibility of safe passage of aircraft through thunderstorm areas. Trudy Glavnoy Geofiz. Obs., no 67 (129) 114-120.

VOSKRESENSKIY, A. I., V. G. MORACHEVSKIY and V. Ya. NIKANDROV, 1957: The use of dry ice for dispersing clouds in the Arctic. Problemy Arktiki, sbornik statey (Problems of the Arctic, A Collection of Articles), no 2, Leningrad, 133-139.

VOTINTSEV, K. K., 1954: Chemical composition of the waters from atmospheric precipitation in the Baykal Area. Dokl. Akad. Nauk SSSR, v. 95, no 5, 979-981

VUL'FSON, N. I., 1953: Method of study of convective movements in the free atmosphere. Doklady Akad. Nauk SSSR, v. 91, no 2, 233-236.

_____, 1956a: Conditions of formation of cumulus clouds in mountainous regions. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 821-830.

_____, 1956b: Method of studying convective movement in the free atmosphere. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 549-561.

_____, 1954: Convective movements in cumulous clouds. Dikl. Akad. Nauk SSSR, 97, no 1, 77-80

ZHAVORONKINA, T. K., 1958: The chemical composition of atmospheric precipitation. Meteor. i Gidrol., no 9, 22-24.

_____, and A. A. DMITRIYEV, 1958: The distribution of concentration of chlorine in atmospheric precipitation over a continent. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 330-336.

APPENDIX D

BIBLIOGRAPHY OF ARTICLES IDENTIFIED BUT NOT AVAILABLE FOR COMPLETE REVIEW

This list supplements previously published bibliographies.

ANON., 1956: Aircraft radar for weather observations. Voprosy Radiolokatsionnoy Tekhniki, no 1.

_____, 1958a: Weather observations by radar. Sovetskaya Aviatsiya, Nov 22, 1958, p. 4.

_____, 1958b: Aircraft breaks up thunderstorm. Sovetskaya Aviatsiya, Aug. 13, 1958, p. 4.

_____, 1959: Artificial atmospheric precipitations. Vest. Akad. Nauk SSSR, no 7, July 1959, p. 70.

ARABADZHI, V. I., 1959: On the electrical properties of thunderstorm precipitation. Dokl. Akad. Nauk SSSR, 127, no 2, 298-301.

BALABANOVA, V. N., 1959: Effects of temperature of supercooled fog on crystallization by silver iodide aerosols. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 924-929.

BARANOV, A. M., 1958: The vertical expansion of clouds of the upper layer over the European part of the USSR. Meteor. i Gidrol., no 6, 22-25.

BARTISHVILI, I. T., 1957: On methods of measuring precipitation in mountain conditions. Trudy, Tbilisskogo Nauchno-Issled. Gidrol. Inst., Vypusk no 2, 189-203.

BEKTOROV, A. B., 1958: Magnesium chloride in the Salfe Lakes of northern Kazakhstan. Vast. Akad. Nauk Kazakhskoy SSSR, no 5, 68-73.

BIBILASHVILI, N. Sh., A. M. ZAYTSEVA, A. A. ORDZHONIKIDZE, and G. K. SULAKEVELIDZE, 1959: Influence of changes in the vertical component of wind velocity on the formation of intensive showers and hail. Dokl. Akad. Nauk SSSR, 128, no 3, 521-524.

BOCHAROV, Ye. I., 1958a: The special transparency of the clouds. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 678-685.

_____, 1958b: The attenuation of infrared radiation by water mists. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 791-795.

BRITAYEV, A. A. and A. N. KORNEEV, L959: Growth of ice crystals by coalescence. Trudy Tsentral. Aero. Obs., no 30, 73-80.

CHIRVINSKIY, P. N., 1954: The first observers of ball lightnings. Priroda, v. XLIII no 8, p. 116.

CHUVAYEV, A. P., 1957: Experiment in controlling the development of powerful convective clouds over large areas. Trudy Glavnoy Geofiz. Obs., no 72, 127-133.

DERGACH, A. L., 1959a: The microphysical characteristics of a low cloud cover and fog. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 55-67.

_____, 1959b: The results of the study of frontal clouds. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no. 1, 100-112.

_____, 1959c: Study of a cumulonimbus cloud without an anvil. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 148-154.

DRIVING, A. Ya., N. V. ZOLOTAVINA, M. N. POCOZOVA and A. L. SMIRNOVA, 1958: Investigation of atmospheric stratification and condensation products by searchlight sounding. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 613-624.

FEIGEL'SON, Ye. M., 1959: The radiational cooling of stratus clouds. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 847-857.

GROMOVA, T. N. and A. D. SOLOV'YEV, 1958: Laboratory equipment for analyzing artificial fogs. Trudy Tsentral. Aero. Obs., no 19, 101.

IMYANITOV, I. M., V. P. KOLOKOLOV, 1956: Investigating the distribution of induced and free electrical charges on aircraft surfaces. Trudy Glavnoy Geofiz. Obs., p. 8-16.

IZERGIN, A. M., 1959: Convective electrical currents atmosphere-earth. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 6, 919-923.

KACHURIN, L. G., 1956: The formation of glazed frost and hoar frost in supercooled fog. Trudy Glavnoy Geofiz. Obs., no 57 (119)

_____, 1959: Comparison between various equations for freezing of supercooled water aerosols. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 1, 122-130.

_____, G. I. ALESHINA, M. A. BELYASHOVA, V. I. ZALIVINA, V. I. KUDRYAVTSEVA, M. I. NESTEROVA, A. A. SEREBRYAKOVA, and L. P. SERYAKOVA, 1956: Analysis of the precipitation zones of stratiform frontal clouds. Trudy Lenin. Gidrometeor. Inst., no 5-6, 208-241.

KHMALADZE, G. N., 1959: Scientific session at the Tbilisi Scientific Research Hydrometeorological Institute. Meteor. i Gidrol., no 2, 70-71.

KLINOV. F. Ya., 1958: Polar snow. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 5, 796-799.

_____, 1957: Ice crystals and ice mists in the atmosphere. Priroda, no 2.

KOGAN-BELETSKIY, G., 1958: About encounters with electric storms and hail during flights at high altitudes. Sovetskaya Aviatsiya, July 29, 1958, p. 2

KONDRAT'YEV, N. N., 1959: Methods and some results of base line phototheodolite clouds. Trudy Tsentral Aero. Obs., no 30, 84-94.

KORNEYEV, A. N. AND B. N. TRUBNIKOV, 1959: Application of the replica method in the study of cloud elements. Trudy Tsentral. Aero. Obs. no 30, 81-83.

KOTOV, N. F., 1958: Use of the results of radar studies of clouds for improving the work of the network of storm warning stations. Trudy Tsentral, Aero. Obs., no 20, 17-25.

KRASIKOV, P. N. and I. M. DIANOV, 1959: An artificial rainmaking method. Byulleten' Izobreteniy, no 5, 49.

KRUTSKAYA, L. I., 1958: Methods for computing the number of ice nuclei forming under the action of cooling reagents. Trudy Tsentral. Aero. Obs., no 19, 81-100.

LEDOKHOVICH, A. A. and V. A. ZAYTSEV, 1959: An air-borne electrical meteorograph (SEM-1). Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 162-167.

LEVIN, L. M., 1958a: Fluctuations of microstructural characteristics of clouds. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 12, 1510-1513.

_____, 1958b: On the size distribution functions of cloud droplets. Optical density of a cloud. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 10, 1211-1221.

_____, 1959: Electrostatic deposition of aersol particles from flow over large bodies. Izvest. Akad. Nauk SSSR. Ser. Geofiz., no 7, 1073-1075.

LITVINOV, I. V., 1959: Method for measuring the distribution of size of snowflakes. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 1011-1017.

MAKHOTKIN, L. G., 1959: On C. G. Breydo's formula for the limiting charge on drops. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 2, 330-331.

_____, and V. A. SOLOV'YEV, 1958: Role of electric charges in the coagulation of fog drops. Trudy Glavnoy Geofiz. Obs., no 73, 116-122.

MATVEYEV, L. T., 1959a: On the theory of cloud formation and condensation trails under the influence of mixing. Meteor. i Gidrol., no 3, 3-9.

_____, 1959b: Several questions on the theory of the formation and evolution of stratiform clouds. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 14-37.

MIKIROV, A. Ye., 1959: On small angles of the scattering indicatrix. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 2, 228-295.

MILIN, V. B., 1954: About the anomalous electric fields in the atmosphere. Dokl. Akad. Nauk SSSR, v. XCV, no 5, 983-986.

MINERVIN, V. Ye., I. P. MAZIN and S. N. BUIKOVSKAYA, 1958: New data on the water content of clouds. Trudy Tsentral. Aero. Obs., no 19, 3-32.

MORACHEVSKIY, V. G. and V. Ya. NIKANDROV, 1959: The effectiveness of CO_2 particles and AgI smoke in dissipating supercooled low clouds and fog. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 135-145.

NASILOV, D. N., 1956: Radio meteorology. (No other information available.)

NEPOMNYASHCHIY, S. I., 1958: Comb-type radiosonde with electric motor. Meteor. i Gidrol., no 6, 47-49.

NIKANDROV, V. Ya., 1959: Some data on the water content of fog in the Arctic. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 146-148.

PINUS, N. Z., 1957: Atmospheric turbulence commensurate with dimensions of airplanes. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 395-400.

PIOTROVICH, V. V., 1958: On the reasons for the increase of the crystals of "intra-water" ice in overcooled water. Meteor. i Gidrol., no 12, 42-43.

PSHENAY-SEVERIN, S. V., 1958: Hydrodynamics interaction of cloud drops at short distances. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 10, 1254-1257.

_____, 1959: On the mutual approach of aerosol particles in a sound field due to Oseen's hydrodynamic forces. Dokl. Akad. Nauk SSSR, 125, no 4, 775-778.

PUDOVKINA, I. B., 1954: A study of atmospheric electricity on the Elbrus, Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 3, 288-292.

RESHETOV, V. D., 1959a: Investigation of unipolar aerosol charges. Trudy Tsentral. Aero. Obs., no 30, 53-61.

_____, 1959b: Problem of atmospheric electricity and aerosols. Trudy Tsentral. Aero. Obs., no 30, 62-72.

ROVINSKIY, F. Ya., 1959: New method for registration of water droplets. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 1076-1078.

SEREGIN, Yu. A., 1958: Dispersion from the earth of supercooled fogs by silver iodide aerosol. Trudy Tsentral. Aero. Obs., no 19, 68-80.

SERGIYEVA, A. P., 1959: Electrical charges of cloud droplets. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 7, 1018-1025.

SHIFRIN, K. S. and Yu. I. RABINOVICH, 1957: The spectral indicatrices of large water drops and the spectral polarization of rainbows. Izvest. Akad. Nauk SSSR, Ser. Geofiz., no 12, 1491-1506.

SHPAK, I. S., and L. P. MURZIN, 1957: A squall in the region of the Tsimla Reservoir on 25 June 1956. Meteor. i Gidrol., no 4, 28-30. 645360.

SHUPYATSKIY, A. B., 1959a: Determining the shape and speed of falling drops. Meteor. i Gidrol., no 5, 42-43.

_____, 1959b: Radar scattering by nonspherical particles. Trudy Tsentral. Aero. Obs., no 30, 39-52.

SULAKUELIDZE, G., 1959: Microphysical traps dropped from airplane. Sovetskaya Aviatsiya, July 1, 1959, p. 4.

TKACHENKO, A. V., 1958: Use of the layer method for forecasting the convective cloud cover of cloudbursts and thunderstorms. Meteor. i Gidrol., no 9, 24-27.

TSITOVICH, T. A., 1959: On the formation of the subfrontal portions of warm frontal cloud systems. Trudy Tsentral Aero. Obs., no 30, 3-38.

TVERSKAYA, N. P., 1958: Study of the collision and coalescence of charged drops. Trudy Glavnoy Geofiz. Obs., no 73, 123-131.

_____, and N. P. YUDINA, 1956: Experimental investigation of water-drop conjoining. Trudy Lenin. Gidrometeor. Inst., no 5-6, 263-267.

VASIL'CHENKO, I. V., 1958: Calculations of the characteristics of a convective cloud stream. Trudy Glavnoy Geofiz. Obs., no 82, 22-25.

VOLKOV, P. A., 1958: On the mechanism of breakage of air bubbles. Meteor. i Gidrol., no 12, 38-40.

VORONTSOV, P. A., 1959: The aerological characteristics of sea fog. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 38-54.

_____, and V. I. SELITSKAYA, 1959: The vertical structure of summer fog in the Kickson Island region. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 87-99.

VOSKRESENSKIY, A. I., 1959: Organization and methods of studying fog and clouds. Trudy Arctic and Antarctic Sci. Res. Inst., v. 228, no 1, 5-13.

VOSKRESENKIY, A. I.,1959 and K. I. CHUKANIN, 1959: The meteorological conditions of icing in St and Sc clouds. Trudy Arctic and Antarctic Sci. Res. Inst., Vol. 228, no 1, 124-134.

_____, and A. A. LEDOKHOVICH, 1959: The Lo-4 thermohygrometer. Trudy Arctic and Antarctic Sci. Res. Inst., Vol. 228, no 1, 168-175.

_____, and V. G. MORACHEVSKIY, 1959: Equipment for seeding supercooled clouds and fog from an airplane. Trudy Arctic and Antarctic Sci. Res. Inst., Vol. 228, no 1, 155-161.

VUL'FSON, N. I., 1959: On the mechanism of instability release in the free atmosphere. Dokl. Akad. Nauk SSSR, 126, no 6, 1244-1247.

ZABRODSKIY, G. M. and V. G. MORACHEVSKIY, 1959: A study of the transparency of clouds and fog. Trudy Arctic and Antarctic Sci. Res. Inst., Vol. 228, no 1, 68-86.

ZAK, Ye. G. and A. A. FEDOROVA, 1958: Results of radar observations of formation and development of precipitation in cumulonimbus clouds. Trudy Tsentral Aero. Obs., No. 19, 33-67.

ZAMORSKIY, A. D., 1953: Drizzle and glazed frost at low temperatures. Meteor. i Gidrol., No. 4.

ZAYTSEV, V. A., and A. A. LEDOKHOVICH, 1959: The temperature near the upper boundary of air mass fogs and stratus clouds. Trudy Arctic and Antarctic Sci. Res. Inst., Vol. 228, No 1, 113-123.

UNCLASSIFIED REFERENCES

1. Izvestiya Akademii Nauk SSSR, Seriya Geofizicheskaya, no 10, Oct 59, pp 1526-1527, (b)(3)

2. FBIS, USSR, L5598, 18 Jun 1958, (b)(3)

3. The Status of Research and Manpower in Meteorology, Washington, Publication 754, NAS-NRC, 1960, p 9. (b)(3)

4. Imyanitov, I. M., Instruments and Methods for Study of Atmospheric Electricity, Gostekhizdat, 1957, pp. 483, U

5. Muchnik, V. M., 1958: Detection of Thunderstorms and Rainstorms by the Radar of a Storm Identification Station. Trudy Tsentral. Aero. Obs., No. 20, 78-80, (b)(3)

6. Muchnik, V. M., 1958: Some Radar Characteristics of Rainstorm and Thunderstorm Cells. Trudy Tsentral. Aero. Obs., No. 20, 82-87, (b)(3)

7. Stepanenko, V. D., 1958: Improving the Meteorological Target Detection Efficiency of the "Kobal't" Radar. Trudy Tsentral. Aero., Obs., No. 20, 67-72, (b)(3)

8. Kostarev, V. V., 1958: Experience in Radar Troposphere Sounding. Trudy Tsentral. Aero. Obs., No. 20, 3-16 (b)(3)

9. Sokolov, V., 1958: Weather Observations by Radar. Sovetskaya Aviatsiya, No. 274, No. 22, p. 3 (b)(3)

10. Vysokovskiy, D. M., 1952: Dispersion and Absorption of Microradio Waves in Atmospheric Formations (rain, snow, cloudiness and fog) and Radio Location, Uspekhi Fiz. Nauk., 47, (b)(3)

11. Shupyatskiy, A. B., 1958: Radar Measurements of the Mean Drop Size and the Water Content in Heavy Rainstorms. Trudy Tsentral. Aero. Obs., No. 20, 56-66, (b)(3)

12. Gorelik, A. G., V. V. Kostarev and A. A. Chernikov, 1958: Radar Measurement of Turbulent Motions in Clouds. Meteor. i Gidrol., No. 5, 12-19, (b)(3)

13. Imyanitov, I. M., M. M. Kulik and A. P. Chuvayev, 1957: Preliminary Data on Experiments for Controlling the Development and the Change in the Electrical State of Strongly Convective Clouds in the Southern Regions of European USSR and in the Transcaucasus. Trudy Glavnoy Geofiz. Obs., No. 68 (129), 33-58, (b)(3)

14. Chuvayev, A. P., 1956: On the Conditions that are Favorable to Artificially Induced Precipitation from Large Cumulus Clouds. Meteor. i Gidrol., No. 11, 15-20, (b)(3)

15. Voskanov, A. I., I. M. Imyanitov, M. M. Kulik and A. P. Chuvayev, 1957: The Possibility of Safe Passage of Aircraft Through Thunderstorm Areas. Trudy Glavnoy Geofiz. Obs., No. 67 (129) 114-120, (b)(3)

18. Imyanitov, I. M., M. M. Kulik and A. P. Chuvayev, 1957: Investigations of Thunderstorm Zones in the Southern Regions of European USSR and the Transcaucasus. Trudy Glavnoy Geofiz. Obs., No. 67 (129), 3-32, (b)(3)

19. Gordon, J. Z., 1951: Investigation of the Evaporation Process of Dry Ice. Trudy Glavnoy Geofiz Obs., No. 013, (b)(3)

21. Sovetskiy Flot, 3 Jan 1957, (b)(3)

22. Lebedeva, N. V., 1955: How are Clouds and Rain Formed? All-Union Society for the Propagation of Political and Scientific Knowledge, Moscow, "Znaniye" Publishing House, pp 24, (b)(3)

23. Nikandrov, V. Ya., 1957: The Problem of the Artificial Control of Cloud and Fog, presented at the IUGG meeting in Toronto, Canada, Mimeographed in English, pp. 13, (b)(3)

24. OTS, PB 131632-27, 15 Aug 58, Soviet Bloc International Geophysical Year Information, p. 9 (b)(3)

25. Belolserkovskiy, V., 1958: Three Days Fight with Clouds, Moskva, No 9, pp 160-170, (b)(3)

26. Golikov, A., 1960: Sun in the Fog, Ogonek, No 6, p. 31, (b)(3)

27. Pettersen, S. et al, 1957: Cloud and Weather Modification -- A Group of Field Experiments, Meteorological Monographs, no 11, July, p. 93, (b)(3)

28. Solov'yev, V. A., 1956: On the method of measuring the charges and size of cloud (fog) droplets. Trudy Glavnoy Geofiz. Obs., 58 (120), 31-41, (b)(3)

29. Myakishev, G. Ya., 1958: Artificial Precipitation. Nauka i Zhizn', No. 4, 77-78, (b)(3)

30. Balabanova, V. N., N. Sh. Bibilashvili, A. I. Kartsivadze, B. V. Kiryukhin and G. K. Sulakvelidze, 1959: Experiments on the Modification of Cumulus Clouds in the Alazani Valley. Izv. Akad. Nauk SSSR, Ser. Geofiz., No. 2, 262-275, (b)(3)

31. Shtal', V. and V. Morachevskiy, 1958: Is it Possible to Actively Influence to Weather? Sovetskaya Aviatsiya, 8 Feb, p. 4, (b)(3)

32. Shtal', V. and V. Morachevskiy, 1958: Active Influence on the Weather. Priroda, Vol. 47, No. 9, 85-88, (b)(3)

34. Bukhikashvili, A. V., 1958: Twenty-five Years of the Institute of Geophysics, Academy of Sciences, Georgian SSR. Izv. Akad. Nauk SSSR, Ser. Geofiz., No. 10, 1153-1161, (b)(3)

35. Voskresenkiy, A. I., V. G. Morachevskiy and V. Ya. Nikandrov, 1957: The use of Dry Ice for Dispersing Clouds in the Arctic. Problems of the Arctic, A Collection of Articles, No. 2, Leningrad, 133-139, (b)(3)

36. Morachevskiy, V. G. and V. Ya. Nikandrov, 1959: The Effectiveness of CO_2 Particles and AgI Smoke in Dissipating Supercooled Low Clouds and Fog. Trudy. Arctic and Antarctic Sci. Res. Inst., Vol. 228, No. 1, 135-145, (b)(3)

37. Chuvayev, A. P., 1957: Modern Possibilities for Preventing Storms and Hail. Trudy Glavnoy Geofiz. Obs., No. 74, 71-102, (b)(3)

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