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*Research Supplement to*
*Scientific Intelligence Report*

# Cloud Physics and Weather Modification Research in the Soviet Union



OSI-SR/63-13 RS
10 May 1963

CENTRAL INTELLIGENCE AGENCY
Office of Scientific Intelligence

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Research Supplement to
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# CLOUD PHYSICS AND WEATHER MODIFICATION RESEARCH IN THE SOVIET UNION

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# PREFACE

The data presented in this supplement provide background information supporting the opinions, judgments, and conclusions that are contained in the Scientific Intelligence Report, OSI/SR 63-13, Cloud Physics and Weather Modification Research in the Soviet Union, 10 May 1963, SECRET.

The evaluation presented herein is based primarily on an external contract study of recent Soviet work by a leading U.S. university. The cutoff date for this report is 1 January 1963.

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# APPENDIX A

## GLOSSARY

Attenuation.--In radar, the reduction in the intensity of the electromagnetic waves from the radar along the path of the signal.

Backscattering.--The radiation scattered at 180° to the direction of the incident wave.

Coalescence.--The merging of two water drops into a single larger drop.

Condensation nuclei.--A particle, either liquid or solid, upon which condensation of water vapor begins in the atmosphere.

Convective cloud.--A cloud that owes its vertical development, and possibly its origin, to atmospheric motions that are predominantly vertical.

Cumulus.--A principal type of cloud in the form of individual, detached elements that are generally dense and possess sharp nonfibrous outlines. These elements develop vertically, appearing as rising mounds, domes, or towers, the upper parts of which resemble a cauliflower.

Cumulus congestus.--A strongly sprouting cumulus with generally sharp outlines and, sometimes, with a great vertical development.

Glaciation.--The transformation of cloud particles from water drops to ice crystals.

Hygrometer.--An instrument that measures the water vapor content of the atmosphere.

Hygroscopic nuclei.--Those condensation nuclei composed of salts that yield aqueous solutions of a very low equilibrium vapor pressure compared with that of pure water at the same temperature.

Ice-crystal nuclei.--Any particles that serve as the centers in the formation of ice crystals in the atmosphere.

Nucleation.--Any process by which the phase change of a substance to a more condensed state is initiated within the less condensed state.

Peltier cooling.--The absorption of heat at the junction of two unlike metals in a thermoelectric circuit.

Radar echo.--A general term for the appearance, on a radar scope, of the radio energy returned from a target. In meteorology the target usually is a rain cloud.

Sounding.--An upper air observation usually made by balloon-borne instruments. Among the elements evaluated are temperature, humidity, pressure, wind speed, and wind direction.

Stratus.--A principal type of cloud in the form of a gray layer with a rather uniform base.

Super cooling.--reduction of temperature of any liquid below its normal freezing point.

# APPENDIX B

## SOVIET AIRPLANES USED FOR WEATHER OBSERVATIONS

| Airplane Designation | Description |
|---|---|
| LO-3 | "Flying Observatory" |
| LO-4 | "Flying Observatory" for use on aircraft with pressurized cabins and speeds greater than 300 km/hr.<br>Principal Components:<br>Temperature unit<br>Hydrometer unit<br>Instrument panel<br>Power unit<br>Cloud indicator unit 117/ |
| IL-12 | Airplane (airspeed 280 km/hr); to make measurements with the following:<br>Two fast responding resistance thermometers<br>Radio altimeter<br>Differential altitude transducer<br>Airspeed transducer<br>Accelerometer 118/ |
| PO-2 | Airplane used in 1948. Measured droplet sizes and liquid water. 119/ |
| LI-2 | Airplane with SM-43 meteorograph |
| IL-28 | Jet bomber used by Uzbek Administration of Civil Air Fleet. Stripped of armament. Tail gunner's section equipped with meteorological instruments. Several flights per day to "great altitudes". Measures "velocity and direction of wind, air pressure -- in short, all the data needed for safe flights by passenger aircraft." 121/ |

| Airplane Designation | Description |
|---|---|
| TU-104 | Jet airplane (airspeed over 800 km/hr); to make measurements in troposphere and lower stratosphere with the following instruments:<br>(1) Screened thermometer with temperature pulsation meter<br>(2) Thermohygrometer<br>(3) Cloud transmissometer<br>(4) Electric field meter<br>(5) Cloud droplet spectrum<br>(6) Water contents<br>Items (1) through (4) are recording continuously 122/ |
| IL-14 | Flying laboratory of the Arctic and Antarctic Sci. Res. Inst., A. I. Voskresenski, leader of the group, stated that the airplane was used during the last 5 years in Central Arctic for studying clouds and fogs. "Flying laboratory has latest equipment." Stayed in Arctic for almost a month and made 16 long flights. Data transmitted back by radio for use by weather forecasters. 123/ |
| KM-2 | Airspeed 180 km/hr. Used to measure icing rate. Data compared with icing rate of IL-12 and TU-4. 124/ |
| TU-4 | Airspeed 350 km/hr. Used to measure icing rate. 125/ |
| AN-2 | Airplane used to observe clouds. (This airplane was used in conjunction with highly instrumented IL-12) 126/ |

# APPENDIX C

## SOVIET INSTRUMENTS FOR CLOUD PHYSICS RESEARCH

| Instrument Designation | Description |
|---|---|
| SM-43 | Meteorograph<br>Components:<br>Stagnation thermometer with bimetallic plates<br>Differential temperature 127/ |
| SEM-1 | Electric Aircraft Meteorograph to replace SM-43<br>Components:<br>K4-51 optical recorder<br>NU-8202 pressure receiver<br>D-25 remote control board<br>Shielded aircraft thermometer with balanced bridge<br>Annunciator clock 128/ |
| SGD | AgI-1956 airborne silver-iodide generator 129/ |
| SIP-3 | Airborne transmissometer 130/ |
| SIV | Zaytsev's liquid-water content meter. Designed for use on PO-2 airplanes. 131/ |
| SIV-3 | Liquid-water content meter for use on LI-2 and IL-14 airplanes. 132/ |
| ——— | Electrical instrument for liquid-water content measurements. 133/ |
| PZK-1 | Instrument for measuring electric charges and sizes of individual drops. 134/ |
| PZK-2 | Instrument for measuring electric charges and sizes of individual drops. 135/ |

| Instrument Designation | Description |
|---|---|
| DSTG | Airborne thermal hygrometer. Measures free air temperature and dew point. 136/ |
| _____ | Airborne device for measuring and recording vertical air motions. 137/ |
| "Metel" | Aircraft carbon dioxide dispensing equipment. 138/ |
| _____ | Airborne dewpoint hygrometer. Cooling agent $CO_2$ in alcohol. 139/ |
| P-60-14 | Fourteen-channel oscillograph recorders with a chart speed of 2.5 mm/sec. Two installed on an IL-12, LI-784 airplane. 140/ |
| Radar sets | Kobalt 3-cm radar.<br>SCR-545-A 10.7 cm radar 141/ |
| _____ | Icing rate meter: Visually observe accumulation of ice on an airfoil with a graduated rule at center. 142/ |
| _____ | "Thunderstorm-by-passer": an instrument that measures electric field strength. When the field exceeds certain values one can differentiate thunderstorms from other clouds. 143/ |
| AFA-27T | Aerial photographic camera 144/ |
| LO-3 | Thermohygrometer -- set of airborne instruments for use on airplanes having speeds of 250-300 km/hr. Measures temperature, humidity, pressure, airspeed, and turbulence. 145/ |

| Instrument Designation | Description |
|---|---|
| LO-4 | Thermohygrometer -- replacement for LO-3 on high-speed pressurized airplanes. Major difference from LO-3: uses semiconductor element to cover dewpoint hygrometer and a photoelectric dewpoint detector. 145/ |
| SIV -1 | Aircraft icing detector -- ice accumulated on rotating cylinders is weighed. Developed by Ts. A. O. 147/ |
| SlO | Aircraft icing rate meter -- a rotating cylinder 50 mm in diameter collects ice, and its thickness is measured. Developed by Scientific Research Institute for Hydrometeor. Instruments. 148/ |
| IV-GGO | Instrument for determining the visibility range of actual objects. 149/ |
| _____ | Sonic anemometer 150/ |
| _____ | Dropmeter. Device for measuring the size and concentration of raindrops by observing the amount of forward-scattered light. 151/ 152/ |
| P-1 | Standard weighing rain gage with accelerated chart speed. 153/ |
| _____ | Lightning recorder -- a cold thyratron is fired with a 100-ft long antenna, detects the rapid electric field change associated with lightning. 154/ |
| "Malakhit" | Radio Theodolite -- for making wind measurements. 155/ |

| Instrument Designation | Description |
|---|---|
| AT-850 | Aerological theodolite 156/ |
| _____ | Sonic thermometer 157/ |
| G-3 | Storm recorder -- makes lightning sferics observations. 158/ |
| AM-2M | Electric thermometer -- makes remote measurements of the temperature of the surface layer of the soil. 159/ |
| M-54 | Ground and snow temperature 160/ |
| _____ | "Anemorhumbometer" -- a new device also used by aviators for measurement of wind velocity and direction. 161/ |
| A-26 | A "long-distance device" that records the lower limits of clouds. 162/ |
| LARMS-A | Automatic radiometeorological station -- telemeters weather reports from glaciers of Antarctic highland to Mirnyy Observatory. 163/ |
| RKZ-1A | Radiosonde -- measures: pressure from 1,060 to 5 mb temperature from +50 to -80°C relative humidity from 15 to 100%. Can be tracked by radar. 164/ |

# APPENDIX D

## LEADING CONTRIBUTORS TO SOVIET CLOUD PHYSICS

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

Atmospheric nuclei and precipitation chemistry
- S. A. Durov
- Ya. I. Frenkel (deceased)
- *R. I. Grabovskiy (author of a book on this subject in 1956)
- N. S. Smirnov

Cloud droplet spectra and liquid-water contents in clouds.
- A. L. Dergach (deceased)
- *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

Raindrop spectra
- *N. V. Krasnogorskaya
- *I. V. Litvinov
- A. Ye. Mikirov

Ice crystals and snowflakes
- I. V. Litvinov
- *Ye. B. Zak
- *A. D. Zamorskiy (author of book on this subject in 1955)

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)

Cloud formation and structure (continued)

V. S. Kozharin
L. T. Matveyev
K. S. Shifrin
*N. S. Shishkin (author of book on clouds, precipitation, and thunderstorms in 1954)
M. P. Timofeyev
*N. I. Vulfson

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

Atmospheric electricity

V. I. Arabadzhi
Ts. G. Breydo
*A. P. Chuvayev
Ya. I. Frenkel (deceased)
*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. Stekolnikov (author of several books on lightning)
P. N. Tverskoy

Instruments

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

Radar meteorology

M. P. Dolukhanov
A. G. Gorelik
V. V. Kostarev
N. V. Kotov
*V. M. Muchnik
Ye. M. Salman
*A. B. Shupyatskiy
*D. M. Vysokovskiy

Cloud seeding and weather control

*A. P. Chuvayev
*I. M. Imyanitov
P. N. Krasikov
V. G. Morachevskiy
*V. Ya. Nikandrov
V. V. Piotrovich
A. D. Solovev
A. I. Voskresenskiy

# APPENDIX E

## MAJOR ORGANIZATIONS AND PERSONNEL ENGAGED IN CLOUD PHYSICS RESEARCH*

### Academy of Sciences, USSR

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

High Altitude Geophysical Institute, Mt. Elbrus

The director is Prof. Dr. G. K. Sulakvelidze. The institute is concerned with cloud modification, hail suppression, and atmospheric electricity studies. It was formed in February 1961 out of what formerly was the Elbrus Expedition, initiated in the late thirties.

*Only the names of personnel engated in cloud physics research are given in this appendix. Names of other personnel in these organizations are not included in this appendix.

## Institute of Applied Geophysics, Moscow

The director is Ye. K. Fedorov. Ths institute is concerned with all types of cloud physics research including cloud seeding.

Aleksandrov, E. L.
Balabanova, V. N.
Belyayev, V. I.
Belyayeva, I. I.
Bibilashvili, N. Sh.
Bocharov, Ye. I.
Bolsheverov, B. M.
Bonchkovskiy, V. F.
Borishanskiy, L. S.
Chudaykin, A. V.
Gromov, A. M.
Khvostikov, I. A.
Klinov, F. Ya.
Krasnogorskaya, N. V.
Krechmer, S. I.
Laktionov, A. G.
Levin, L. M.
Litvinov, I. V.
Maleyev, M. N.
Mamina, Ye. F.
Merzhanov, K. M.
Mikirov, A. Ye.
Novikov, Ye. A.
Ordzhonikidze, A. A.
Pavlova, I. S.
Peterimova, N. I.
Petrov, G. D.
Pshenay-Severin, S. V.
Pudovkina, I. B.
Rodionov, S. F.
Rovinskiy, F. Ya.
Sergiyeva, A. P.
Shaposhnikova, I. I.
Shchelokov, V. V.
Skatskiy, V. I.
Smirnov, N. S.
Starostina, R. E.
Tantsova, N. N.
Teverovskiy, Ye. N.
Vulfson, N. I.
Zaytseva, A. M.
Zhigalovskaya, T. N.

## Institute of Physical Chemistry, Moscow

The director is V. I. Spitsyn. The institute is concerned with nuclei and growth of water drops.

Batova, G. A.
Churakov, V. N.
Deryagin, B. V.
Dubinin, M. M.
Dukhin, S. S.
Izmaylova, G. I.
Kudryavtseva, N. M.
Leonov, L. F.
Moskvitin, N. N.
Nikolskiy, A. P.
Petryanov, I.
Prokhorov, P. S.
Rozenblyum, N. D.
Sarakhov, A. I.
Starozhilova, A. I.
Todes, O. M.
Valesenko, G. Ye.
Yashin, V. N.

Institute of Physics of the Atmosphere, Moscow

The director is A. M. Obukhov. The institute is concerned with theoretical studies of convection and convective clouds.

Bibikova, T. N.
Driving, A. Ya.
Feygelson, Ye. M.
Gutman, L. N.
Polozova, M. N.
Smirnova, A. I.
Tsvang, L. R.
Zolotavina, N. Y.

CHIEF, DIRECTORATE OF THE HYDROMETEOROLOGICAL SERVICE

Main Geophysical Observatory, Leningrad

The director is M. I. Budyko. The observatory is concerned with all types of cloud physics research, with emphasis on convective clouds and with cloud modification studies.

Arkhipova, Ye. P.
Bashkirova, G. M.
Bazilevich, V. V.
Budilova, Ye. P.
Chestnaya, I. I.
Chikirova, G. A.
Chukanin, K. I.
Churinova, M. P.
Chuvayev, A. P.
Dergach, A. L. (deceased)
Dianov, I. M.
Drozdov, O. A.
Dubov, A. S.
Dvali, Ye. R.
Frenkel, Ya. I.
Gayevskiy, V. L.
Gigineyshvili, V. M.
Gordon, I. Z.
Imyanitov, I. M.
Khimach, M. A.
Kolokolov, V. P.
Kotov, N. V.
Krasikov, P. N.
Krasilshchikov, L. B.
Kryukova, G. T.
Kulik, M. M.
Ledokhovich, A. A.
Loch, B. F.
Makhotkin, L. G.
Mamontov, N. V.
Matveyev, L. T.
Mikhailovskaya, V. V.
Minin, I. K.
Morachevskiy, V. G.
Morozyanskiy, A. L.
Myukhkyurya, V. I.
Nikandrova, G. T.
Nikandrov, V. Ya.
Ogorodnov, D. Ye.
Osipova, G. I.
Pastukh, V. P.
Pershina, T. A.
Pinegin, G. N.
Piotrovich, V. V.
Polyakova, Ye. A.
Rabinovich, B. I.

Reynet, Ya. Yu.
Salman, Ye. M.
Selezneva, Ye. S.
Selitskaya, V. I.
Sereyev, O. D.
Shifrin, K. S.
Shishkin, N. S.
Shtal, V.
Shvets, M. Ye.
Solovev, A. D.
Sokhrina, R. F.
Streltsova, M. B.
Tarasov, A. V.
Timofeyev, M. P.
Titov, N. A.
Vasilchenko, I. V.
Vinograd, P. L.
Vorontsov, P. A.
Voskana, A. I.
Voskresenkiy, A. I.
Zabrodskiy, G. M.
Zamorskiy, A. I.
Zaytsev, V. A.
Ziganov, N. P.
Zykova, V. V.

Central Aerological Observatory, Dolgoprudnaya, near Moscow

The director was G. I. Golyshev. The observatory is concerned with all types of cloud physics research, with emphasis on stratiform clouds and cloud modification.

Bergun, K. I.
Borovikov, A. M.
Britayev, A. A.
Burkovskaya, S. N.
Chernikov, A. A.
Fedorova, A. A.
Gayvoronskiy, I. I.
Gorelik, A. G.
Gromova, T. N.
Khrgian, A. Kh.
Kondratyev, N. N.
Korneyev, A. N.
Kostarev, V. V.
Krutskaya, L. I.
Malkina, A. D.
Marfenko, O. V.
Mazin, I. P.
Minervin, V. Ye.
Pinus, N. Z.
Reshchikova, A. A.
Reshetov, V. D.
Seregin, Ya. A.
Shmeter, S. M.
Shupyatskiy, A. B.
Shur, G. N.
Stepanenko, V. D.
Tonkova, Z. V.
Trubnikov, B. N.
Tsitovich, T. A.
Zak, Ye. G.

## CHIEF DIRECTORATE OF THE NORTHERN SEA ROUTE

### Arctic and Antarctic Scientific Research Institute

The director is A. F. Treshnikov. The institute is concerned with stratified clouds and cloud modification.

Dergach, A. L. (deceased)
Voskresenskiy, A. I.
Zabrodskiy, G. M.

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