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PRACTICAL EXPERIMENTS WITH A MIXTURE OF SODIUM CHLORIDE AND CEMENT AS A REAGENT FOR SEEDING LARGE CUMULUS CLOUDS

by Ye. P. Budilova, Ye. Ye. Korniyenko, V. T. Lenshin and D. D. Stalevich

Introduction

Theoretical and experimental investigations into the use of hygroscopic substances as reagents for seeding large cumulus clouds with the purpose of producing artificial rain were carried out in 1960-1965 in the Department of Physics of clouds and active seeding of the Main Geophysical Observatory i/n A. I. Voyeykov.

The theoretical assessment of the optimal use of the reagent and the sizes of its particles, depending on the parameters of the convective clouds to be seeded, was finalized by the experimental method. Although the field tests involving the use of a hygroscopic agent for seeding purposes were episodic in nature and the resulting assessment of the effectiveness of that seeding method could be considered merely as preliminary, it was established that positive results could be achieved under certain conditions.

Practical tests with a mixture of sodium chloride and cement as a reagent for seeding convective clouds in the steppe regions of the Ukraine were carried out in May-June 1966 by the decision of the Main Administration of the Hydrometeorological Services. The tests were carried out by the workers of the Main Geophysical observatory i/n Voyeykov and the Ukrainian Hydrometeorological Scientific Research Institute (from 20 May through 13 June) who used an IL-14 flying laboratory equipped with a set of aerological apparatuses /5/ and a packaging and measuring device. Most of the experiments were carried out in the area of the meteorological testing ground of the Ukrainian Hydrometeorological Scientific Research Institute.

The purpose of the tests was:

a) to get additional experimental data on the optimal conditions of seeding convective clouds in high and low temperatures using a mixture of sodium chloride and cement as a reagent;

b) to test the packaging and measuring device developed by the Main Geophysical Observatory i/n Voyeykov for introducing the reagent into the clouds;

c) the development of seeding methods and ways of controlling them by the use of the data from the precipitation measuring and pluviographic network and radar stations.

Preparing the Reagent and the Experimentation

Ordinary table salt (NaCl) and cement (M-400 or M-500) in a 4:1 mixture were used as starting material for preparing the reagent. The following technology was used in preparing the reagent:

a) the salt was dried in a crucible furnace (for 1.5-2 hrs. at a temperature of 150-200°) with a view to dehydrating it;

b) the salt was ground in a ball mill in order to reduce the particles to a 5-7 micron radius. Theoretical calculations showed it to be the optimal size;

c) cement was added to prevent the salt particles from sticking together later on. The cement was therefore put into the ball mill drums half an hour to an hour before the end of the salt-grinding process thereby ensuring the proper mixture of the components.

The finished reagent was stored in metal (or polyethylene) hoppers with a capacity of 20-40 liters in which it could be kept (when sealed) without changing the initial spectrum of the particles for several years.

Packages made of filter paper in the form of cylinders of various sizes and containing from 0.1 to 0.5 kilograms /3/ were filled with the reagent 2-3 hours before the laboratory-plane took off for seeding operations. Tied with cord at both ends, the reagent-containing packages were placed in cardboard boxes and kept in the plane, and then placed (singly or in pairs) in each of the 10 containers of the measuring device.

The expected intensity of atmospheric convection was calculated by the stratum method /1/ and the results of the calculation for the Ukrainian territory were mapped on the basis of the radio-sounding data 3 hours before take-off.

After establishing a two-way radio communication between the plane and the radar facilities of the testing ground, the plane left for the area scheduled for seeding operations where an assessment was made of the general condition of the cloud area, their forms and quantity, the tendency to further development of breakup, the altitude of the base of the convective clouds, the upper boundary of the main cloud area and the altitude of the most developed cloud peaks; established also was the presence of clouds with indications of crystallization (or lack of it), natural precipitation zones as well as their location at time of the seeding operations.

Large cumulus clouds of a liquid structure were selected for seeding purposes. Their condition was determined by the appearance and the optical phenomena at the cloud tops. Isolated large cumulus clouds in the stage of development or a group of several clouds usually ranged in banks were selected for seeding.

The reagent was measured after the geometrical dimensions and some of the dynamic characteristics of the clouds had been established. Use was made in this connection of the recommended expenditure of the reagent developed by the Main Geophysical Observatory i/n Voyeykov on the basis of the theoretical investigation in connection with the introduction of a hygroscopic reagent into the cloud by the point-source method (Fig. 1). In view of the fact that the doses were calculated on the assumption of a single dispersion of the reagent (actually, however, the reagent had a relatively wide spectrum of particle dimensions ranging from 2 to 50 microns), the doses of the reagent occasionally differed from the calculated values.

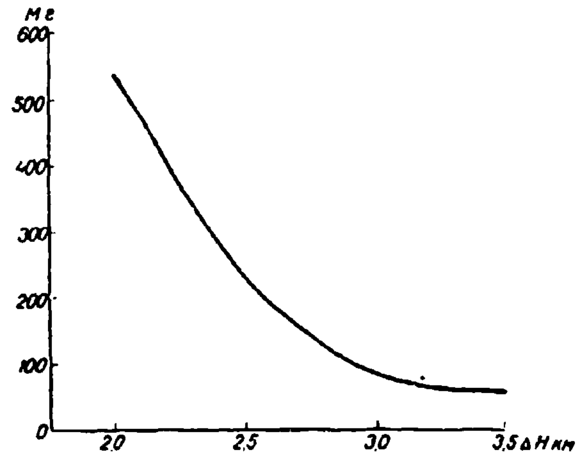

Рис. 1. Зависимость дозировок гигроскопического реагента в пакете от вертикальной мощности конвективных облаков ΔH при воздействии по типу точечного источника через каждые 100 м пути.

Fig. 1. Relation between the measured hygroscopic reagent in the package and the vertical thickness of convective clouds ΔH seeded by the point-source method every other 100 meters of space.

The packages containing the hygroscopic reagent were dropped by the measuring device at intervals of 1.: 1.5 and 2.0 seconds, with the plane flying above the upper part of the cloud. The figures on the use of the reagent are cited in tables 3 and 4 in which account is taken of the fact that the plane usually flew at 230-250 km/hr.

Control of the Seeding Operations

The seeding operations were observed from the plane as well as by the use of radar stations and the precipitation measuring and pluviographic network of the meteorological testing ground.

Observations are made from the plane as it flies around the seeded cloud on the same level. Following the observations of the evolution in the apices of the clouds the plane dropped to the lower boundary of the clouds where observations were made at the base of the clouds, of the incipient precipitation and the characteristic formation of precipitation zones. Notes were made of the time the precipitation began, and its intensity was estimated visually; in addition, the size of the precipitation zone was measured a number of times in two mutually perpendicular directions, in the direction of the seeding and perpendicular to it (or in the direction of the wind and perpendicular to it at a 700 millibar level). Raindrop samples were taken at the crossing of the rain zones in the area of the highest intensity. In some cases it was possible to observe the precipitation zones until their complete degradation, and watch the direction and speed of the shifting zones.

Radar observations were possible in one-third of the experiments. A radar station was used to fix the coordinates of the seeding area, establish the presence or absence of a radio-echo at the time of seeding and the duration and magnitude of the radio-echo on the circular-scope indicator as well as the trajectories of the precipitation sources above the testing ground and its nearest surroundings. In a number of cases it was possible to estimate the quantity of artificial precipitation on the testing ground on the basis of the figures provided by the pluviometric posts. But the basic data on the convective cloud seeding (especially beyond the range of the experimental testing ground) were obtained by observations from the plane.

Analysis of the Experiments

Sixty-three experiments in convective cloud seeding by the mentioned hygroscopic reagent were carried out during the field investigations in 1966. Observations of the seeding effect were made in 47 experiments. The basic characteristics of the cloud selected for seeding purposes are cited in tables 1 and 2.

Table 1

Таблица 1

	ΔH км							
	1,0—1,5	1,51—2,0	2,01—2,5	2,51—3,0	3,01—3,5	3,51—4,0	4,01—4,5	Total
а) n	6	11	17	11	11	4	3	63
P%	9,5	17,5	27,0	17,5	17,5	6,3	4,7	100
б) n	3	8	16	8	8	1	3	47
P%	6,4	17,0	34,0	17,0	17,0	2,2	6,4	100

The vertical thickness of the convective clouds ranged from 1.1 to 4.1 kilometers. The frequency of the vertical thickness ΔH is shown in table 1 for the total number of tests (a) and for the tests involving observations of the seeding effect (b).

As indicated in table 1 (b), the thickness of the clouds exceeded 2 kilometers in 76.6% of the cases.

The temperatures at the upper boundary of the clouds, $t_{u.b}$, are shown in table 2.

Table 2

	$t_{в.г}$				
	from 6,0to 0,0	from —6,1 to —6,0	from—6,1 to —12,0	from—12,1 to —18,0	Total
а) n	2	16	31	14	63
P%	3,2	25,4	49,2	22,2	100
б) n	2	14	22	9	47
P%	4,3	29,8	46,8	19,1	100

In one-third of the cases the temperature at the upper boundary of the convective clouds was above -6°.

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Thirty-one of the seeded 47 clouds under observation produced precipitation, that is in 66% of the cases.

The intensity of the observable artificial precipitation may be divided into two types:

1) from scattered drops to a very light rain. Such precipitation was observed in seven cases which is 15% of the cases of convective clouds under observation, and 22.5% of the total number of cases in which the seeding resulted in artificial precipitation;

2) from light to moderate rain. Such precipitation was noted 24 cases, that is in 51% of the clouds under observation, and in 77.5% of the clouds with artificial precipitation.

In 16 cases there was no precipitation, which is 34% of the total number of cases under observation after the seeding.

We should point out that in table 5 the number of seeded clouds under observation included the clouds with a vertical thickness of at least 1.8 kilometers. The seeding of such clouds does not produce precipitation if they are not entirely supercooled. It is obviously inexpedient to see them. Not counting these clouds (there were five of them in our experiments), the use of a mixture of sodium chloride with cement for seeding purposes may be presented in table 6 in a form which is more indicative than table 5.

Table 6

Results of experiments	Number of cases	%
Without precipitation	11	26
With precipitation:	31	74
1) from scattered to very light rain	7	22.5
2) light to moderate rain	24	77.5
Number of cases in which the seeding effect was observed	42	--
Total number of clouds seeded	58	--

Precipitation was thus noted in 74% of the total number of cases under consideration. Precipitation of the first type was noted in 17% of the cases, and of the second type in 57%. Heavy precipitation was not observed in any of the experiments.

It should be pointed out that some clouds could produce natural precipitation, especially clouds with a great vertical thickness at low negative temperature at the upper edge. That is why the precipitation occurring after the seeding (74%) cannot be entirely considered as artificial. Furthermore, the precipitation of the first type (22.5% of the cases of rain clouds) may have no practical importance.

It appears from Fig. 2 that the seeding of clouds with a vertical thickness of over 2.4 kilometers was, as a rule, effective. In some cases a negative effect of the seeding was noted even in clouds whose vertical thickness exceeded 3.0 kilometers. Such phenomena are noted also when clouds are seeded with crystallizing reagents /2, 4/. This shows that the result of the seeding depends not only on the vertical thickness of the cloud, the temperature at the upper boundary and the doses of the reagent but also of other unaccounted for factors producing a considerable effect on the rain-making process in the clouds. Such factors may include certain unfavorable structural and dynamic characteristics of the clouds developing by the time of the seeding or immediately after it.

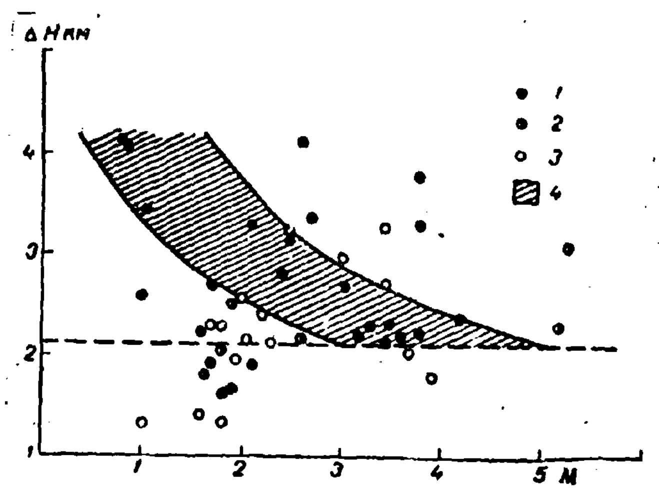

Рис. 2. Эффект воздействия смесью NaCl с цементом в зависимости от вертикальной мощности конвективных облаков и расхода реагента на 1 км пути.

1 — дождь от слабого до умеренного; 2 — осадки, не выходящие за пределы очень слабых; 3 — без осадков; 4 — зона наибольшего эффекта воздействия.

Fig. 2. The effect of seeding with a mixture of sodium chloride & cement determined by the vertical thickness of the convective clouds & the use of the reagent per 1 km of space.

1- light to moderate rain; 2-very light precipitation; 3-no precipitation; 4-zone of the greatest seeding effect.

An analysis of the use of the reagent per unit of distance, depending on the vertical thickness of the convective clouds, shows that as the thickness increases from 2.1 to 4.0 kilometers, a positive seeding effect may be expected by a corresponding reduction of the reagent from 4 to 1 kilogram per kilometer. Thus when the reagent is being dropped (from an IL-14 plane) every 1.5 seconds, reagent-containing packages weighing from 0.4 to 0.1 kilogram should be used. This conclusion agrees with the results of the theoretical calculations (Fig. 1).

Precipitation is usually seen to begin 12-18 minutes after the seeding. In most cases the precipitation lasted 15-30 minutes, and in some cases 1 hour and even longer.

The size of the precipitation zones produced by a single cloud (perpendicular to the seeding direction) was 1-5 kilometers, but more frequently 2-3 kilometers.

Estimating the possible volume of artificial precipitation. A full estimate of the actual volume of artificial precipitation on the basis of the experiments could not be made, as the precipitation could not be measured in all cases. But available materials indicate the possibility of estimating the upper limit of the artificial precipitation resulting from the use of a hygroscopic reagent. This can be done by the use of the largest quantity of carefully measured artificial precipitation as well as the average monthly recurrence of convective clouds above the experimental grounds, bearing in mind the ratio of the number of convective clouds producing artificial precipitation, following the use of a hygroscopic reagent, to the total number of seeded clouds under observation.

The largest amount of artificial precipitation (on the experimental ground) occurred on 22 May 1966. That case was used as a basis for the calculations shown below. The precipitation from the cloud lasted a total of 50 minutes, and the ground surface area (bounded by a 0.1 mm isohyet), according to the precipitation-measuring network, amounted to 160 km^2. The precipitation chart was compiled on the basis of the measurements made by 19 pluviographs 11 of which were located in the precipitation zone under the seeded cloud. The amount of precipitation was established by the planimetric method. The total precipitation amounted to 71,000 tons; the average thickness of the precipitation region was 0.45 mm.

Information based on many years of rain-making experiments shows that an average of 120 Cu cong. a month suitable for seeding are observable in summertime over the experimental ground. According to our figures, the number of cases with significant precipitation accounts for 57% of the total number of experimental clouds.

In terms of the number of clouds producing artificial precipitation when seeded with hygroscopic reagents, it amounts to n = 120 X 0.57 = 69 clouds.

Taking into account the ratio of the precipitation area from one cloud (s = 160 km^2) to the experimental area (S = 3750 km^2), it is possible to determine the total region of additional precipitation: 0.45 X 3 = 1.35 mm/month, that is 3.8% of the average monthly precipitation on the experimental area. It should be pointed out that the amount of precipitation including the zones where it was less than 0.1 mm is somewhat larger than what we used in our calculation (according to the radar station data, the total light area under the cloud break from the beginning to the end of the precipitation was at least 220 km^2), and it may therefore be assumed that the average monthly additional precipitation may amount to 4-5%.

Thus the possible upper limit of the additional precipitation on the experimental area (when a mixture of sodium chloride and cement is used for seeding purposes) is about 1.5 mm/month. In areas with sufficient humidity this quantity may, of course, be larger.

A summary table of the seeding results is shown in the appendix.

Conclusions

1. In the 1966 experiments the large cumulus clouds seeded with a mixture of sodium chloride and cement (in a 4:1 weight ratio) produced artificial precipitation ranging from light to moderate in 57% of the cases. The usual duration of the precipitation was 15-30 minutes, and in some cases 1 hour and longer.

2. According to an approximate estimate, the maximum possible quantity of artificial precipitation on the experimental meteorological proving ground of the Ukrainian Hydrometeorological Scientific-Research Institute produced by large cumulus clouds seeded with hygroscopic reagents cannot exceed 5% of the average monthly natural precipitation. This figure may be higher in areas with a more frequent recurrence of large cumulus clouds.

3. Practical tests with the hygroscopic reagent revealed that its optimal use per 1 kilometer of large cumulus clouds to be seeded ranged from 4 kilograms (with ΔH = 2.1 km) to 1 km (with ΔH = 4.0 km). This conclusion agrees with the results of the previous experiments carried out by the Main Geophysical Observatory i/n Voyeykov.

Bibliography

1. Budilova, Ye. P. and Lenshin, V. T. Predicting the Intensity of Atmospheric Convection by the Layer Method. Transactions of the Main Geophysical Observatory i/n Voyeykov, No. 202, 1967.

2. Gromova, T. N. and Sumin, Yu. P. On the Use of Cuprous Sulfide for Seeding Supercooled Convective Clouds. See this collection.

3. Zykov, N. A. (et al.). Radar Observations of the Results of Seeding Large Convective Clouds. Transactions of the Main Geophysicial Observatory i/n Voyeykov, No. 186, 1966.

4. Lenshin, V. T. and Shishkin, N. S. The Use of Water Solutions of Lead Iodide to Seed Supercooled Convective Clouds in the Area of the Valday Rain Gage Facilities. Transactions of the Main Geophysical Observatory i/n Voyeykov, No. 202, 1967.

5. Litvinov, G. I. and Svarchevskiy, V. N. A Flying Laboratory. Geophysical Instrument-Making, No. 11, 1962.

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13. ABSTRACT

This paper reviews the ~~satisfactory~~ results of artificial rain-making by seeding convective clouds with a mixture of sodium chloride & cement. Light to moderate artificial rain, lasting from 15-30 minutes to an hour, was produced in 57% of the cloud-seeding cases involving the use of a hygroscopic reagent. The best results were achieved by the use of 4 kg to 1 kg of the reagent per 1 km of cloud area. The area covered by the artificial rain was 1-5 kilometers but more often 2-3 kilometers. The maximum possible quantity of artificial precipitation did not exceed 5% of the average monthly natural rainfall. In most cases a positive seeding effect was achieved with clouds whose vertical thickness exceeded 2.4 kilometers. ( )

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