Utah State University
DigitalCommons@USU

Reports

Utah Water Research Laboratory

January 1977

Weather Modification Studies: The Potential for Creating and Utilizing Ice Crystals in Weather Modification Activities

Kenneth G. Hubbard

Follow this and additional works at: https://digitalcommons.usu.edu/water_rep

Part of the Civil and Environmental Engineering Commons, and the Water Resource Management Commons

Recommended Citation

Hubbard, Kenneth G., "Weather Modification Studies: The Potential for Creating and Utilizing Ice Crystals in Weather Modification Activities" (1977). *Reports.* Paper 404.
https://digitalcommons.usu.edu/water_rep/404

This Report is brought to you for free and open access by the Utah Water Research Laboratory at DigitalCommons@USU. It has been accepted for inclusion in Reports by an authorized administrator of DigitalCommons@USU. For more information, please contact dylan.burns@usu.edu.

UtahStateUniversity
MERRILL-CAZIER LIBRARY

Final Project Report

WEATHER MODIFICATION STUDIES: THE POTENTIAL FOR CREATING AND UTILIZING ICE CRYSTALS IN WEATHER MODIFICATION ACTIVITIES

UWRL Study Number WR-13-1

Kenneth G. Hubbard

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

TABLE OF CONTENTS

ABSTRACT

A method utilizing ice crystals to circumvent nucleation processes in cloud seeding activities is discussed in the framework of nuclei activation concepts. Ice, in the form of small crystals, would be a highly efficient cloud seeding material up to $0^{\circ}C$. The lower limit on humidity would necessitate dispensing the crystals into air that is saturated with respect to ice but no requirement for 100 percent RH (relative humidity) was found. In fact, the lower limit varies with temperature linearly from about 95 percent RH at $-5^{\circ}C$ to 75 percent RH at $-30^{\circ}C$. Preparation of small crystals was found possible at liquid nitrogen temperatures and the volume which could potentially be seeded seems to be large enough to seriously consider the ice crystals as a possible triggering material.

LIST OF FIGURES

1.0 Introduction

The importance of the ice phase in precipitation processes was pointed out in a classical work by Bergeron (1935). Over the relatively short period of time since 1935, much work has been undertaken to develop cloud seeding as a usable tool and the most recent evidence suggests that a positive change can be derived from modification of winter orographic clouds.

The use of silver iodide as an artificial ice nuclei stems from the discovery by Vonnegut in 1946 that tiny particles of this substance could induce ice crystals from a supercooled cloud.

Studies have been made of the efficiency of silver iodide as an ice nucleating agent and are conveniently expressed as a function of the threshold temperature and a curve relating the number of "active" particles per gram to the temperature. Because this curve deals with the number of particles active per gram, it has incorporated within it information about the size distribution of silver iodide particles. In Fig. 1 such a curve is reproduced from Davis (1972) for AgI-KI which represents a kerosene burning generator, and is labeled simply AgI ($-4^{\circ}C$).

It should be obvious from Fig. 1 that the more efficient nucleating materials will:

1) Have a threshold temperature as close to $0^{\circ}C$ as possible.
2) Be capable of existence in the form of finely divided particles.
3) Be deliverable to temperature regions less than or equal to the threshold value in a manner which does not reduce the quality of 1) or 2).

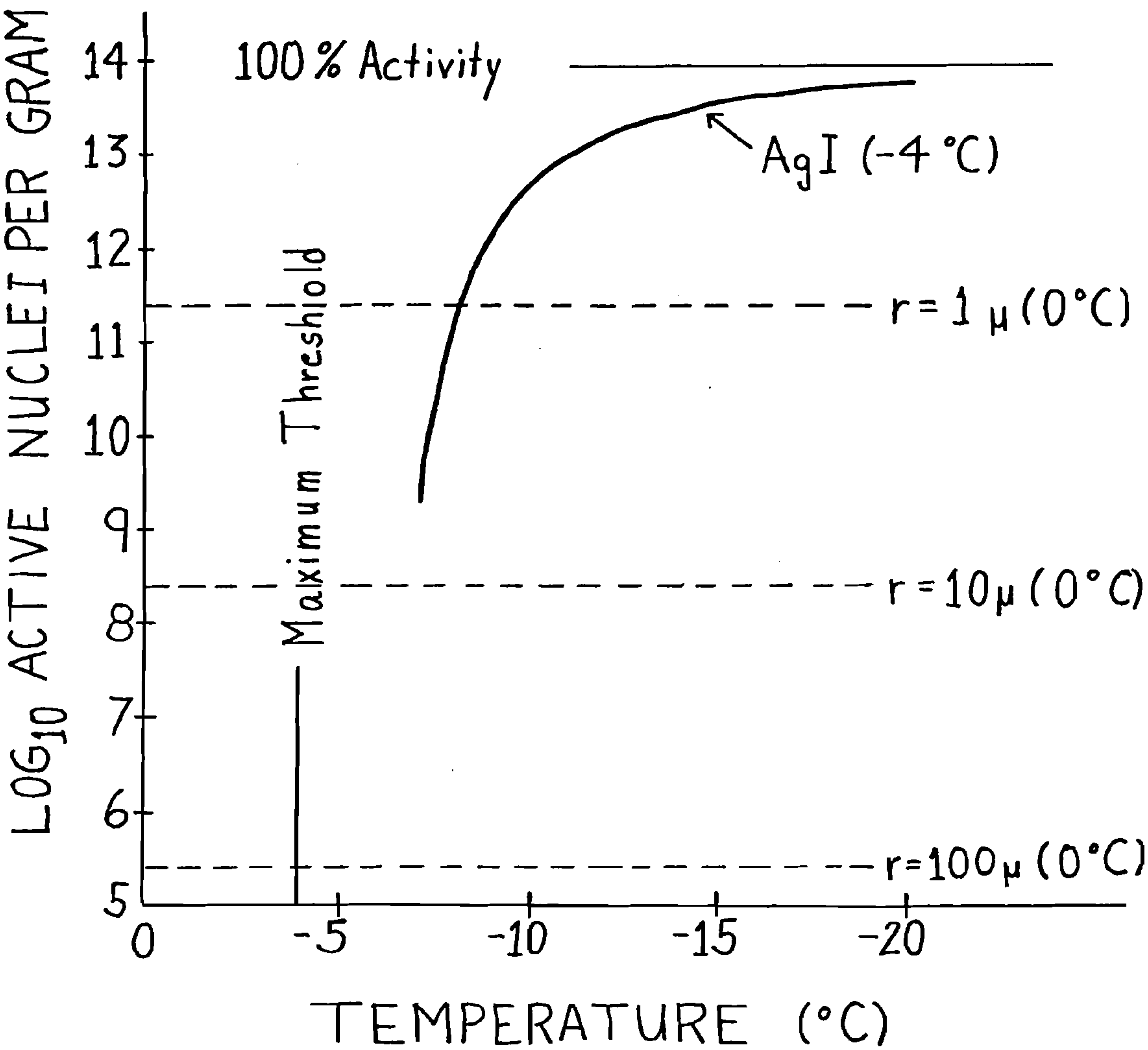

Fig. 1. The activity of AgI compared to the activity of ice particles of a given radius r.

Silver iodide is known to have a threshold as high as $-4^{\circ}C$ (vertical asymptote) and the potential for fine division is represented by the asymptote of 100 percent activity (horizontal).

1.1 Nucleation Processes

Recent evidence suggests that the silver iodide activation process is also a function of supersaturation with respect to ice. Huff (1973) has clearly shown that the higher the supersaturation with respect to ice the higher will be the probability of an AgI particle acting as an ice deposition nuclei. It should be mentioned here that the ice production caused by deposition when small droplets are present is thought to be insignificant in comparison to the production caused by the freezing of small droplets encountered. Thus, depositional growth is important when the air is less than 100 percent water saturation but greater than 100 percent ice saturation.

The margin in percent between ice saturation and water saturation can be expressed solely as a function of temperature. In Fig. 2 it is shown that the percentage excess saturation with respect to ice can vary from 0 percent at $0^{\circ}C$ to 34 percent at $-30^{\circ}C$ before becoming saturated with respect to water. In cases where there is subsaturation with respect to water, one would not expect to find water droplets present.

Huff found that the depositional nucleation was actually reduced as the seeding material was more finely divided. He links this result to the speculation that the probability of finding a nucleation site on a particle is a function of the size of that particle. It is conceivable then that there is a lower limit beyond which further reduction in particle size causes an overall decrease in nucleation efficiency.

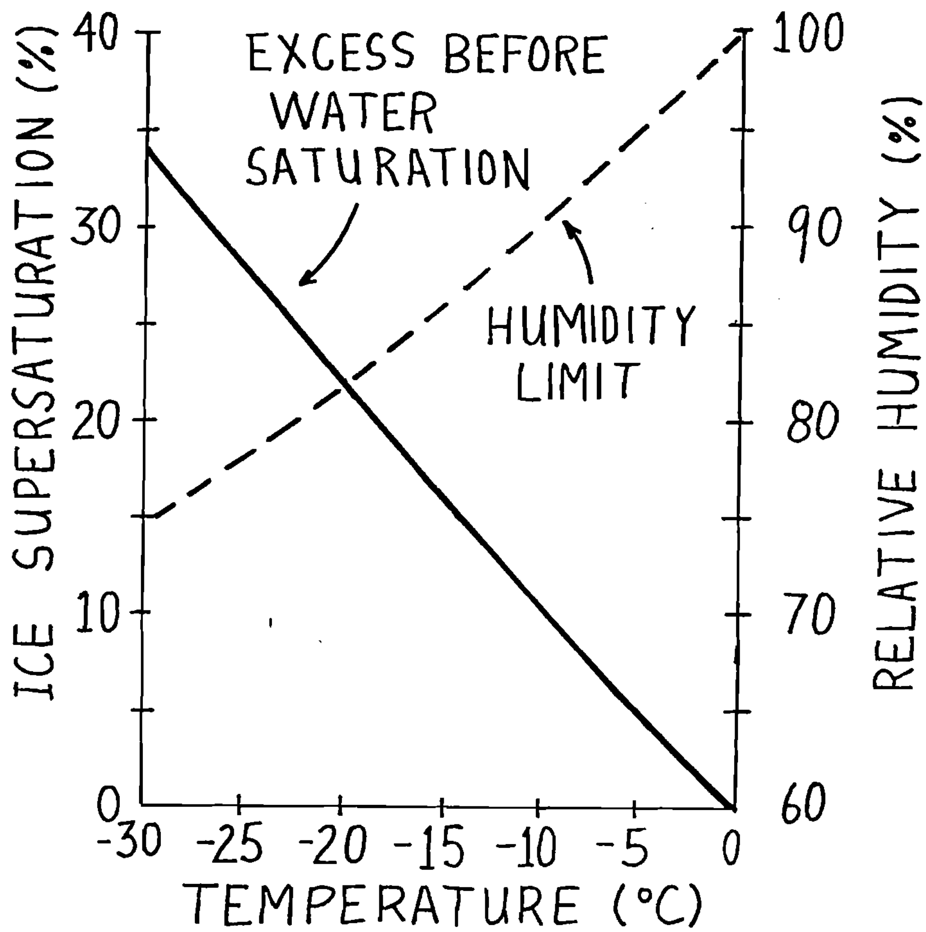

Fig. 2. The lower limit of humidity for the ice phase and the excess saturation with respect to an ice surface before water saturation is reached.

1.2 Mono-Dispersed Ice Particles

Ice has the ability to exist at all temperatures colder than $0^{\circ}C$ and in dispensing ice particles one might think of this temperature as the upper limit of activity or threshold temperature. The limit on relative humidity is set by the saturation with respect to an ice surface. When this limit is not met or exceeded, the ice particles will evaporate. When humidity is measured with respect to a water surface, the relative humidity limit for the ice process is also shown in Fig. 2. The limit is 90 percent at $-11^{\circ}C$ and 80 percent at $-22.5^{\circ}C$.

As mentioned before, tiny cloud droplets become unstable below 100 percent relative humidity. The presence of solute in these droplets may bring this limit down to 99 percent which is still relatively high when compared to the limit for ice deposition.

From the above, it is possible to say that depositional ice growth is possible over a large range of relative humidity and temperature values.

Hypothesized introduction of ice particles into a cloud would result in an activity spectrum as drawn in Fig. 1. Three different mono-dispersed sizes are assumed and the ice process is assumed to be feasible as long as the lower humidity limit criterion is met.

It should be noted that the actual introduction of ice particles would be superior to the introduction of AgI. The list below summarizes the qualities thought to be most important:

1) Given the condition of ice saturation ice particles will be active whereas AgI particles exhibit further dependence on the excess with respect to this saturation.

2) The temperature range over which AgI can be used is limited by the threshold temperature (< 0^{o}C) while ice particles can be used for all temperatures 0^{o}C and colder.

3) Ice particles would be as effective in freezing supercooled droplets present as would AgI particles.

Two features which favor AgI are:

1) AgI can travel through temperature regions higher than its threshold value.

2) AgI could exist at subsaturation with respect to ice, for instance, -10^{o}C and 80 percent relative humidity.

2.0 Seedable Volume and Seeding Efficiency

A simple concept of what volume can be seeded per unit mass of seeding material given a size distribution and the desired spatial concentration of particles is called here the seedable volume.

In Fig. 3 the seedable volume has been described as a function of particle size and desired concentration. With a crystal size of 20μ radius, a crystal concentration of 1 per liter is possible over a volume of 40,000 m^3 for each gram of ice used. Thus to seed a cubic kilometer would take about 74 lbs of ice. At a crystal size of 1μ radius, the same cubic kilometer can be seeded with 4.18 grams ($\sim$ 1/100 lb).

The feasibility of using the ice crystals for seeding would in practice depend very much on the mean size of the crystals. Because of the difference in densities between ice and AgI, slightly more particles are possible from ice than from AgI at the same crystal size. This is not a large effect but from Fig. 3 one can see that the same seedable volume is possible for ice crystals of 1.8μ as for AgI particles of 1μ.

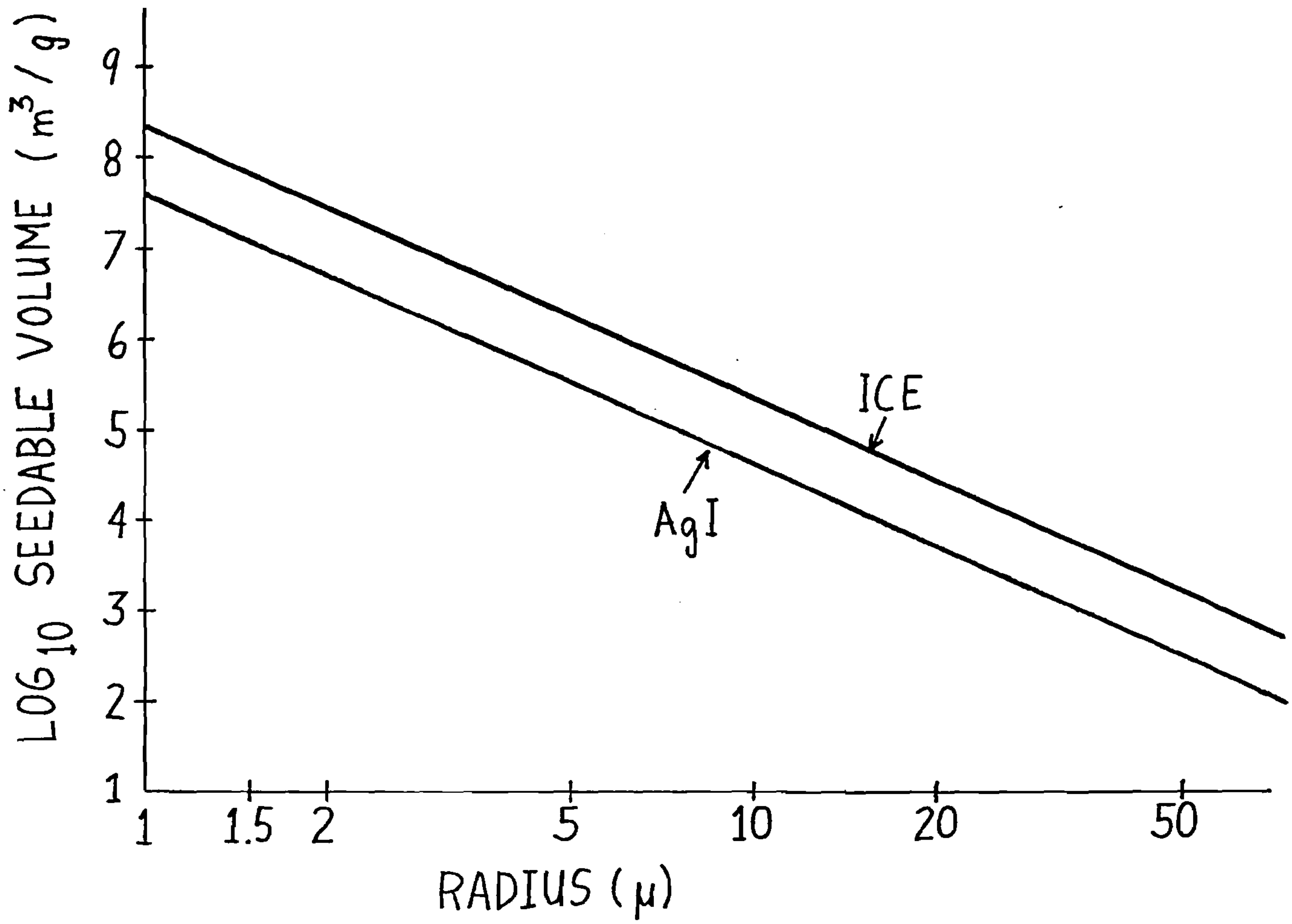

Fig. 3. The seedable volume per unit of seeding material for a given size particle. The curves are for the desired concentration of 1 per liter.

If one assumes that the average radius of the AgI particles used in operational cloud seeding today is 1μ, then to be as efficient on a per gram basis would require that ice crystals be dispensed with an average radius of 1.8μ. This raises an interesting question. Should efficiency be defined on a mass base? Certainly the cost per mass is not equal for all materials. The environmental effects from all materials are not the same per unit mass. Perhaps we should speak of the ratio of the volume seeded to the total cost for a given concentration of nuclei over a range of temperatures as the efficiency of the particular material used. Or perhaps we should interpret the efficiency of a given material in terms of temperature and relative humidity regions in the atmosphere and use the most efficient material in each region.

3.0 Experimental Procedure

In addition to studying the possible use of ice particles in weather modification activities as denoted above, an experiment was designed to determine size characteristics of ice particles produced in the laboratory. A description of this experiment is given below.

3.1 Materials

The items necessary to carry out the experiment were:

1) Cold Box - The UWRL Refrigerator Cold Box was used. It is operated at about +2°C.

2) Liquid Nitrogen - A limited amount was obtained for the purpose of further cooling.

3) Mortar and Pestle - It was decided to grind the ice mechanically using a mortar and pestle.

4) Formvar and Glass Slides - The ice crystals were replicated on the slides, i.e., their shapes were preserved in the formvar layer.

5) Microscope - For viewing the slides.

3.2 Experiment 1

A log of the first experiment (1/19/77) is given below:

11:00 AM All materials were assembled in the UWRL cold box. A styrofoam container was obtained to hold the mortar and pestle.

11:15 AM Several pieces of chunk ice were ground to powdery texture.

11:30 AM Two slides were made. Each slide was coated with formvar and the ground ice was added by holding the mortar over the slide and lightly tapping.

The slides were left to dry with L.N. in the sides and bottom of the container.

3:30 PM The slides were taken to the Biology Laboratory for viewing under the microscope. A count suggests the average diameter to be about 50μ ($r = 25\mu$).

It was noted that some problems were encountered with crystal melting and that the formvar seemed thick and difficult to apply uniformly to the slides.

3.3 Experiment 2

A second experiment was carried out to remove some of the shortcomings of the first experiment.

4:00 PM A repeat of grinding under liquid nitrogen was done; this time all slides were kept below $0^{o}C$ and over a L.N. surface until ready for viewing.

4:45 PM Slides were taken to the Biology Laboratory and viewed under the microscope. The melting process was observed this time as the crystals took on heat from the microscope. Crystals were of uniform size and some agglomeration was observed during the melting. The slide now appeared as water droplets of about 10μ diameter. Some were larger where agglomeration occurred. It was concluded that the crystal radii were about 5μ.

The amount of grinding was minimal and it was concluded that mechanical grinding under liquid nitrogen would produce ice crystals of an appropriate size for use in cloud seeding.

4.0 Conclusions and Recommendations

On the basis of the evidence presented above, several conclusions will be set forth:

1) Particles of ice introduced into a cloud would be highly efficient in triggering ice processes.
2) Ice particles are "active" over a wider range of humidity and temperature than their common counterparts the ice nuclei.
3) Ice particles introduced into a cloud would circumvent the time and uncertainties associated with nucleation.
4) Ice particles can exist at a small size and therefore would be competitive in the seedable volume category.
5) There is a lower limit in humidity and an upper limit in temperature which must be met for the existence of ice particles.

It is further concluded that:

6) Ice particles would be environmentally safe.

Recommendations which follow from this study are that:

1) Further investigation be made into methods of dispensing ice crystals from airborne vehicles, as would follow from conclusion 5.

2) Consideration be given to the use of tiny ice crystals in such applications as fog dissipation at airports where the temperature and humidity might otherwise limit the effectiveness of AgI or other nuclei.

3) A means be perfected for generating ice crystals in a uniform size distribution.

4) The concept of a materials ice nucleation efficiency be modified to include the range in factors critical to ice formation and existence as well as other pertinent categories: cost per unit raw material, cost per unit delivery, environmental effect per unit delivered.

References

Bergeron, T., 1935: On the physics of clouds and precipitation. Proc. 5th Assembly U.G.G.I., Lisbon, 2, 156.

Davis, B. L., 1972: An examination of the theory of heterogeneous nucleation of ice. J. Atmos. Sci., 29, 557-564.

Dennis, R., 1976: Handbook on Aerosols. NTIS. U.S. Dept. Comm. TID-26608.

Huff, P., 1973: Supersaturation dependence of ice nucleation by deposition for silver iodide and natural aerosols. Dept. of Atmos. Resources, U. of Wyo., Report No. AR 108. 29 p.

Vonnegut, B., 1947: The nucleation of ice formation by silver iodide. J. Appl. Phys., 18, 593-595.