AFTER TWENTY-NINE YEARS - A PROPOSAL

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With the 30th anniversary of the discovery of a practical way to modify supercooled clouds(1) less than a half year away, it seems that at the present time it is logical to consider our progress in this intriguing field and to assess practical possibilities for the future.

To place our current field activities in perspective to that of our knowledge of the field in 1947, I have included Figs. 1 and 2 which I prepared on February 6, 1947.

While some of us are inclined to be impatient or frustrated with the progess that has been made over the period of 29 years, there are aspects of the problem that are not easily solved.

The foremost obstacle to progress that requires a solution has long been referred to as the "people problem". Not only are there individuals or groups who deride and belittle the potential for the modification of clouds and weather, but there seem to be an equal number who feel far more can be done than is likely to be possible under the most ideal physical conditions.

On the other hand, consider the conservation that would exist if the disastrous floods of last summer on the Red River of the North could be directly ascribed to rains that developed in a cloud seeding program. Just as the Feather River flood of the mid-fifties and the Rapid City flood of the early seventies had peripheral cloud seeding activities, there are people who are prone to jump at conclusions without much valid data.

The "people problem" will always be with us and should be carefully considered and assessed no matter what national or global program is pursued. Proper and intelligent public communication and majority participation are essential ingredients to the elimination or control of this problem.

I should like to leave these aforementioned social problems to the anthropologists, psychologists, lawyers and public relations experts and direct attention to some of the mechanics of the weather modification process. Despite many attempts and much effort to develop better, more effective and less expensive cloud seeding materials, there is as yet no substance that remotely competes with dry ice or silver iodide in ease of use and field effectiveness for producing modification of supercooled clouds. Each of these materials has unique properties and, when properly utilized, are highly complimentary.

Although there are a number of proposed substitutes such as cupric sulfide, metaldehyde, phloroglucinal, pentaerythritol and other organic subatances, I doubt if any of those thus far proposed are likely to displace dry ice and silver or lead iodide for practical utilization for some time to come.

Much effort has been directed toward the utilization of silver iodide, ranging all the way from dispensing it in finely powdered form to melting it in a combustible solid, to burning silver iodide-sodium iodide dissolved in acetone or other combinations, to using it as a component in pyrotechnic flares, explosive artillery or rockets. I would like to redirect attention to the effective utilization of dry ice (solid carbon dioxide). It is my considered opinion that whenever an aircraft is used for seeding purposes and the plane is capable of flying into or above supercooled clouds, it is a great waste of money and opportunity to not use dry ice fragments for the seeding agent.

It has been my experience in watching and in reading about dry ice seeding operations, that far too much dry ice has been used in most seeding programs. Since dry ice is so cheap relative to any other seeding substance (20¢ to 30¢ per pound at current 1976 prices) as compared to a cost of a hundred times more in the case of silver iodide, the attitude seems to be, "since we can easily afford it, why not use plenty!"

In our Project Cirrus operations, we rarely used more than two pounds of crushed dry ice per mile of flight, and more commonly limited ourselves to one pound per mile. Since the temperature effectiveness of dry ice is superior to silver iodide at all temperatures colder than $0^{o}C$, even one pound per mile of the dry ice, if effectively utilized, can produce many more ice embryos than is possible with silver iodide.

I have witnesses the utilization of from 10 to 200 pounds per mile or even per drop! This often defeats its purpose since the extremely cold air generated by the massive drop causes the entire air parcel to pass through the seeded area and thus into the unsuitable air below.

The biggest advantage in the utilization of dry ice for supercooled cloud seeding is the fact that a fragment about a centimeter in cross section will fall a mile before it is completely sublimed. Thus it was our practice during our Project Cirrus studies to crush blocks of dry ice so that the largest pieces were about 1 centimeter diameter, using all the smaller fragments including the finest powder.

The limitation in the use of dry ice is, of course, the fact that it _must_ be put into air that is _colder_ than $0^{o}C$, and _at least_ supersaturated with respect to water. Under such conditions a blue fog of ice embryos will stream from a fragment of dry ice with a concentration well in excess of 10^{14} embryos per gram at $-16^{o}C$.

Thus I strongly urge a revival in the utilization of dry ice in cloud seeding activities. The fact that most of the current weather modification activities in the United States are based on the use of aircraft makes it all the more relevant to do so.

The Removal of Supercooled Clouds

A short time ago I suggested [2] that dry ice be used to bring more sunshine to the earth by removing supercooled stratus clouds. Extensive solid decks of such clouds often greatly reduce the amount of sunshine reaching the earth. While my main proposal was focused on providing more direct sunshine for solar energy collectors, the same feature should be considered for corn, wheat, sorghum and other ground crops that thrive on direct sunshine. A climatological evaluation should be prepared to determine whether such cloud removal would benefit crops and be economical. At the same time, the cloud removal technique could be utilized for training purposes as well as for evaluating proposed new seeding substitutes. Parallel legs five to ten miles long could be produced using one pound of crushed dry ice per mile of flight. Substitute materials could then be dispensed parallel to the dry ice reference line. Since the vortices from wing tips and propeller blades also generate ice crystals by homogeneous nucleation, any material to be compared, which requires that the substance is dispensed while flying <u>in</u> the cloud, must have a parallel flight line of the airplane flying <u>in</u> the cloud making a "dry" run.

In this manner one can make visual and photographic evaluations of the effects produced by the seeding materials, thus eliminating the need for statistical studies!

The Production of Clouds to Control Ground Temperature

Under suitable conditions it is just as easy to <u>produce</u> stratus clouds as to remove them. This might be of extreme importance for the alleviation of excessive heating from the unobstructed sun during corn tasseling. We also established this technique during our Project Cirrus exploratory experiments in 1947.

To establish the possibility of producing stratus clouds by seeding, we used a 100 gram pilot balloon filled with helium and carrying a chunk of dry ice suspended in an open mesh bag. As the balloon climbed into the sky, it was watched by theodolite or ordinary binoculars. If, during its ascent, a persistent condensation trail formed, the approximate altitude was noted. Such a trail established the presence of a layer of moist air that was supersaturated with respect to ice. We commonly found such layers existing at altitudes between 15,000 and 25,000 feet.

Such layers could be seeded with dry ice fragments by flying within the top of the moist layer, dropping dry ice fragments into the clear air at the rate of a pound per mile of flight. Quite commonly, when doing so, a condensation trail would form in the engine exhaust plume. Since the air temperature in this portion of the troposphere was never colder than -40°C, the trail remained as a localized water cloud which eventually merged and evaporated onto the ice crystals generated by the dry ice seeding.

As with the removal of a supercooled cloud, the same flight technique should be used in producing a cloud in supersaturated air as would be used for producing holes in a supercooled cloud deck as described in the Project Sunshine paper previously cited.

For a very modest outlay of funds it would be extremely easy to establish the possibilities of cloud production of removal. In view of the multimillion dollar losses that occur when excessive heat prevents the pollination of corn and other crops, such experimental activities should be started without further delay.

The Prevention of Frost by Cloud Production

The presence of a relatively thin cloud of ice crystals produced through the dry ice seeding of air supersaturated with respect to ice might also be useful in controlling nighttime temperatures at times when there is the danger of frost. Just as a daytime cloud will reduce the amount of heating produced by insolation during the daytime, the presence of a similar cloud at night can prevent the radiative cooling of the earth that occurs under a clear sky condition. Thus outearation (outgoing earth radiation), which is the cause of late spring and early fall frosts, can be reduced if an artificial cloud can be formed to prevent this nighttime radiative cooling.

The Educational Value of Cloud Production and Removal

Since it is unlikely that anyone would object to such operations, and since a successful effort at cloud production or removal (depending on circumstances and need) would have dramatic economic and social benefits, such activities would have an educational value that would benefit everyone.

Conclusions

I strongly recommend the development of such activities by the agricultural community as soon as possible. There are so many benefits that would occur, it is unlikely that any serious "people problem" would occur.

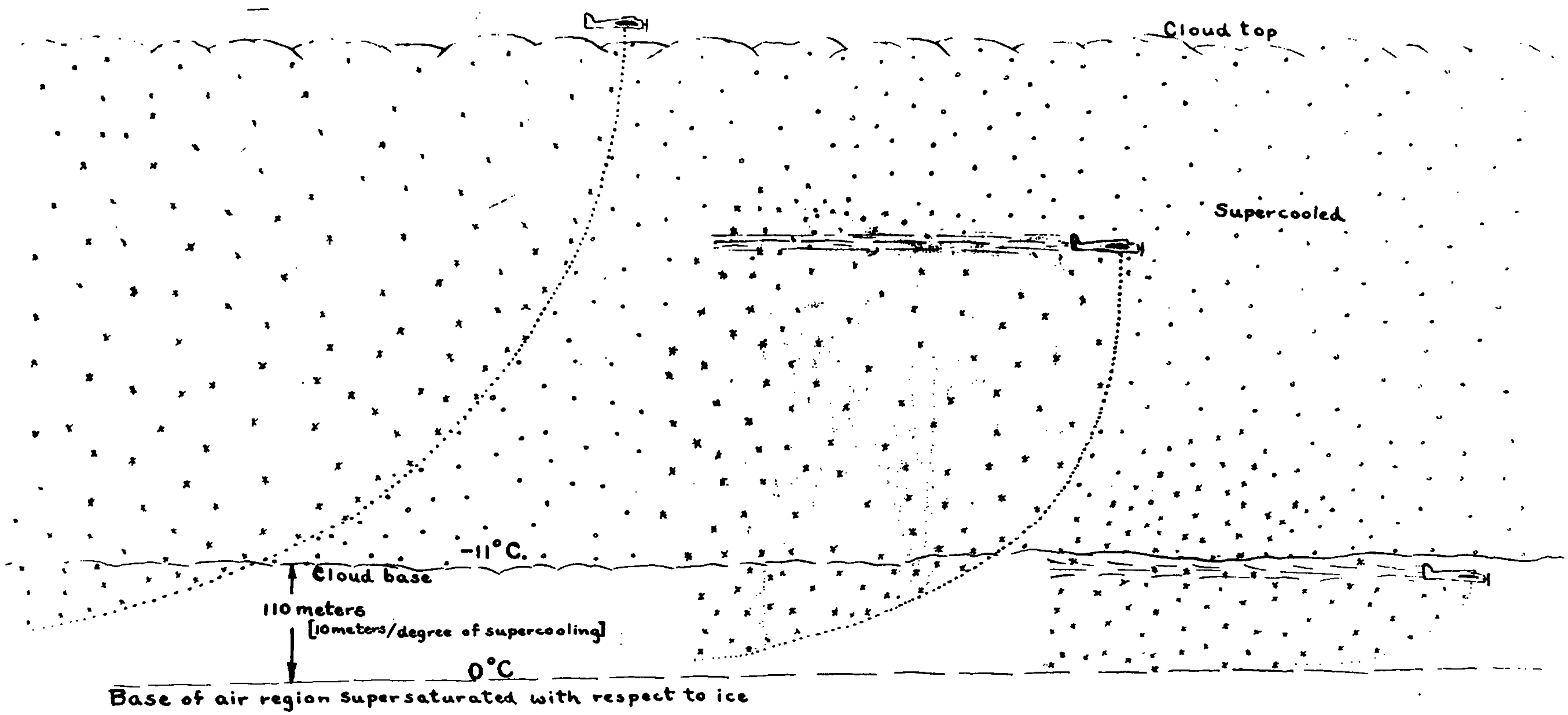
The use of dry ice or any other practical means for achieving homogeneous nucleation (liquid nitrogen, carbon dioxide, propane, etc.), completely eliminates any possibility that the seeding materials not utilized could produce distant or long range effects. Since these materials can only generate pure ice embryos, they are completely gone once they move into dry air or temperatures warmer than $0^{o}C$.

Thus we come full circle, an experience that often occurs in science and human affairs.

REFERENCES

1. Schaefer, V. J., "The Production of Ice Crystals in a Cloud of Supercooled Water Droplets." Science, 104, 2707, pp. 457-459 (1946).

2. Schaefer, V. J., "Project Sunshine". J. Wea. Mod. Vol. 7, No. 1, p. 1 (Apr. 1975).



FLIGHT PATHS FOR SEEDING
SUPERCOOLED CLOUDS WITH DRY ICE

* * * AREA AFFECTED BY SEEDING

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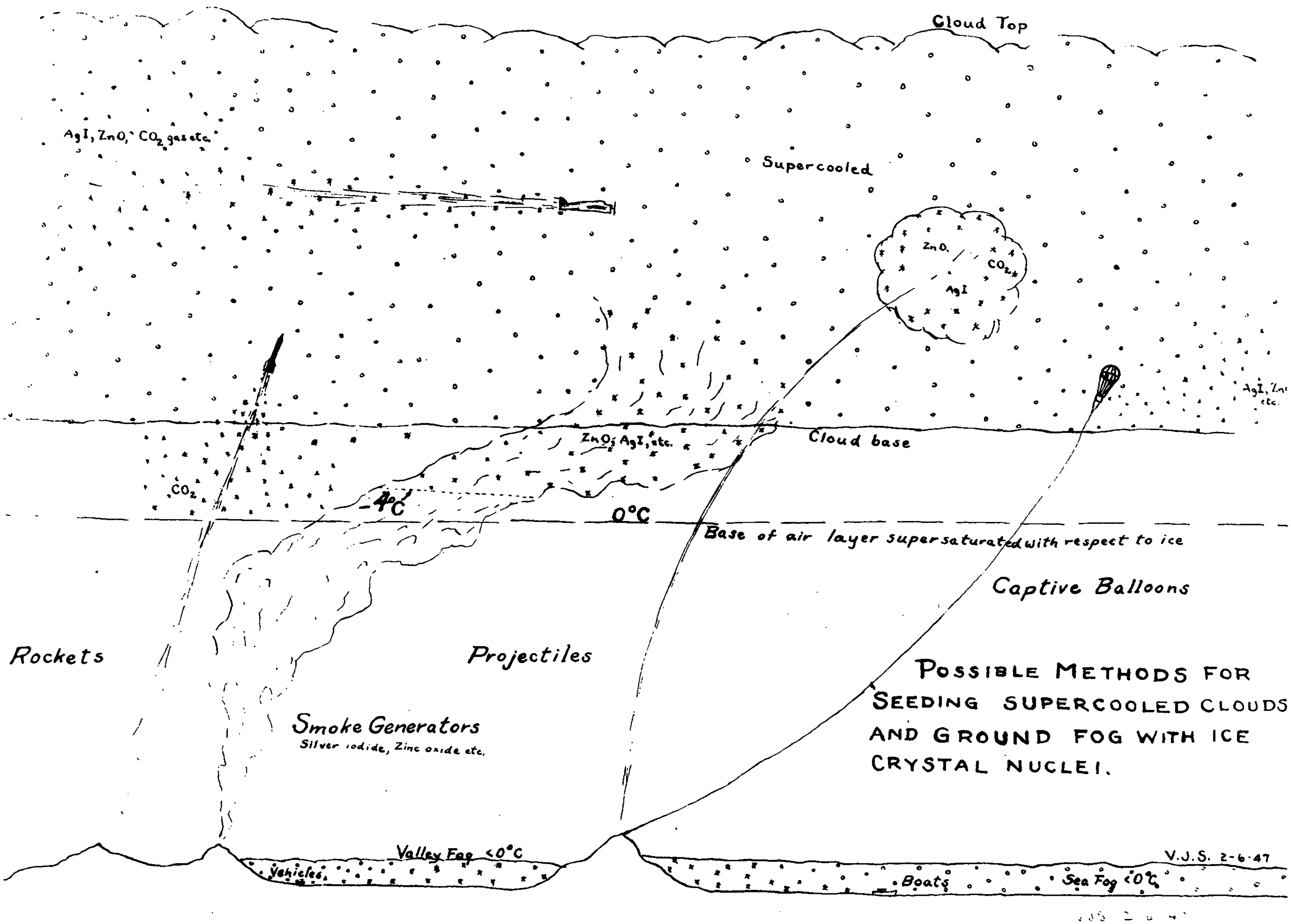

Cloud Top
AgI, ZnO, CO_2 gas etc.
Supercooled
ZnO
CO_2
AgI
AgI, Zn etc.
Cloud base
ZnO, AgI, etc.
CO_2
-4°C
0°C
Base of air layer supersaturated with respect to ice
Captive Balloons
Rockets
Projectiles
Smoke Generators
Silver iodide, Zinc oxide etc.
POSSIBLE METHODS FOR SEEDING SUPERCOOLED CLOUDS AND GROUND FOG WITH ICE CRYSTAL NUCLEI.
Valley Fog <0°C
Vehicles
V.J.S. 2-6-47
Boats
Sea Fog <0°C