WORLDWIDE EVALUATION FOR CREDIBILITY

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1. STATUS OF MULTI-PROJECT ANALYSES

Some people are hoping for the day when an elegantly designed experiment, brilliantly evaluated, will make precipitation management credible to those who look at the field from the outside, but it doesn't appear as though credibility will come that way. Rather it will come from reporting on information assembled from a large number of imperfect experiments and operations, that show even though there is diversity in the way different types of clouds respond to seeding, similar clouds respond similarly around the world.

Todd and Howell (1985a) reported on what they were finding as they assembled a "World Atlas and Catalog of Reported Results from Precipitation Management by Cloud Seeding" based upon several hundred evaluations. Since then this effort has been considerably extended and published (Todd and Howell 1985b). The major findings don't surprise those who have worked long in the field, but they have not been previously presented to show the outsider how extensively seeding has been practiced or how consistently it has been reported to have produced positive results.

Relating different cloud-seeding responses to cloud types and characteristics in an organized way has shown a physical basis for a sound technology. The problem is that few projects include enough similar clouds to achieve statistical significance within themselves. It is necessary, then, to assemble information from a large number of projects to demonstrate that there is a broadly-based technology. Such combining complicates the rules as to what is satisfactory exploratory and confirmatory evidence in the games that the evaluators have been playing.

For many past projects there is much good information in radar records, time-lapse photography, aircraft logs, special soundings, weather data collections, etc., waiting to be used. There are more than 40 projects every year around the world, collecting probably more than 2000 new seeded cases a year, many of which should be available for in-depth studies. A little coordination to acquire data in comparable formats ought to help greatly to make it more usable for multi-project analyses. Who ought to analyze these data? The commercial seeders do not have much margin for taking on extra tasks, yet they have contributed tremendously by documentating operations and producing objective analyses of consistently good quality. Some have completed 100 or more projects and have learned conceptually and qualitatively much of what we propose to find out. On the other hand, a world academic effort to quantify this would probably be too slow starting and too clumsy. But if several of the many national programs would support analyses of their findings in context with what could be learned from the many other projects of the world, there would be fast, broad spectrum learning.

2. STRONG RESPONSES TO SEEDING

2.1 Cumulus congestus

When the Project Cirrus seeded cumulus clouds, dramatic things happened after seeding, but there was no agreement as to how they were related to the seeding. Since then, experimenters around the world have demonstrated in well over 30 projects that ice-phase seeding done any number of ways can make robust cumulus congestus with tops between -10 C and -20 C produce substantially more (two to five time as much) precipitation as similar nonseeded clouds (Todd and Howell, 1985). If the top is a little warmer than -10 C the effect diminished to nil. For cloud tops colder than -20 C the per cent increase due to seeding becomes less and harder to relate to the seeding, but the indicated absolute increase becomes more per cloud, because bigger clouds process much more water. At the large cloud end of the spectrum, the hail suppressors are seeding the storm feeder clouds as they struggle through the cumulus congestus stage. They report increasing the cloud's total precipitation by a modest +12% median response for over 20 reporting projects.

The cumulus congestus studies are made more definitive when the experimenters pick isolated clouds so that they can estimate the rate of cloud water condensed and how long the clouds lasted, and calculate the precipitation from individual seeded and unseeded clouds using aircraft and radar observations. Because there is only moderate uncertainty in dealing with these clouds, and because such cumulus congestus are so numerous, many projects that have concentrated on them have achieved impressively statistically significant results. If properly assembled and presented, this information collected from many projects, should be sufficient to convince any reasonable person that there is now the basis for a usable technology for increasing precipitation.

There is much still to learn about the finer points of how these cumulus respond to seeding over the whole range of cloud top temperatures and other conditions. The fact, there appear to be more than 10 quasi-independent factors that governing how effectively such clouds respond to treatment makes this truly a large problem. Clearly there is a potential for using a very large number of cases to work out the relationships with so many potential input parameters. This should make use of cases drawn from projects all over the world.

2.2 Cumulonimbus

Project Whitetop shocked the cloud seeding world when it produced statistically significant decreases in precipitation from seeding summer convective clouds. It found that the decreases occurred from a heavy broadcast seeding that included large cumulonimbus which produced a substantial portion of the summer precipitation. Since then, at least 12 projects indicate decreases from such seeding of apparently similar clouds. Here the evidence is not nearly as well developed as it is for the cumulus congestus. Generally there are so few of the large cumulonimbus on any one project that statistics are indeterminate even though such clouds produce most of the season rainfall. It would be very important to learn more about the conditions for decreasing precipitation from these clouds. To do it effectively one would have to draw cases from the broadest selection of projects worldwide.

3. OTHER RESPONSES

3.1 Hail suppression

There is greater uncertainty in estimating the potential amount of hail than rain that a cloud would produce. Hence, it takes a greater number of cases to evaluate the effect of seeding to suppress hail with the same certainty as evaluations of rain responses. Only a few projects have had enough cases to report statistically significant hail reduction. Yet the Atlas shows 57 projects reporting less hail and only 3 reporting more hail due to suppression seeding. There is still doubt about the technology, though, because increased hail occurred on two of the most heavily researched and closely watched projects. It seems that general credibility for hail suppression is most likely to be achieved if success for suppression can be related to physical factors such as the size, type, and physical characteristics of the storms, and how they are seeded. It appears that such a relation may exist, because in North Dakota success is related to seeding the smaller "hailers" but not the "supercells", and in Russia there is concern that the technology is not now effective against "superpower storms" though it is reported to work quite effectively on the smaller ones. It would be informative to collect physical characteristics from a large number of cases from the projects of the world and see if there is a worldwide credible quantitative physical relationship of cloud type and characteristics to the reported success of suppression. Miller 1979 takes a step on such a multi-project comparison.

3.2 Stratus

From the first experiments of Project Cirrus it was demonstrated that a class of nonprecipitating supercooled stratiform clouds could be made to precipitate by ice-phase seeding. That the effect was real could be documented photographically from above. The remaining problems were to find out how much clearing or precipitation could be produced, over how wide a range of conditions it would work, and where there was practical application for this type of seeding. Some mountain crests appear to have several hundred hours a year of such stratus. Though these yield less than one millimeter an hour to seeding, they can produce important increases on a seasonal basis.

3.3 Nimbostratus

The Atlas shows that, over the past 39 years, when the seeding is reported to have taken place in nimbostratus, seeders seem to have decreased precipitation over their targets about as frequently as they have increased it. Post-analysis indicates that some target decreases are associated with downwind increases. A multi-project analysis effort such as Bigg (1985) reported, if the cases could be sorted to separate stratus from cumulus, would shed much light on this. Shaffer (1983) does a post hoc sorting that separates increase from decrease cases in the Colorado River Basin Pilot Project. Also, Leskov (1974) reported that there have been over 20 years of experiments in the Ukraine to find the time of travel downwind from the seeding until the fallout reached the ground. This varied from 45 minutes to 3 hours depending on the cloud parameters. There is a need to fit information from more of the projects of the world into a generalization that will make this a reliable and transferable technology.

3.4 Hygroscopic seeding

The Atlas lists 27 projects reporting increases of precipitation from hygroscopic seeding and only two decreases, but we have yet to see published the conditions for success. So here, too, there is a need to collect the case data from many projects that have observations of the characteristics of the clouds to learn which respond.

4. CONCLUDING REMARKS

The evidence that there is a usable technology for seeding some types of clouds is as strong as the evidence for many other technologies that our society accepts and uses routinely. But world cooperation among cloud seeders is needed to speed development and demonstration of technologies for managing precipitation from a broader selection of cloud types and over a range of characteristics. The time is right for the weather modification enthusiasts of the world to work together to achieve greater credibility for their technology.

5. REFERENCES

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