Weather Modification Frequently Asked Questions

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1. How does cloud seeding work?

Cumulus clouds–the billowy, cauliflower-shaped clouds often seen in Texas skies during much of the year–are important rain producers in every sector of the state. As the predominant cloud type during the warmest eight months of the year (March-October), cumulus (or convective) clouds are responsible for producing the bulk of rainwater given by the atmosphere in any given year in Texas. These towering cloud formations form from strong updrafts of warm, moist air into an atmosphere that is unstable. Intense daytime heating of the near-surface layer of air, or a wedge of cold air moving across the state (as a cold front), usually triggers the formation of convective clouds.

Not all cumulus clouds become rain producers. In fact, only a small percentage of them ever develop the capability to yield an appreciable amount of rainfall. Those convective clouds that do produce rainwater are often inefficient: For all the moisture they incorporate from below, only a tiny fraction of that moisture (as cloud droplets) is ever used to grow large raindrops, which ultimately fall to the ground as rainfall. This may be due to the fact that an insufficient number of ice particles exists within the cloud, thereby limiting the amount of cloud droplets that can coalesce to create raindrops. Or the clouds simply do not live long enough, on their own, to allow those tiny cloud droplets to collide enough times with neighboring droplets to yield larger drops–and eventually rainwater. Seeding is intended to introduce into the cloud many more of these ice crystals (also called cloud nuclei) to allow much more of the moisture supply within the cloud to be converted into rainwater.

If done in a timely way and properly, cloud seeding can assist the natural process in clouds by giving them enough "seeds" to make a meaningful number of large raindrops. If a lot of the growing convective cloud has pushed upwards above the freeze level, the bulk of the cloud water above that freeze level becomes supercooled (which is to say, the cloud droplets remain in liquid form and do not turn into ice). But those supercooled cloud droplets readily attach to an ice crystal (natural or artificial), converting the ice crystal into a tiny snowflake or graupel, which can quickly grow into a raindrop before the cloud begins to collapse.

Silver iodide is a favored seeding agent because its crystalline structure is nearly identical to the natural ice crystal. When placed in the upper portion of the growing convective cloud rich with supercooled droplets, the silver iodide crystal can grow rapidly by tapping that vast field of available moisture. Indeed, because the vapor pressure gradient over ice is less than that over water, an ice crystal such as silver iodide will more readily attract the tiny cloud droplets than those droplets will collide with each other. In a matter of moments, the ice crystal is transformed into a large raindrop which is heavy enough to fall through the cloud mass as a rain shaft.

The silver iodide particles (nuclei) are sometimes released from below cloud base, using the strong updraft of the cloud to transport the "seeds" high into the core of the cloud where supercooled cloud droplets are plentiful. Pyrotechnics, or flares, consisting of silver iodide burn while mounted on the wings of an aircraft that maneuvers within the updraft field below the bottom of the cloud. At times the seeding material can be dispensed below cloud base from an aircraft that is equipped with wing-tipped generators that contain a solution of acetone mixed with seeding material. The seeding of clouds may also be achieved from above cloud top, using an aircraft equipped with a rack containing ejectable pyrotechnics. These droppable flares are ignited as they fall from the plane's belly into the upper region of seedable convective clouds. Either way, from above cloud top or below cloud base, seeding with silver iodide is designed to give an ample number of "seeds" with which to grow rainwater: one gram of silver iodide can supply as many as ten trillion (10,000,000,000,000) artificial ice crystals!

Some convective clouds, especially in drought periods, never cultivate much "supercooled" cloud droplets, so seeding with silver iodide may be counterproductive. The clouds still have an immense amount of water in them, but most, if not all of it remains as very tiny droplets well below the freeze level. In these instances, a hygroscopic material (like common salt) may work better than silver iodide to seed such clouds effectively..

2. Where is cloud seeding being done in Texas?

One of the Nation's most enduring weather-modification projects is located in West Texas between the Permian Basin and the South Plains, at the headwaters of the Colorado River of Texas. The rain-enhancement project of the Colorado River Municipal Water District (CRMWD) was begun in 1971 to generate additional rainwater, and hence runoff, into the two reservoirs (Lake Thomas and E. V. Spence Reservoir) on the Colorado. The District employs its own team of experts and uses its own weather radar and specially-equipped aircraft to conduct seeding operations each year from April to October. With its base of operation in Big Spring, the District's seeding program covers some 2.6 million acres (or about 4,000 square miles) between Lubbock and Midland. As with all organizations that conduct cloud-seeding activities, or contract with firms for cloud-seeding services, the CRMWD holds a weather-modification license and permit from the Texas Department of Licensing and Regulation (TDLR).

Eight other cloud-seeding projects operate elsewhere in West and South Texas during the warmer half of the year. A number of counties between Midland and San Angelo led the way in forming a weather modification association in 1995 to sponsor cloud seeding in a 6.4 million acre area of the Edwards Plateau. The counties' water-conservation districts served as a convenient way to finance the cost of a cloud-seeding operation through ad valorem taxes. The association formed by these districts, the West Texas Weather Modification Association (WTWMA), decides when and how rain enhancement operations are done through a governing board with representation from each of the seven counties participating in the project, as well as from the City of San Angelo. For a program lasting some 5-6 months, the cost of cloud seeding (now approximately 4 to 5 cents per acre) was assessed uniformly over the entire target, using acreage in each county as the basis for cost assessment. Initially, the WTWMA contracted for cloud-seeding services, but it eventually invested in its own aircraft, radar facilities, and personnel. The WTWMA has been conducting its own weather modification program since 1996.

The WTWMA served as a prototype for the formation of other, similar groups sponsoring weather-modification operations in other parts of West and South Texas. Several counties south of San Antonio formed the South Texas Weather Modification Association in 1996, and that organization has been seeding clouds ever since in what is now a 6.6 million-acre area from San Antonio to Beeville. Another weather modification sponsor materialized in 1998 when three counties along the Rio Grande formed the Texas Border Weather Modification Association. That organization has been seeding clouds since the summer of 1998 from a base of operation in Del Rio. Still, another group of counties farther south formed the Southwest Texas Rain-Enhancement Association in 1999, seeding in a 5-county area using aircraft based in Laredo and Cotulla. The same year, the Edwards Aquifer Authority designed a cloud-seeding program for the watershed of the invaluable Edwards Aquifer and hired a contractor from Fargo ND to conduct cloud-seeding activities over a 6 million acre region of the Texas Hill Country. That program was redesigned in 2002, with four of the counties in the original EAA target being seeded for the EAA today by the two rain-enhancement projects to the south of the Balcones Escarpment (Southwest Texas Rain-Enhancement Association and the South Texas Weather Modification Association).

Two rain-enhancement projects were established in the spring of 2000 in the northern High Plains of Texas. These projects, which cover a combined 8.2 million acres, are sponsored by large water districts, the North Plains Groundwater Conservation District (NPGWCD) and the Panhandle Groundwater Conservation District (PGWCD), with seeding aircraft launched from airports in Dumas and Pampa.

One project, the Seeding Operations and Atmospheric Research (SOAR) Program, is a spinoff from what was the largest rain-enhancement project in Texas during the latter half of the 1990s. The High Plains Underground Water Conservation District (HPUWCD), based in Lubbock, seeded within a 17-county area of the South Plains of Texas from 1997-2002. Before that program was ended in August 2002, two of the counties (Terry and Yoakum) formed the SOAR program and picked up, in addition to Gaines County, an additional 2 million acres in eastern New Mexico. The SOAR Project, which today covers 5.8 million acres, is the only weather-modification program that embraces territory in both Texas and a neighboring state.

The state's newest program is that of the Trans Pecos Weather Modification Association (TPWMA), which began seeding for the first time in the spring of 2003 in a 4-county area along and west of the Pecos River. The TPWMA procured its own equipment, including two aircraft and a radar, and hired its own personnel to run its operation, which covers 5.1 million acres in the region between El Paso and Midland.

3. How successful is cloud seeding?

Over 50 years of research and actual cloud seeding in more than 40 countries have demonstrated that properly-designed programs operated by competent persons can increase seasonal rainfall appreciably and beneficially. The American Meteorological Society (AMS) and the World Meteorological Organization (WMO) have issued policy statements on weather modification that attest to the efficacy of existing technology to enhance precipitation.

It is likely that cloud seeding is more effective in non-drought periods. This is because seeding is predicated upon the availability of clouds—especially the right kinds of convective clouds. It is presumed that, during severe to extreme droughts, the number of days with treatable convective clouds is reduced. Still, there is ample evidence suggesting that, even when drought is harsh, there are opportunities to seed clouds.

Consequently, those using weather-modification technology are urged to view cloud seeding as a viable, long-term water management strategy for augmenting fresh-water supplies, not as a short-term, quick "fix" to the drought problem. Those doing cloud seeding are urged to commit to its use over a period of at least several years, not merely for a few months. If cloud seeding is done in the midst of a bad drought and results are not satisfactory, the inclination after a few months is often to deduce that cloud seeding, because it does not appear to have delivered the desired results, should be discarded. It cannot be overstated that drought is not the optimal time period for cloud seeding.

Using Federal funds to assess the long-running rain-enhancement program of the CRMWD in the Big Spring area during 1987-1990, the TNRCC performed a series of cloud-seeding "experiments" which produced evidence that timely seeding, with silver iodide, enables convective clouds to live longer, process more cloud water, and produce significantly more rainfall (from 50 to 100 percent from individual cells). Moreover, an ongoing statistical evaluation of the CRMWD's 29-year cloud seeding program has revealed that rainfall, averaged over the growing season in the area where seeding has been concentrated, has been increased, during the years of seeding, by an average of 20-30 percent. A similar study of rainfall data from a 5-year cloud-seeding program conducted for the City of San Angelo (1985-1989) found that rainfall during the months of seeding in the area where seeding was focused had been increased 25 to 42 percent.

Since 2001 the Texas Department of Agriculture, and more recently the Texas Department of Licensing and Regulation, have conducted independent evaluations of ongoing cloud seeding activities in Texas. A statistical analysis of seeded clouds in Texas during 2005 (a total of 494) estimated that an additional 129,272 acre-feet of water was generated by the seeding of single-cell thunderstorms. By including more complex, multi-cell storms in the study, the analysis estimated as much as 2.3 million acre feet was produced above and beyond what those clouds would have furnished had they not been seeded. Comparing the seeded single-cell storms with neighborhood untreated clouds (designated as “control clouds” for the sake of analysis) revealed that seeded storms lived 57 percent longer, covered 29 percent more area, and yielded a “precipitation mass” that was 88 percent greater than for cloud towers left unseeded. During 2005, a total of 4,383 pyrotechnics (flares) containing seeding material were dispersed at the nine project sites. It was estimated that the seeded activity provided eligible (“seedable”) thunderstorms with 75 ice nuclei per liter of air within the cloud mass.

There is no evidence that the seeding contributes to less rainfall anywhere else. What is more, there is no evidence that seeding causes clouds to grow substantially taller and produce unwanted effects (such as damaging winds, hail, and flash floods). To the contrary, the available evidence from over eight years of research in West Texas suggests cloud seeding, when done timely and accurately, contributes to more gentle, widespread, and longer-lasting rains.

4. What role does the State of Texas assume in weather modification?

The Texas Department of Licensing and Regulation (TDLR) is the State agency responsible for administering the Texas Weather Modification Act, enacted in 1967 by the Texas Legislature and now codified as Chapter 301 of the Texas Agriculture Code. The Act requires the agency to regulate the use of cloud seeding through a licensing and permitting procedure. Furthermore, the Act charges the TDLR with promoting the development, and demonstration, of cloud-seeding technology through research.

The TDLR recently assumed the role of sponsorship of weather modification operations from the Texas Department of Agriculture. Since 1997 the Texas Legislature has directed a State agency (initially, the Texas Natural Resource Conservation Commission (TNRCC), then in 2001 the Texas Department of Agriculture and, more recently, in 2003 the TDLR) to dispense funds to reimburse political subdivisions (such as water districts and county commissions) for costs incurred in conducting cloud seeding operations. State funds appropriated for the 2002-03 biennium have been virtually exhausted, and no new funds were made available for the biennium (2004-05) that ended on August 31, 2005.

The TDLR can provide technical assistance to individuals, and organizations, interested in devising, and implementing, weather modification programs. George Bomar is the TDLR staff meteorologist who administers the State’s regulatory program in weather modification. If assistance is desired, he can be contacted in Austin at 512/936-4313; **gbomar@license.state.tx.us**.

5. What impact does cloud seeding have on hail?

Though very little research on hail suppression has been done in Texas, we do know from sound research conducted in other parts of the U. S. that seeding for enhancing rainfall very likely lessens the amount, and size, of hailstones. This is because the additional ice crystals injected into a growing thundercloud compete with the hail seeds (or "embryos") for the available cloud moisture, thereby reducing the chance that many hailstones would grow large. With the ice crystals using more of the available cloud droplets to grow large raindrops, there would be less cloud moisture available to grow the embryos into damaging hailstones.

Seeding clouds to suppress hail, on the other hand, appears to increase the efficiency with which the clouds convert the cloud droplets into rainfall. To date, available evidence suggests seeding to suppress hail, if anything, increases, rather than decreases, rainfall from seeded thunderstorms. No appreciable, substantive evidence has been proffered to suggest that seeding clouds to suppress hail has the effect of breaking up the clouds to prevent them from raining as they would have done “naturally.”

6. Is there a large amount of silver iodide, or other material, in the rainfall that reaches the ground from seeded clouds?

Actually, the amounts of silver detected from rainwater samples collected in Texas have been quite small. The typical concentration of silver in rainwater, or snowfall, from a seeded cloud is less than 0.1 micrograms per liter (one part in 10 billion). That concentration is well below the acceptable concentration of 50 micrograms per liter as established by the U. S. Public Health Service. Many areas where cloud seeding is practiced have much higher concentrations of silver in the soil than are found in rainfall from seeded clouds. Moreover, the concentration of iodine in iodized salt used on food is far above the concentration found in rainwater from a seeded cloud. No significant environmental impacts have been observed around cloud-seeding operations, including those projects that have been existent for 30-40 years.

7. What about the "downwind effects" of seeding?

The notion that rainfall increases produced in one area by seeding must be offset by decreases somewhere else has never been substantiated. Rainfall data from a number of cloud-seeding project areas have been examined in detail for evidence of “extra-area” effects. In some cases, there is evidence that cloud seeding in one area has actually increased rainfall at distances of up to 100 miles, or more, downwind from the area of intended effect. This has been documented with the long-running (30-year) rain-enhancement program of the Colorado River Municipal Water District.

8. What does one do to get a cloud-seeding program underway?

The area within which cloud seeding would be performed must be identified at the outset of any effort to build a rain-enhancement program. A next step would be to identify the source, or sources, of funding to cover the expense of seeding. Once this is accomplished, the individual or organization sponsoring the effort needs to draw up a set of specifications, giving details on how the operation is to be conducted (e.g. what type of aircraft are to be used). The State of Texas, through the TDLR's meteorologist George Bomar (512/936-4313), can provide a generic set of specifications that can be adapted to a specific region and time. These "specs" are then provided potential contractors, whose responses in the form of bids can lead to further negotiations.

If a contractor is chosen, it may be the contractor's responsibility to obtain a weather-modification license, and permit, from the TDLR. On the other hand, the sponsoring group(s) may opt to apply for the license and permit. Increasingly, with the help of existing projects and State assistance, some sponsors are choosing to establish their own cloud-seeding infrastructure (in lieu of choosing a contractor), procuring their own seeding aircraft and radar and hiring their own personnel to run the operation. In those instances, the sponsor(s) would become the applicant for a license and permit.

Weather modification law in Texas requires the applicant for a permit to publish a "Notice of Intention to Conduct Weather-Modification Operations" in area newspapers for three consecutive weeks. This Notice apprizes the public of its right to request a public hearing on the proposed cloud-seeding project. In the absence of a call for a hearing, a permit application can be processed by the TDLR within 30-60 days.

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