Frequently Asked Questions About Cloud Seeding

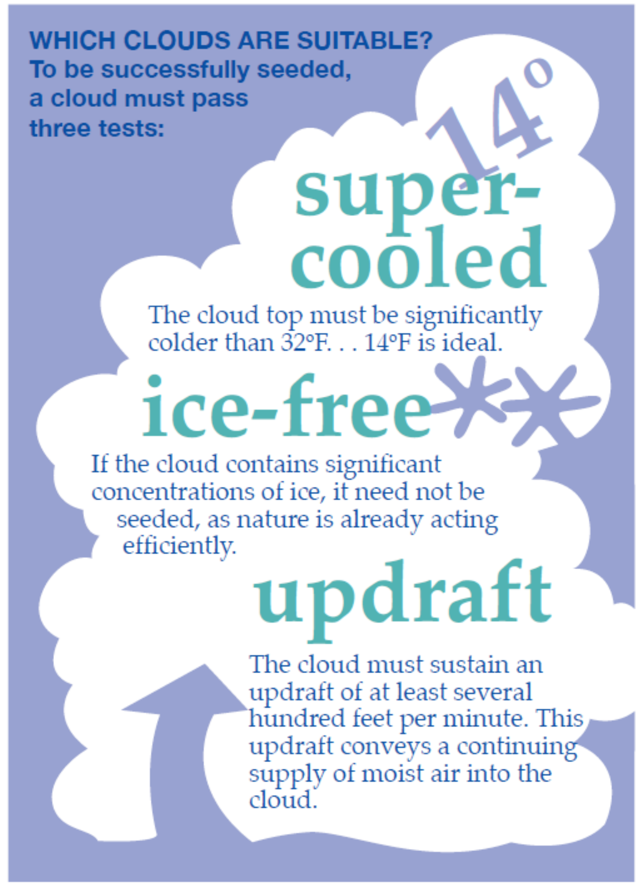
Cloud seeding, often called weather modification, is a scientific process intended to enhance rain and snow, reduce hail damage, and alleviate fog. Current technology dates back to 1946, when scientists working at the General Electric Research Laboratory discovered that silver iodide and dry ice could be used to enhance ice crystal formation in clouds. While silver iodide and dry ice are still used today, research and development efforts over the last 60 years have led to vastly improved understanding of precipitation processes, and greatly enhanced seeding methods.

This brochure addresses the most common questions about the technology and provides the interested reader with references for additional information.

Cloud Processes and Seeding Methods

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. Are all clouds good candidates for seeding?

No. For summertime cloud seeding, only clouds that possess a sustained updraft of moist air, a lack of natural ice, and grow to heights cold enough to contain supercooled liquid water are suitable for cloud seeding.

3. What are clouds seeded with?

Clouds are seeded with silver iodide complexes, artificial ice nuclei that provide a crystalline structure on which supercooled liquid water (SLW) droplets can attach.

4. How long after seeding before a treated cloud starts to change?

Seeding effects can range from almost immediate to up to 30 minutes depending on the seeding delivery method (***direct injection*** at cloud top, or ***base seeding*** - releasing seeding agent in the updraft below the cloud base). Direct injection is more immediate, but involves flying in-cloud and working at higher altitudes, requiring aircraft with higher performance (and costlier) capabilities. Updraft treatment at cloud base is easier to accomplish, but requires the seeding agent be transported by the cloud's updraft to where it can become effective, thus taking a little longer. As both methods offer advantages in certain situations, both options will be available to be used.

5. What has research shown us about clouds and precipitation?

A number of scientific research experiments have been conducted, many in Texas counties, from which we have learned much about the basic processes of cloud and precipitation formation and development in our type of climate. Much of what has been learned has been applied to cloud seeding technology, thereby making cloud seeding more effective now than ever before.

6. Who decides when clouds are seeded?

The radar meteorologist is the director of operations for cloud seeding missions. A number of factors play a part in the decision-making process, including safety criteria, radar information, pilot observations, and aircraft instrument data.

7. If a cloud is seeded, does it rain somewhere other than where it would have rained naturally?

Evidence indicates that seeded storms often rain over larger areas than unseeded storms. This means some areas that would not have received rain often do as a result of seeding. By seeding developing clouds before they start to produce precipitation, the precipitation process is accelerated and rain falls sooner, and from smaller clouds than it would naturally. Some redistribution of rainfall can occur within the scope of the storm itself, with computer models suggesting that regions of very intense precipitation may be slightly reduced while the total storm rain volume is increased.

8. How is seeding agent delivered to suitable clouds?

In this operations all seeding will be done by aircraft. Base-seeding aircraft release seeding agent into updrafts from below the developing storm using a combination of ejectable flares dropped from a flare rack mounted on the underside of the aircraft fuselage, or from burn-in-place flares mounted in flare racks on the aircraft wings.

9. Isn't flying aircraft around thunderstorms dangerous?

Flying around thunderstorms can be dangerous if pilots are not properly trained. For this reason, all pilots that fly seeding aircraft are trained through classroom education, intern experience, and/or field experience with a qualified weather modification pilot instructor. With these requirements in place the flight safety record has been excellent.

10. If it gets too wet, who tells the cloud seeders to stop?

If a county or part of a county is too wet, cloud seeding can be suspended until drier conditions return. We will be able to control the cloud seeding operation locally.

11. Who seeds clouds and what kind of training is required?

The Texas Department of Licensing and Registration (TDLR) weather modification program issues licenses and permits for these projects, many of which have been in existence since 2000. The projects use specialized aircraft and sophisticated weather radar systems, operated by skilled meteorologists. In order to be licensed, the applicant must possess a baccalaureate or higher degree in meteorology and at least five months of relevant field experience acceptable to the Department in weather modification; possess a baccalaureate or higher degree in physical science or engineering and at least ten months of relevant field experience acceptable to the Department in weather modification; or possess other training and relevant experience that the Department accepts as indicative of sufficient competence in the field of meteorology to engage in weather modification activities.

Climate and Environment

12. What effects do cloud seeding chemicals have on the environment?

The published scientific literature clearly shows ***no environmentally harmful effects*** from cloud seeding with silver iodide aerosols (WMA, 2009). The silver concentration in rainwater from a seeded storm is well below the acceptable environmental concentration of 50 micrograms per liter as set by the U.S. Public Health Service. Also, the concentration of iodine in iodized salt used for human consumption is far above the concentration found in rainwater from seeded clouds. Because silver iodide is such an effective ice nucleus, it is used in minute quantities. No significant environmental impacts have been observed around cloud-seeding operations, including those projects that have been existent for 30-40 years.

13. Does rain water from a seeded cloud taste or smell different than natural rain?

No. There is no discernible difference between rainwater from a seeded cloud and rainwater from a non-seeded cloud.

14. Can cloud seeding change weather patterns or affect the climate?

No. Cloud seeding changes individual clouds or groups of clouds. Changes to large-scale weather and climate patterns are determined by much greater forces such as global circulation patterns and ocean temperatures.

15. Can cloud seeding end droughts?

Though drought is sometimes the impetus for implementing a cloud seeding program, it is not generally advocated for such purposes. The reason for this is that droughts are caused by prolonged periods that do not produce clouds conducive to precipitation production. Therefore, cloud seeding opportunities during these periods are few, often providing limited results (See Question #2). A long-term and well-designed cloud seeding program can potentially soften the impact of drought, however, since increased precipitation before and after drought would temper the reduction of rainfall during the drought period.

16. Does cloud seeding affect precipitation downwind?

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.

Programs, Evaluations, Economic Benefits and Costs

17. Where is cloud seeding 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).

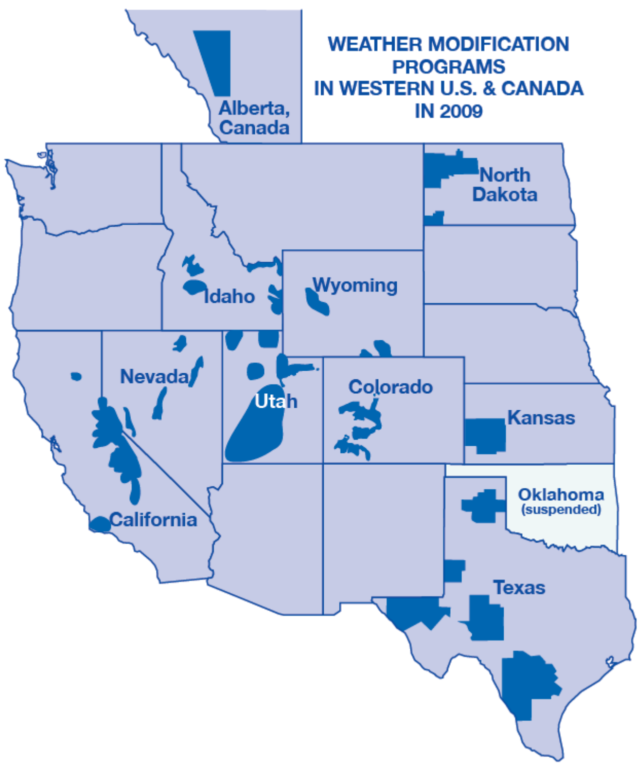
Two rain-enhancement projects were established in the spring of 2000 in the northern High Plains of Texas. These projects, which cover a combined 8.2 million acres, are sponsored by large water districts, the North Plains Groundwater Conservation District (NPGWCD) and the Panhandle Groundwater Conservation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

18. 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.

19. Who pays for cloud seeding?

The costs of cloud seeding are paid with funds from the participating cities and counties.

20. Who else is doing weather modification?

The latest data from the World Meteorological Organization compiled for 2009 listed more than 100 projects ongoing worldwide in more than 34 countries. The National Oceanic and Atmospheric Administration (NOAA) documented 45 projects conducted in ten U.S. states. Project objectives included fog dispersal, snowpack and rainfall enhancement and hail suppression.

REFERENCES

Weather Modification Association (WMA), 2009: Position statement on the environmental impact of using silver iodide as a cloud seeding agent. WMA website, www.weathermodification.org.

Wise, E.A., 2005: Precipitation Evaluation of the North Dakota Cloud Modification Project (NDCMP)., M.S. Thesis, Department of Atmospheric Sciences, University of North Dakota, Grand Forks, ND., 63 pp.