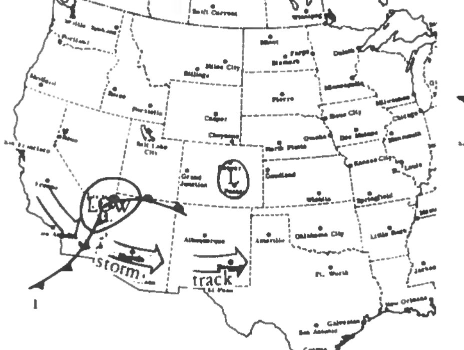
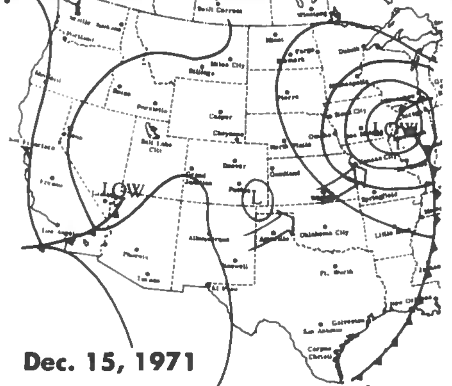


Dec. 13, 1971

Low pressure storm center moved from Nevada, New Mexico across Great Plains.

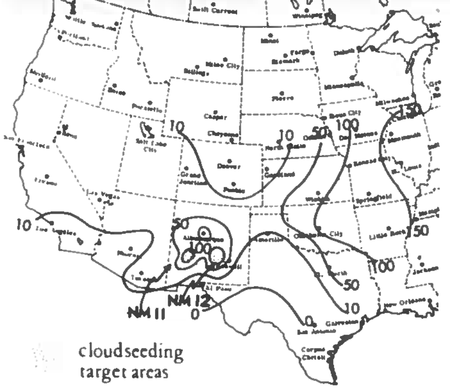
Dec. 14, 1971

Precipitation belt was seeded for two target areas in southern New Mexico.



Dec. 15, 1971

Storm passed eastward through Oklahoma, picking up more moisture from the Gulf.



Both cloud seeding target areas received 100% of monthly normal; other areas dry.

Pattern of Storm Movement Is Shown

A LOW PRESSURE storm center and its associated weather fronts moved eastward from southern Nevada across New Mexico and rapidly northeastward through the Great Plains area on December 13th to December 15th, 1971.

The precipitation belt associated with it was seeded for two target areas in Southern New Mexico on December 14th (NM-11 and NM-12). The rain and snow pattern is expressed as a percentage of the December monthly normal.

It will be noted that 100%, or the normal for the entire month, occurred on that one day in both target areas, falling off sharply in all directions. It was not until this storm passed eastward through Oklahoma, where it picked up additional moisture from the Gulf of Mexico, that it intensified and produced heavy rainfall again.

Seeding Does Not Deprive Other Areas of Moisture

By Dr. Irving P. Krick
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WHEN PEOPLE contemplate a cloudseeding program they often ask: "when you increase the precipitation in a project area, do you decrease it elsewhere?"

The answer is no, but some remain unconvinced. Therefore, an attempt will be made in this brief article to point out why this notion is invalid.

First, let's review the elementary principles of cloudseeding, as well as the mechanics of natural precipitation processes in the atmosphere.

In nature, clouds and rain develop only when natural particles of soil, dust, salt and other so-called nuclei are present in sufficient quantities to attract moisture from the water vapor ever-present in the atmosphere and form water droplets or ice crystals. A second prerequisite for development of precipitation is the presence of rising air currents.

In discussing the presence of condensation and ice nuclei, one must consider the variability of these precipitation producing particles. Dr. Vincent Schaefer, the co-discoverer of cloudseeding principles, has made many measurements of the concentrations of various nuclei. He reports that they can vary a million-fold from one airstream to another and, therefore, can vary in this manner from one day to the next during changing weather situations.

This fact is partially responsible for the difficulty experienced in forecasting amounts of rain during storm periods. No routine measurements of condensation and ice nuclei are presently under way. Thus, the forecaster must decide simply on the basis of the origin and physical character of the airstreams and their behavior in past situations, how much rain is apt to fall, or if indeed any precipitation is likely.

A further complication is the fact that in many airstreams, ice producing nuclei are not only deficient, but also are ineffective until air temperatures within clouds are 20° or more below freezing, namely in the 10° to 15°F. range. Yet, in the middle latitudes (where the United States is located) the bulk of the precipitation, rain and snow, develops in the high levels of the atmosphere where temperatures are below 10 to 15°F and ice nuclei trigger the precipitation process.

Therefore, if he can provide a controlled number of artificial ice nuclei which go to work at about 25°F during situations that favor precipitation, the cloud seeder will be able to exert a measure of control on the amounts of rain or snow that fall. The mere presence of sufficient numbers of artificial ice nuclei in storm situations leads to an increase in the fall-out of precipitation.

Nature seldom yields more than 5 to 7 percent of the moisture passing overhead as water reaching the ground. Therefore, even a small percentage increase in this value by cloudseeding, can frequently double the amounts of precipitation, because seeding is effective through thousands of feet of cloud thickness which natural ice nuclei, even in sufficient quantities, would leave untapped.

In regard to the second prerequisite for precipitation, namely rising air currents, there are several ways in which nature develops vertical currents. In the Southern Great Plains area everyone has observed the billowing cumulus clouds in summer which by afternoon may join together and develop a shower, indeed in some cases severe thunderstorms. This situation is produced by heating of the ground by the sun during the morning hours. This action develops rising air currents, forming the clouds which ultimately may precipitate some of their moisture.

Sometimes, however, the clouds do not reach sufficiently cold levels of the atmosphere for natural ice nuclei to trigger the precipitation process. In such cases, cloudseeding providing controlled application of ice nuclei is effective because sufficient numbers of artificial nuclei are provided and they trigger rainfall at much higher temperatures than nature, and therefore at lower altitudes within the clouds. In most cases, these situations will yield showers and thunderstorms which will persist into the evening and die out during the night, when there is no longer surface heating to add new sources of rising moisture laden air to moving storm systems.

The continual development of rising air currents to feed such showers is important in understanding why cloudseeding does not decrease precipitation outside of the areas treated. As storm systems move along in the prevailing high level wind systems and pass beyond the so-called target areas, they simply revert to "doing what comes naturally." In other words, they simply become responsive to natural nuclei.

More importantly, cloud systems are produced when air masses of different origin clash. For example, in the Southern Great Plains, warm, moist air from the Gulf of Mexico frequently is pushed aside by either heavier cold Polar air coming down out of Canada, or cool air moving across the United States from the Pacific Ocean.

In either case, the warm air is lifted, extensive cloud sheets are formed and precipitation develops. Storms of this type can move for hundreds and even thousands of miles under the impetus of the mechanical lifting of warm air by the intruding cold air systems. Any cloudseeding which is done during the passage of these so-called weather fronts across a contract area may yield additional precipitation over the treated area, but as the storm moves on, the natural precipitation mechanisms take over.

Another way of looking at this is that nature would be "robbing Peter to pay Paul" whenever it rained anywhere, if the mechanisms just outlined were inoperative, storms moving into the United States from the Pacific Ocean, for example, would rain themselves out in California, Oregon and Washington with nothing left for the remainder of the country. This does not occur. By viewing the TV weather shows each day, these principles will become apparent.

The general west to east movement of the great storm systems passing across the United States is usually pointed out by the weather forecasters. The continuous rain belts accompanying them are always present. The experienced cloud seeder obtains maximum results when working on these broad rain belts. This technique requires continuous operation aimed at the contract area, while the storm is passing through. Ground-based silver iodide generators whose dispersion plumes rendezvous continuously with the moving cloud sheets passing over the contract area have proved most effective for these major operations.

Actually, the cloudseeding process when operated on a large scale (of the order of tens of thousands of square miles) affects moving storm systems so that they do a more efficient job as they move on from the cloudseeding areas to regions downwind.

In properly controlled cloudseeding operations where predetermined numbers of artificial nuclei are injected into moving storm systems, some rather interesting effects on the character and distribution of precipitation can be achieved. During operations by our organization in many countries and over projects sometimes covering millions of square miles, we have observed the following:

(1) Rainfall patterns under cloudseeding tend to be more uniform. The high intensity bursts of rain which characterize natural precipitation over areas such as the Southern Great Plains are eliminated for the most part and rainfall amounts made more uniform. This reduces flooding and soil erosion, adds to the percolation of water into underground storage basins and is generally of a more beneficial character than natural rainfall under severe thunderstorm conditions.

(2) Severe weather phenomena such as hail and tornadoes can be reduced in intensity.

(3) The corollary to this more uniform pattern of precipitation which develops from cloudseeding is smaller sized water droplets. There is always a fixed amount of moisture available for producing precipitation. If one introduces large numbers of artificial condensation or ice nuclei into the system to augment natural nuclei, the competition for the available moisture continuously sustaining the clouds increases, and raindrop sizes become smaller. This gentle rain has a beneficial effect, particularly in agriculture.

(4) Widespread cloudseeding in areas of storm genesis, has been found to be very beneficial in augmenting and spreading out rainfall patterns as the storm develops and moves on. Very frequently this action becomes possible in the Southern Great Plains area as storms from the Pacific cross the Continental Divide and encounter new sources of moisture from the Gulf of Mexico. Water vapor in airstreams is the latent source

Continued on Reverse Side

Texas F-S Editor Charles Taylor poses a tough weather question for Dr. Krick.

Cloud Seeding

Continued from Opposite Side

of energy which generates and propels these great systems across the country.

Nuclei perform the function of transforming water vapor into raindrops, or snowflakes. This process releases great quantities of heat which in turn, energize the storm systems.

A simple illustration of this is the tropical hurricane which is maintained through the conversion of heat energy within the system as large amounts of water vapor are drawn up into it from the ocean surface in tropical latitudes. Condensation of this water vapor releases heat which is the source of energy that maintains a hurricane. Its course is determined by the high altitude wind systems.

If a hurricane reaches land areas, the tremendous sources of moisture available during its travel over water are cut off or greatly reduced. In addition, the increased friction in passing over the land helps cause such storms to die out. Occasionally, they may move into an area where cold air currents are coming down from Canada or crossing the country from the Pacific just as they arrive. In such cases, they will be regenerated by the vertical motion induced as the colder airstreams wedge under the tropical air currents carried along in the hurricane.

These mechanisms relating to the precipitation process and the way in which storms are generated and propagated must be understood by the cloudseeder in order to do his job effectively. It can be seen from the preceding discussion that cloudseeding on a large scale enhances precipitation not only in a target area but also downwind, because the seeded storm system may be enlarged and further energized as it moves along.

Therefore, we have recommended large scale programs in the old dust bowl region and states to the west to enhance storm development before systems reach the areas susceptible to drouth.

ALL OF THESE principles were known and recognized by the Water Resources Development Corp. during the early days of cloud seeding. Cloud seeding in one area does not prevent or reduce rainfall in another area. Many years of records demonstrate this.

For example, on Jan. 11, 1951, a storm moving into California was seeded in project Area CA-1. It produced on that one day, 50 percent of the normal rainfall for the entire month of January. As the storm continued to move eastward, steered by prevailing upper air winds, it was seeded again for project A-1 in Arizona on January 12. In this instance, 100 percent of the normal monthly rainfall was observed to occur, double the percentage increase produced in California.

The following day, as the storm moved across the Rocky Mountains to the Great Plains, it was operated for Project C-1 in Colorado. Here 150 percent of the normal January rainfall was achieved.

A current example is shown in the accompanying chart for a storm that developed Dec. 13, 1971 and which was seeded for two projects in New Mexico. Maximum values of rainfall were achieved in both projects. As the storm moved on to the northeast in the prevailing winds at high levels, substantial amounts of precipitation occurred in western Oklahoma without seeding.

In our view, this was a storm system which was regenerating east of the Rockies, and the cloud seeding operation assisted in augmenting energy releases as it passed over the New Mexico targets, adding to the size and rainfall production of this system as it moved along.

People contracting for cloudseeding are always interested in knowing how much additional rainfall one produces from the cloudseeding operations as related to the amounts nature would have produced. Therefore, evaluation procedures have been developed in order to identify these increases.

It has been the practice of the Water Resources Development Corp., and its associated companies over the past 20 years, to express rainfall figures for operational periods in terms of a percentage of the average rainfall during years before cloudseeding began. We relate the rainfall in the project area and surrounding regions by expressing observed rainfall everywhere as a percentage of the average for a 20 year period before cloudseeding began in the United States, namely 1930 through 1949. This average is therefore the "normal" or reference base data we use in evaluating all projects.

There is no such thing as an average or normal rainfall year; it is either wet or dry. However, even in the dry years, a deviation between the target and control areas is discernible, if the operation is successful.

To illustrate this, consider a control area which shows a value of 25 percent of normal during an operational program and a target area with 50 percent of normal. One would be observing a dry year, yet rainfall in the target would be double that in the adjacent control area.

In a wet year, a control area might show 125 percent of normal and the target area 200 percent or more. It is extremely important to understand this distinction between the seeded and unseeded areas in determining the efficiency of an operation. During periods of drouth people sometimes fail to perceive that cloudseeding may still be improving a situation, although not producing a wet year. For example, in 1951 which was a dry year in much of the Southwest, many people in cloudseeding project areas did not realize that it would have been even drier had there been no cloudseeding.

Should projects of an inter-state nature be instituted, farmers and ranchers can look forward to the end of drouth and an increased standard of living together with a stabilization of their economy. Even in the wetter years, cloudseeding by spreading out rainfall patterns and gentling the rainfall, can be extremely beneficial. I cannot think of a situation where a farmer would not welcome an occasional bumper crop.

Drouth Cost

The Office of Emergency Preparedness (OEP), Dallas, estimates $150 million in federal assistance was extended to farmers and ranchers in 377 counties of Oklahoma, Texas, New Mexico and Arizona during the drouth that prevailed in 1970 and 1971.

Principal items included:

Sale of feed grains at reduced prices	**$3.8 million**
Emergency conservation measures	$5.8 million
Freight cost-sharing on hay transport	$1.0 million
FHA Emergency loans	$29.7 million
FHA Operating loans	$52.1 million
FHA Ownership loans	$55 million
Weather modification experiments	$626,500
Small Business Administration loans	$1.8 million

Editorial Comment

What Would You Give for an Inch of Rain?

HOW MANY TIMES could you have made a good crop if you had received an additional inch of rainfall at a critical time, but harvested a short crop because the rain didn't come? All farmers have had this experience and know that timing is a key factor in utilization of rainfall.

Weather modification, such as the cloud seeding projects advocated by The Farmer-Stockman, involves efforts to provide this extra bit of rain when needed. The aim is to "normalize" the rainfall; not to create damaging downpours. The goal is to head off disastrous drouths by triggering precipitation from potentially productive storm clouds that may be available.

Just what is an extra inch of rainfall worth? That's a hard question to pin down, because there are so many variables in growing crops and pasture other than precipitation. Nevertheless, Merlin C. Williams, director of the South Dakota Weather control commission, has sent us a copy of a preliminary report that indicates a benefit to cost ratio as high as $20 for a dollar spent on weather modification. Mr. Williams calls the report preliminary because not all variables have been analyzed.

The estimate takes as a basis a full scale statewide weather modification program at an approximate cost of $1 million a year. Using average acres devoted to corn (2.5 million) and calculating that the extra inch of rainfall would add 4 bu. per acre to the harvest, the increased return would amount to more than $11 million on corn in South Dakota that year.

Similar estimates show gains of 1.9 bu. per acre on spring wheat to add $3.8 million, 1.7 bu. per acre for winter wheat for $1.3 million more income, 300 lb. per acre increase in alfalfa hay to add $6.2 million, plus $2.9 from wild hay, and $3.5 million more from range and pasture. Even cutting the estimates in half, it still leaves a benefit to cost ratio of $10 to $1, which is not a bad return on the investment in cloud seeding.

Statewide figures may not have a direct application on your farm, but you can figure out how many acres you have, and how many bushels or pounds more production another good rain next summer might yield.