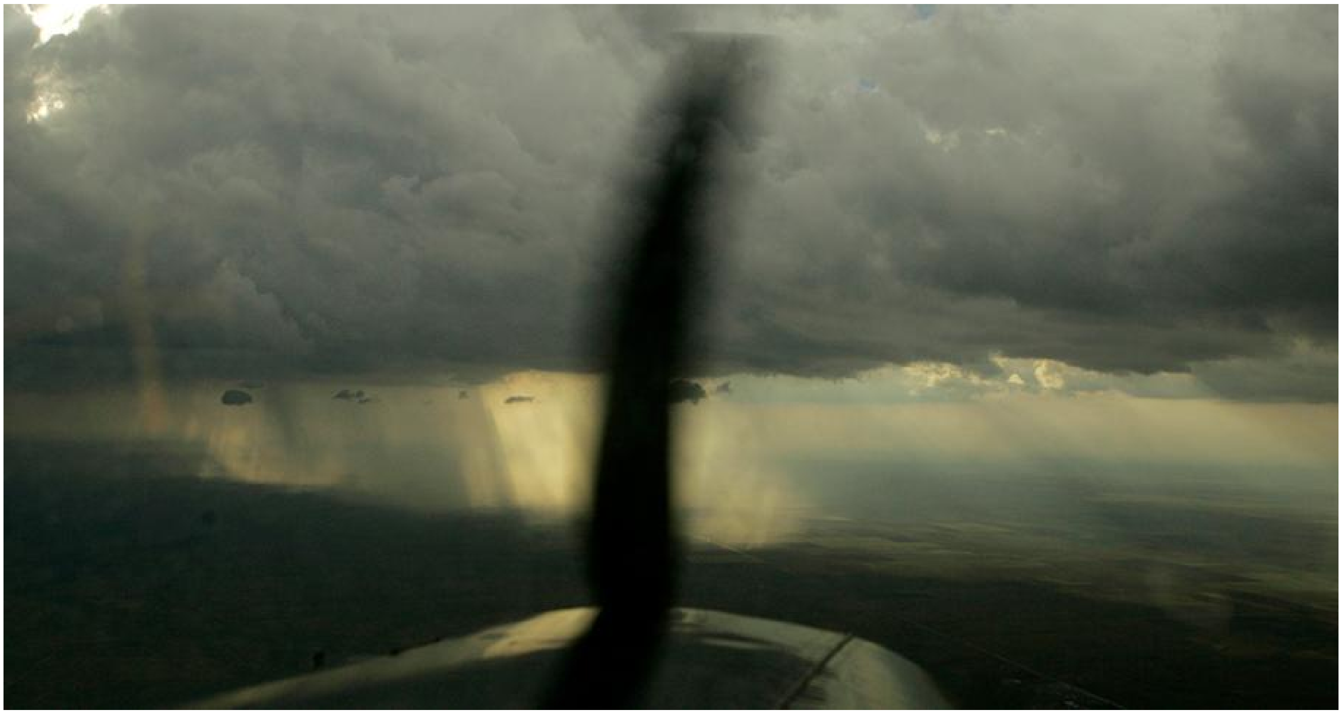
GEOENGINEERING

8 states are tweaking the weather (and it might not work)

Chelsea Harvey, E&E News reporter • Published: Tuesday, March 16, 2021



A pilot flies a single-engine plane into a line of thunderstorms during a cloud seeding mission over Kansas. Weather modification is used to fight drought related to climate change, but it's unclear if it wor
AP Photo/Charlie Riedel

Part one in a series.

The mountaintops rumble to life unnaturally each year as snow clouds darken the sky across the West.

Open flames burst from the throats of metal chimneys, mounted on squat towers nestled among the peaks. With a low hiss, puffs of particles belch from their mouths into the air, where the wind catches them and whisks them away.

These aren't ordinary particles. They're tiny bits of crushed-up silver iodide, a crystal-like photosensitive substance once used in photography.

But it's not used to take pictures out in the mountains. It's meant to make snow.

As the wind whips the particles across the mountaintops, drafts of air sweep them higher into the sky — so high that some of them eventually touch the clouds. There, an elegant transformation takes place.

The crystalline silver iodide particles have a structure similar to ice — and inside a cloud, like attracts like. Water droplets begin to cluster around the particles, freezing solid as they gather together.

These frozen clusters eventually grow too heavy to stay in the air. They fall from the cloud and drift gently toward the Earth, dusting the mountaintops with fresh snow.

This is not a page from a science fiction novel. "Cloud seeding" is a real practice — in fact, it's been around for decades. It's used today to boost precipitation in at least eight states across the western U.S. and dozens of countries around the world.

Interest in cloud seeding is growing as temperatures steadily rise, increasing drought risks in places like the Mountain West. But there's a catch. Scientists aren't sure how well cloud seeding works today, let alone in a warmer climate.

Amid growing concerns about water resources in the western U.S., scientists are working to answer those questions. Today, cloud seeding research represents the cutting edge of weather and climate science — a convergence of questions about the influence of warming on our dwindling water resources and our ability to control those consequences.

"Certainly we're in a better position now to address that question than we were 10 years ago," said Jeff French, an atmospheric scientist at the University of Wyoming. "The state of the science has progressed to the point that it is a question that we can and should be trying to address now."

Cloud seeding can take a few different forms. In some places, it's used to boost rainfall or prevent hailstorms. But in the U.S., it most commonly aims to enhance snowfall, and usually with silver iodide.

Extra snow can be a boon for water resources, especially in places like the drought-plagued West. Snowpack is a vital source of fresh water for millions of people across the country when it melts in the spring.

Boosting snowpack is being pursued with growing urgency. Much of the western U.S. has been gripped by drought for the last 20 years.

Scientists **recently concluded** that the past two decades represent the driest span in the region since at least the late 1500s. This "megadrought" has been heavily influenced by climate change, they found.

Rising temperatures and the ongoing drought have taken a major toll on Western water resources.

Recent studies find that large patches of the Mountain West have experienced major snowpack declines over the last few decades (***Climatewire***, Dec. 13, 2018). The snow season is also growing shorter as the climate warms and spring gets an early start.

Meanwhile, Western water managers are contending with the growing threat of shortages. Flow has dwindled on major water systems like the Rio Grande and the Colorado River, which each supply water to millions of people.

With temperatures steadily rising, cloud seeding poses one attractive solution.

"Water managers basically have two choices, and both of them are implemented," said French. "One is to somehow reduce the demand through conservation, and the other is to somehow increase the supply. And cloud seeding is a relatively inexpensive proposition."

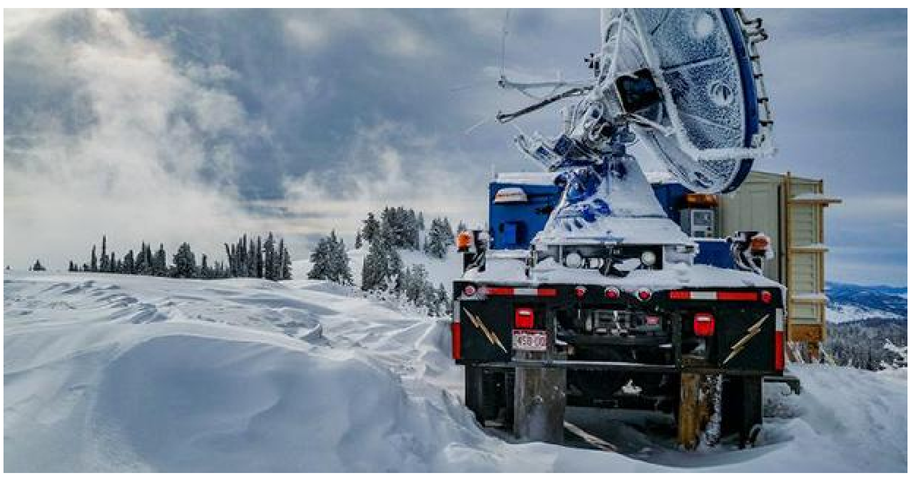
Proving that it works, though, is another matter.

Weather experiments are notoriously difficult to conduct. The scientific gold standard would be a study that proves cloud seeding produced an outcome that definitely would not have happened without it. But that kind of research requires a combination of specialized experimental design and highly advanced technology.

For most of cloud seeding's long history, it just wasn't possible. Only within the last few years has technology advanced enough for researchers to really dig into the problem.

"We now have much better tools to try to observe cloud seeding as it's happening," French said. "So it's sort of about taking this new technology that has been developed over the last 20 years, or improved upon over the last 20 years, and applying it to really a very old problem."

Decades of questions



A radar truck measures precipitation during a recent cloud seeding experiment in the western United States. Joshua Aikins

Humans have been experimenting with weather control for the better part of the last century.

Vincent Schaefer, a researcher with General Electric, is often credited with the first cloud seeding experiments in the 1940s. Much of Schaefer's work during and after World War II centered on preventing aircraft from icing over in midair. So he designed a special homemade freezer to help him better understand the way ice forms inside clouds.

As the story goes, Schaefer entered the lab one day to discover that his freezer had been turned off. Hoping to cool it as quickly as possible, he placed a block of dry ice inside the box. A cloud of glistening ice crystals instantly formed in the air.

In 1946, Schaefer conducted the first true cloud seeding experiment by aircraft. He dropped 6 pounds of crushed dry ice into a cloud in the Adirondack Mountains of New York. Almost immediately, snow began to fall.

In later experiments, Schaefer and other GE colleagues would discover that certain types of particles are more effective at helping ice crystals form. Silver iodide, they found, is one of the best.

Weather modification quickly captured the attention of the U.S. government. Over the next few decades, it would fund cloud seeding experiments on everything from drought management to military applications.

In 1947, Project Cirrus — a collaboration between GE and the U.S. military — made history as scientists' first attempt to modify a hurricane. On Oct. 13, the operation dumped nearly 200 pounds of dry ice into a cyclone that was churning off the coast of Florida.

In the 1960s and early 1970s, the federal government continued to experiment with the idea of cloud seeding hurricanes — but to little avail. Scientists eventually concluded that it wasn't effective.

Beginning in the early 1960s, the Bureau of Reclamation funded a series of cloud seeding experiments known as Project Skywater, aimed at boosting water resources in the Western states. Reports suggest the project had mixed results.

In the late 1960s and early 1970s, the U.S. military even experimented with weather modification as a weapon of war. Operation Popeye, as it was dubbed, aimed to generate enough rainfall to disrupt enemy supply routes in Vietnam.

These efforts were short-lived. In 1977, an international treaty banned the use of weather modification for military purposes.

There was a common thread among many of these early experiments: Either they weren't useful, they were quickly discontinued or scientists couldn't tell how well they were working.

"There was a ton of research done in the '60s and '70s and '80s," said French, the University of Wyoming scientist. "But all of that kind of came to a halt when I think there was a realization that agencies were spending millions upon millions of dollars year after year, and the results continued to sort of be inconclusive."

The problem, he said, is that weather modification studies are really difficult to design and carry out.

To prove that cloud seeding has a real effect, scientists have to demonstrate that whatever outcome it produces would not have happened without it. That requires setting up an experiment with at least two tests — one with cloud seeding and one without it — in the same location and under identical weather conditions.

Because the weather changes so quickly, that's really difficult to do. And even when it's possible, such studies require advanced monitoring technology, including high-tech radar. This kind of tech just wasn't widely available until recently.

That means cloud seeding research has mainly relied on statistical studies instead. These studies measure the precipitation produced with cloud seeding in one location, and then they compare it to a different location where no cloud seeding took place.

The two settings aren't identical in these kinds of studies. That means they don't definitively prove that the precipitation produced by cloud seeding in one area would not have happened without it.

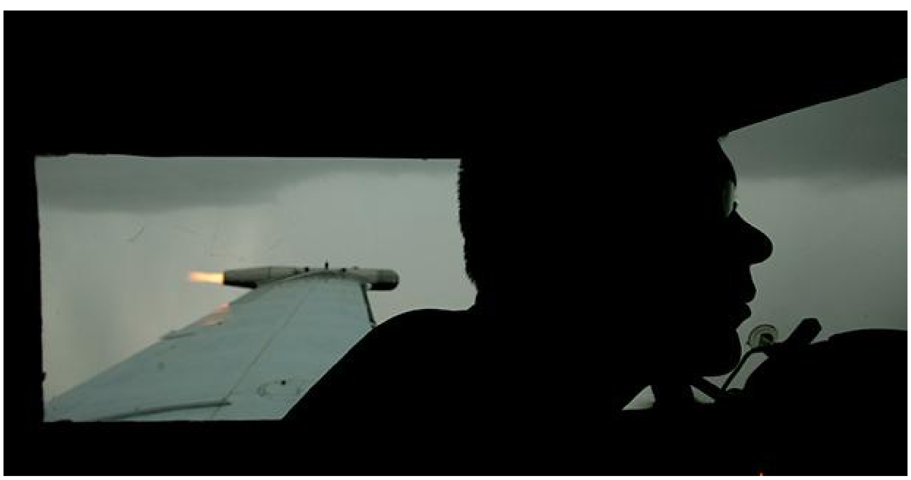
In 2003, the National Research Council published a comprehensive **report** on weather modification, highlighting these problems. It concluded that "there is still no convincing scientific proof of the efficacy of intentional weather modification efforts."

Still, NRC recommended continued research on weather modification — in no small part because of its potential to address the West's worsening water concerns.

That same hope has led state water agencies to keep funding cloud seeding operations, even after federal research efforts dropped off in the 1980s.

"I think there's a pretty easy explanation for why it continued," French said. "Cloud seeding is rooted in a pretty solid, well-understood physical basis of why it *should* work."

States embrace uncertainty



A wing-mounted generator emits particles in the clouds during a cloud seeding mission. AP Photo/Charlie Riedel

Today, cloud seeding operations take place in at least eight states across the western U.S., with varying levels of investment often shared among state agencies, utilities and private companies such as mountain resorts.

Cloud seeding programs in the upper Colorado River Basin, for instance, cost around $1.5 million each year. The costs are split among state agencies in Colorado, Utah and Wyoming, where the majority of the operations take place, as well as Nevada, California, New Mexico and Arizona, which also stand to benefit from increased flow on the Colorado River.

In the last few years, cloud seeding has featured more prominently in drought management strategies across the West. The cost-sharing agreement in the Colorado River Basin was finalized in 2018, after states had spent years individually managing their cloud seeding operations. The agreement extends through the fall of 2026.

Since 2018, Wyoming and Colorado have strengthened their programs by investing in aerial cloud seeding operations — that's seeding conducted by aircraft — in addition to the ground-based machines they already have scattered throughout the mountains.

These are relatively inexpensive investments, all things considered — a low risk for a potentially high reward. But is it actually making a difference?

Most programs point to statistical studies to justify their efforts. These studies indicate that seeded clouds can produce around 5% to 15% more snowfall compared with areas where no cloud seeding took place.

If that's right, it puts the cost of cloud seeding at around a few dollars per acre-foot of water (equivalent to about half an Olympic-size swimming pool). That's far less expensive than the cost of many other water-saving interventions, such as water conservation, recycling or desalination, which can cost hundreds of dollars per acre-foot.

Still, statistical studies don't prove that cloud seeding is actually causing the heavier snowfall. That requires a more specialized scientific experiment — and only within the last few years have scientists finally been able to make that happen.

As recently as 2015, an extensive **report** prepared for the Bureau of Reclamation concluded that continued research is still warranted, but it noted that "the 'proof' the scientific community has been seeking for many decades is still not in hand."

Cutting-edge research

On Jan. 19, 2017, a research plane roared through the gray skies above Idaho's Payette River Basin, spewing silver iodide into the air. Assembled on the snow-capped peaks below, snow gauges and portable radar machines were poised to measure the snow that scientists hoped would follow.

It was the beginning of an experiment that would turn cloud seeding science on its head. Known as the SNOWIE project — short for "Seeded and Natural Orographic Wintertime Clouds" — the study provided some of the first quantitative evidence that cloud seeding actually works.

For three days that January, weather conditions would align to set up the perfect cloud seeding experiment. The sky was cold and cloudy — but no snow was falling. Over the course of these three days, the research plane would make more than a dozen trips over the mountaintops, releasing the same amount of silver iodide each time.

"For three days there was cloud cover, but no snowfall, no natural precipitation," said Katja Friedrich, an atmospheric scientist at the University of Colorado, Boulder, who helped lead the SNOWIE project. "We put the seeding material into the supercooled liquid cloud, and we were able to generate precipitation. And that was very revolutionary."

Thanks to high-tech radar equipment, the scientists were able to monitor the response of the clouds from the moment the silver iodide was released into the air until the moment snow began to fall. Over the course of those three days, the scientists estimated that around 286 Olympic swimming pools' worth of snow fell from the clouds they seeded.

Friedrich and her colleagues, including scientists from Colorado, Wyoming, Illinois and Idaho, published their findings in a groundbreaking **paper** last year in *Proceedings of the National Academy of Sciences*.

SNOWIE came in the midst of a kind of a renaissance for cloud seeding research in the United States. After years of relatively little scientific interest in weather modification, a series of projects over the last decade have paved the way for new insights.

The Wyoming Weather Modification Pilot Project, launched in 2008, was among the first of these. Funded by the state of Wyoming, the project aimed to evaluate the success of cloud seeding efforts spanning three target areas in mountain ranges across the state.

"The results that came out on that — they were positive, but they weren't sort of 100% fully conclusive," said French.

But the project did highlight some major advancements in cloud seeding research over the last few decades, including improvements in radar and other observation tools, as well as major leaps in computer modeling.

With these new and improved technologies, the SNOWIE project catapulted cloud seeding research to the cutting edge of weather and climate science.

"The question is not anymore, 'Does cloud seeding work?'" said Sarah Tessendorf, an atmospheric scientist with the National Center for Atmospheric Research and another scientist who worked on the SNOWIE project. "The questions really are, 'How and when does it work? How effective is it under different conditions?'"

As droughts and warming squeeze water supplies in the American West, scientists are busy trying to answer those questions.

The SNOWIE project is still lending insight four years after it ended, Tessendorf said. Thanks to recent advancements in computer models, scientists can now simulate the effects of silver iodide on clouds — and they can use these simulations to conduct controlled experiments, exactly the kinds of studies that cloud seeding research has been missing.

At the same time, the data collected by the SNOWIE project is helping scientists validate their models and make sure their simulations are realistic.

"I really feel like today, in this day and age, we are at a pretty exciting stage with the science behind cloud seeding, being that we've been able to collect some really great data over the last few years," Tessendorf said. "And with the computer capabilities, there's really a lot of promise to make advancements in this field."

But experts also advise keeping expectations in check. The science so far suggests that cloud seeding is far from a silver bullet when it comes to dealing with drought.

For one thing, the SNOWIE experiments generated a fairly modest amount of snowfall.

"As we've shown in the paper, we cannot really generate an awful lot of snow," Friedrich said. "We can generate snow, but not that we can really overcome a drought situation."

Moreover, the SNOWIE project took place across a single, small slice of Idaho over the course of just three days.

With the momentum from the SNOWIE project still strong, scientists are hopeful they'll be able to answer many of the biggest questions still remaining about how well cloud seeding works. But it may take time and much more research.

"The bigger question is does it 'work' — and I put 'work' in quotes — on the scale of an entire season over an entire mountain range?" said French, the University of Wyoming scientist, who also contributed to the SNOWIE project.

"Can we really make an impactful difference? And in my mind we're still quite a ways away from answering that question."

Next: *How seed clouding is being used to fight climate change.*

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