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Extreme events, such as Texas flooding in July, often stir up long-running conspiracies of modification, military involvement.

In early July, a storm dumped as much as 20 inches of rain in parts of central Texas, the equivalent of months' worth of rain. It swelled the Guadalupe River with such devastating force that at least 130 people died in the flooding, including dozens of children. Amid the grief and confusion, blame emerged in an unexpected place. A small cloud-seeding flight conducted by a startup named Rainmaker two days prior became the target of unfounded accusations. Elected officials and online influencers questioned whether the operation triggered or worsened the deluge.

The flight, more than 100 miles away and lasting about 20 minutes, released 70 grams of silver iodide into a set of clouds and prompted a drizzle that produced less than half a centimeter of rain on farmlands struggling with drought. Scientists said the distance made it scientifically impossible for the small seeding event to have played a role in the flooding. Even if it had, it would have been an insignificant amount of rain.

"The air that was over that area when the cloud seeding occurred was about 1,000 miles away by the time the big storm happened," said Robert Rauber, a professor of atmospheric sciences at the University of Illinois Urbana-Champaign. "We cannot control storms like that, and we cannot make big storms. It's just not possible."

Extreme weather events like that in Texas often stir up long-running conspiracies about weather modification and even U.S. military involvement. And this time, it tapped into a growing wave of political and cultural anxiety around weather modification. In recent years, lawmakers in several states have introduced bills seeking to ban or restrict cloud seeding, often citing conspiracy theories about aircraft "chemtrails" or fears of government weather control.

Tennessee lawmakers banned the release of airborne chemicals in 2024. Florida is advancing a bill to ban geoengineering and weather modification in the state.

After two severe hurricanes hit Florida in 2024, Rep. Marjorie Taylor Greene, R-Georgia, suggested the federal government is controlling the weather. In July, she introduced legislation to ban weather modification and geoengineering in response to the Texas floods. The bill would ban the release of chemicals into the atmosphere to alter the weather, temperature or climate, or to block sunlight.

Some people even took vigilante action. In the days following the Texas floods, Veterans on Patrol, an anti-government extremist group, took credit for sabotaging a weather radar system in Oklahoma. Its leader

claimed that the radar was a weapon used for weather warfare and that the U.S. military intentionally caused the flooding. It was part of a larger project called Operation Leaning Tower, as the group had targeted other radar towers for months.

Following the surge of weather conspiracy theories and the incident in Oklahoma, the Environmental Protection Agency launched two websites on July 10 that addressed concerns the government was manipulating the weather and debunked conspiracies about cloud seeding, contrail emissions from planes and geoengineering— techniques that alter the atmosphere to offset the warming climate.

As wild theories spread faster than facts, global warming worsens and regions like the Southwest struggle with prolonged drought, scientists believe understanding cloud seeding and clouds' interactions with the planet has never been more important.

Cloud seeding requires clouds

Cloud seeding is a form of weather modification. All particles in clouds, whether water droplets or ice crystals, form on a foreign particle that is not water, like dust, salt or pollen. These particles are also known as aerosols.

In cloud seeding, scientists try to add more of these particles so water molecules are more likely to encounter them. The process entails releasing particles like silver iodide or natural salts into clouds. They act as nuclei to attract moisture, helping water droplets and ice crystals form and grow large enough to fall as rain or snow, depending on the temperature, increasing precipitation.

The natural salts used in cloud seeding are the equivalent of adding table salt to the atmosphere, and scientists have found no effects from silver iodide on humans or the environment.

"People have been worried about silver iodide in the past, but the amounts are so small it's insignificant," said Eric Betterton, a professor emeritus in atmospheric sciences at the University of Arizona. "It's really hard to even find the silver after it rains. So there are no known effects of the seeding agents on the environment."

But the technique has limits. It doesn't create storms or control the climate. Cloud seeding simply speeds up clouds' natural processes that cause rain and snow to fall.

"It's important to understand that cloud seeding is dependent on the existence of clouds," Betterton said. "Weather modification cannot create clouds. It cannot create storms."

Rauber believes cloud seeding can result in about a 5% increase in a cloud's precipitation.

"The amount of water we make is not like doubling the snowpack," he said. "We're talking about a small percent change in the snowpack, at most a couple percent. But from the point of view of water resources in the western United States, that's not insignificant."

Cloud seeding is typically conducted during the winter to enhance snowpack that melts and runs off in to rivers and reservoirs. Scientists can count on storm clouds to form in mountainous areas like northern Arizona's Mogollon Rim during the winter, making cloud seeding experiments and operations easier to conduct.

Some summer time seeding occurs in clouds that would not normally precipitate. Larger storms that will likely rain on their own are not targeted for cloud seeding, as they are already efficient.

Conspiracies, chemtrails and sabotage

In the 1990s, Betterton was researching cloud seeding along the Mogollon Rim. He knew his team owed the public transparency on experiments occurring in their area, so he conducted community outreach meetings ahead of their cloud seeding flights to explain their plans.

Attendees expressed their concerns. Many were worried about stripping precipitation out of a cloud and robbing people downstream of rain. Others wondered about the impacts of silver iodide on the ground below.

Betterton and his team explained that cloud seeding benefits all and that concentrations of silver iodide following a seeding were so low they were nearly undetectable.

"The concerns were legitimate and reasonable, and the community was well within their right to ask," Betterton said.

"But it's harder to deal with fears and misinformation now," he said. "Today we deal with social media. People follow their prejudices, no matter what one says or demonstrates. I think the best thing to do is to be patient, forthright, and keep on the message of the truth, hoping some people will eventually realize they were wrong."

Another weather modification conspiracy theory that has gained traction in recent years stems from the condensation trails, or contrails, that commercial jets emit.



A Lone Contrail Crosses the Sky

Some people believe contrails are actually chemical trails – “chemtrails” emitting chemicals for nefarious purposes like population control, mind control or attempts to geo-engineer or modify the weather.

“Chemtrails are a product of a conspiracy theory that the government is placing chemicals in to aircraft fuel that produce plumes designed to control society,” Rauber said.

In fact, he said, jet exhaust primarily contains water vapor and carbon dioxide, similar to chemicals that come out of a car’s exhaust pipe. Then the engine heated water vapor hits frigid atmospheric air. If the atmosphere is humid, ice particles emitted can survive for some time before evaporating, leading to a long, white cloud behind the aircraft. If the atmosphere is dry, they tend to evaporate quickly.

“If someone is worried about ‘chemtrails,’ they should stop driving their cars, which are spewing the same exhaust right at the level we breathe instead of at 30,000 feet,” Rauber said.

As for the federal government's role, it has taken part in weather modification projects in the past.

In 1947, the military partnered with GE Labs to conduct the first hurricane cloud seeding experiment with dry ice; the results were inconclusive. In the Vietnam War's Operation Popeye, the military launched a classified weather modification program in an attempt to extend the monsoon season to interrupt supply routes.

Project Stormfury was conducted by the National Oceanic and Atmospheric Administration to cloud-seed hurricanes to modify storms' strength and wind speed. They ran experiments on four hurricanes between 1961 and 1971 before concluding that any observed changes were within storms' natural variability. The EPA's finding: No existing technology can modify hurricanes.

While the federal government is not currently participating in weather modification, it supports cloud seeding efforts at the state level to offset drought and research efforts to understand cloud seeding and cloud physics.

As of July 2024, nine states were actively pursuing cloud seeding programs: California, Colorado, Idaho, Nevada, New Mexico, North Dakota, Texas, Utah and Wyoming. Arizona and Montana were researching cloud seeding's possibilities but not seeding at that time.

Any entities working in weather modification must report all activities to NOAA under the Weather Modification Reporting Act.

In the West, water is everything

Cloud seeding can't summon rain out of nowhere. But in the water-stressed West, researchers believe even a light boost in snow or rainfall can help refill rivers and reservoirs that millions of people depend on.

The goal of cloud seeding is basically to enhance the snowpack over a winter season," Rauber said. "Snowpack is really a reservoir. That water, when we have a dry period without clouds, can be used to extend the water resources."

This goal is more urgent than ever. The Southwest is experiencing one of its worst droughts on record, with drier than-normal conditions since 1994. Climate change is amplifying the drought's impacts and making the region's water future more uncertain. Snowpack has thinned, rivers like the Colorado are stretched and some communities are eyeing every possible way to enhance water supplies, no matter how small.

Rauber said there are three main ways to extend water supplies beyond normal precipitation and runoff: cloud seeding, desalination (turning seawater into fresh water) and ground water pumping.

Desalination plants can provide steady supplies of freshwater, but they are expensive to build and run.

Groundwater pumping is another option to draw water up from underground aquifers to meet demand. But in much of the Southwest, those aquifers are being tapped faster than they can naturally refill. Some wells are already going dry, and experts warn this strategy won't be sustainable long-term.

That leaves cloud seeding as a lower cost, albeit less productive, option, but one that's more vulnerable to political backlash and public misunderstanding.

"Cloud seeding, desalination and underground reservoirs, those are our choices," Rauber said. "With cloud seeding, we're just trying to make a small amount of precipitation to enhance water resources. In the western United States, banning it just means we have one less tool in our toolbox."

Prolonged drought and climate change will only make these tools more necessary, according to Rauber.

“Everyone needs to take a deep breath and say, ‘What technologies can we use to help us through the future water crisis?’ because it is coming,” he continued. “There’s going to be less snow in the mountains over time. It’s going to be drier than before.”

Efforts like Rainmaker’s 20-minute flight in south Texas are usually part of local programs funded by water districts or utilities. The mission was meant to help parched farmland. It did not fuel a disaster more than 100 miles away.

But that hasn’t stopped fear and political action from growing. And the legislation to ban or restrict weather modification could setback research at a critical time.

As global warming worsens, scientists believe understanding cloud behavior is essential. But even basic questions, like how long a cloud lives or what makes it rain, can be surprisingly complex. Scientists are still trying to understand how clouds behave and how tiny aerosol particles impact their ability to reflect sunlight and produce rain.

Knowing how clouds interact with a warming and increasingly polluted atmosphere is why scientists want to continue studying cloud seeding, not ban it. In a hotter, drier world, they say, every drop of water and every data point could matter.

Scientists have much to learn about clouds, but they know the limitations of cloud seeding. You can’t engineer a flood.

Submitted by LCDR Dennis Ruth, USN (Ret.)