

Why GAO did this study

According to the Fifth National Climate Assessment, demand for water is increasing and the frequency and intensity of drought are projected to worsen in the western U.S. The ability to increase precipitation through cloud seeding could help mitigate some of the water management challenges caused by drought. Cloud seeding has been practiced in the U.S. since the 1940s. Recently however, advances in radar and sensor technology have enabled research with enough precision to show that cloud seeding may be effective under certain conditions.

This report discusses (1) the emerging and current technologies for cloud seeding (and weather modification generally), (2) the potential benefits of cloud seeding, (3) challenges surrounding the use and development of cloud seeding, and (4) policy options that may help address challenges or enhance benefits of cloud seeding.

GAO reviewed cloud seeding technology across development and operational stages; interviewed a range of stakeholder groups, including government, industry, academia, and professional organizations; convened an expert meeting that included academics, state and federal agency officials, and representatives from industry organizations. We also reviewed key reports and scientific literature. GAO is identifying policy options in this report (see next page).

View [GAO-25-107328](#). For more information, contact Karen L. Howard, PhD, at (202) 512-6888 or HowardK@gao.gov.

Cloud Seeding Technology

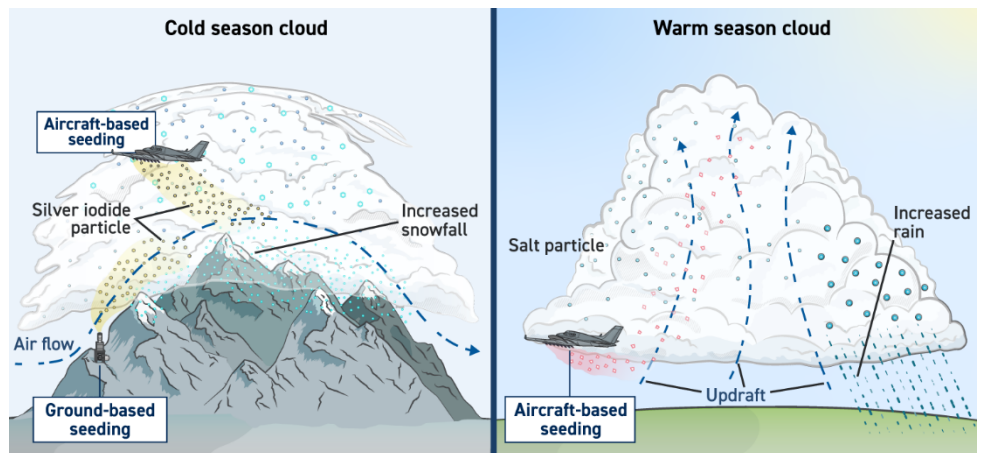
Assessing Effectiveness and Other Challenges

What GAO found

Cloud seeding is a decades-old approach to modifying weather that uses a range of supporting technologies for research and operations. According to NOAA, the most common uses of cloud seeding are to increase precipitation or suppress hail, usually by adding tiny particles of silver iodide. Nine U.S. states are currently using it, while ten have banned or have considered banning cloud seeding or weather modification in general. Federal cloud seeding involvement and support is minimal.

Cloud seeding may increase water availability and result in economic, environmental, and human health benefits. In the studies GAO reviewed, estimates of the additional precipitation ranged from 0 to 20 percent. However, it is difficult to evaluate the effects of cloud seeding due to limitations of effectiveness research.

Figure: Cold season and warm season cloud seeding



Sources: GAO summary of information from North Dakota Atmospheric Resources Board (<http://www.nawmc.org/cloudseeding/methods.html>) and *Can we control the weather?*, HOWSTUFFWORKS (<https://science.howstuffworks.com/nature/control-weather.htm>); GAO (illustration). | GAO-25-107328

GAO identified challenges to the use and development of cloud seeding, including:

- Reliable information is lacking on the conduct of optimal, effective cloud seeding and its benefits and effects. Without such information, operations will be less effective and the return on funding investments is unclear.
- Cloud seeding operations can only enhance precipitation when the right kind of clouds are present, which limits opportunities for success.
- Existing research we reviewed, while limited to a handful of recent studies, suggests silver iodide does not pose an environmental or health concern at current levels. However, it is not known whether more widespread use of silver iodide would have an effect on public health or the environment.
- Federal reporting requirements may not include all information necessary to adequately monitor cloud seeding. As a result, opportunities to better evaluate the benefits and potential effects of cloud seeding may be missed.
- The public may not fully understand cloud seeding, including how it differs from geoengineering, which affects the climate on longer time scales.

GAO identified five policy options that could help address these challenges or enhance potential benefits. These options are intended to inform policymakers of potential policy implementations. For the purposes of this report, ‘policymakers’ includes Congress, federal and state agencies, research institutions, industry, and other stakeholders. The status quo option illustrates a scenario in which current efforts proceed without intervention.

Policy Options to Help Address Challenges to the Use and Development of Cloud Seeding

Policy Option	Opportunities	Considerations
<p>Maintain status quo efforts (report p. 21) <i>For example, cloud seeding operators, federal agencies, and researchers continue to apply technologies and approaches that are already tested and commercially available.</i></p>	<ul style="list-style-type: none"> Some current state programs may already be optimized for local conditions. Additional resources and time that may be required for other policy options could instead be used for other priorities. 	<ul style="list-style-type: none"> Current efforts are not likely to address all challenges described in this report.
<p>Encourage targeted research to reduce uncertainty (report p. 22) <i>For example, government entities, researchers, and operators could promote and support research partnerships to address uncertainties.</i></p>	<ul style="list-style-type: none"> Partnerships could enable more coordination and focus on local needs and broader issues, such as basic cloud-physics questions while improving local commercial operations. More research could lead to better understanding of potential environmental and human health concerns of seeding. More awareness of benefits could improve use of funds and awareness of equity issues. 	<ul style="list-style-type: none"> The public and policymakers often face short-term pressures regarding water, but cloud seeding research is best done over the long-term. More research may not be enough to address some uncertainties. New partnerships may also require more deliberate planning and consultation across sectors to identify suitable groups.
<p>Support more evidence-based operations (report p. 22) <i>For example, policymakers could use licensing and permitting requirements to ensure operations conduct evaluations.</i></p>	<ul style="list-style-type: none"> Ensuring evaluations are done consistently across cloud seeding operations could help address standardization challenges. 	<ul style="list-style-type: none"> Required funding and expertise for evaluations may not be available.
<p>Improve monitoring and oversight (report p. 23) <i>For example, NOAA could use its existing authority to work with other government entities, researchers, and operators to update required data for reporting, and make changes to improve standardization of annual reports.</i></p>	<ul style="list-style-type: none"> Better quality and transparency of information would improve broad understanding of cloud seeding. NOAA’s weather modification reporting form could require more specific information (e.g., flare constituents and seeding yield statistics). Standardized federal data and reporting could improve data uniformity, making research and understanding generalizable and better support independent evaluations. 	<ul style="list-style-type: none"> Managing the increased volume and rate of data may become cost prohibitive. Some operators may not share some information on cloud seeding flares due to proprietary concerns. Various entities may lack incentives or awareness of reporting requirement. Groups may also vary in their ability to report information due to funding and operational constraints.
<p>Expand education and outreach (report p. 24) <i>For example, government entities, industry associations, scientific societies, researchers, and operators could promote awareness of the distinction between long-term climate or geoengineering applications and short-term cloud seeding to alter local precipitation.</i></p>	<ul style="list-style-type: none"> Better understanding of definitions and differences can inform debate about potential risks and benefits of cloud seeding. 	<ul style="list-style-type: none"> Better understanding of definitions may not address some sources of negative public perception. Additional funding would likely be required for larger outreach initiatives.