STATEMENT OF DR. ROGER PIELKE JR.
to the SUBCOMMITTEE on DELIVERING on GOVERNMENT EFFICIENCY (DOGE)
of the COMMITTEE on OVERSIGHT and ACCOUNTABILITY
of the UNITED STATES HOUSE OF REPRESENTATIVES

HEARING on
PLAYING GOD WITH THE WEATHER – A DISASTROUS FORECAST
U.S. Capitol Visitor Center HVC-210
16 September 2025

Summary: This testimony discusses policy issues associated with weather modification and geoengineering. The testimony clarifies key concepts and recommends options for Congressional consideration to improve research and oversight of weather modification and geoengineering. My testimony begins with three recommendations, followed by ten take-home points, which are then expanded upon in the main body of my testimony.

Recommendations

1. Congress should enact legislation to improve oversight of weather modification activities, including: (a) requesting an assessment from the National Academy of Sciences that precisely quantifies what is known and unknown about the effectiveness of weather modification projects to date and clarifying the prospects for ever being able to achieve certainty in quantifying effectiveness, and (b) improving the required reporting and communicating of weather modification activities under P.L. 92-305 (e.g., to include post-deployment evaluations of outcomes).
2. Congress should standardize U.S. federal law governing weather modification, ensuring that all states are governed by identical legislative authority.
3. The United States should lead diplomatic talks on an International Solar Engineering Non-Use Agreement, with the ultimate goal of reaching broad agreement on a collective ban on outdoor experiments involving solar geoengineering and sufficient institutionalized capability to monitor the atmosphere to ensure compliance with the ban, among other topics.

Ten Take-Home Points

1. Weather modification and geoengineering have various definitions in science and policy. Precision is necessary for effective discussion of research and policy.
2. Under U.S. law a "weather modification activity" is defined as: "Any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere" (Pub. L. 92-305, 85 Stat. 735).[1]
3. According to the Intergovernmental Panel on Climate Change (IPCC) "geoengineering" refers to "a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change."[2]
4. Weather modification activities have been widely implemented in the United States and around the world for more than 70 years.

[1] https://www.ecfr.gov/current/title-15/subtitle-B/chapter-IX/subchapter-A/part-908
[2] https://apps.ipcc.ch/glossary/ – The definition of "geoengineering" is found in IPCC AR5 WG3.

5. Despite that, the effectiveness of weather modifying activities for modifying the weather is unknown.
6. There is no record of geoengineering being implemented anywhere in the world.
7. Due to (5) and (6) there is no basis for claims that governments or others are altering the weather, as sometimes is claimed.[3]
8. Supporters of geoengineering deployment experiments include those who believe that human-caused changes in climate are an emergency, those who believe that geoengineering is preferable to mitigation via emissions reductions, and those who support (or are involved in) geoengineering research.
9. The U.S. Congress has options for improving research, understanding, and oversight of "weather modifying activities."
10. I am a signatory to a call for a Solar Engineering Non-Use Agreement.[4] Others support solar geoengineering experiments in the atmosphere.

The remainder of my written testimony elaborates on these ten take-home points.

[3] See for example: https://www.bbc.com/audio/play/p0m0chcz
[4] https://www.solargeoeng.org/

1. *Weather modification and geoengineering have various definitions in science and policy. Precision is necessary for effective discussion of research and policy.*
2. *Under U.S. law a "weather modification activity" is defined as: "Any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere" (Pub. L. 92-305, 85 Stat. 735).*[5]
3. *According to the U.N. Intergovernmental Panel on Climate Change (IPCC), "geoengineering" refers to "a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change."*[6]

Table 1. The table below shows different types of weather modification. Source: NRC 2003.[7] Historically, hurricane and tornado modification was a focus of the U.S. government, but is no longer supported by the federal or state governemnts.[8]

Type of Weather Modification	Main Purpose / Objective	Key Techniques or Methods	Geographic / Operational Examples	Notes on Effectiveness or Uncertainty
Precipitation Enhancement	Increase rainfall or snowfall to augment water resources	Cloud seeding (ice-phase and mixed-phase clouds), hygroscopic seeding (warm clouds)	U.S. states (southern & western), South Africa, Thailand, Mexico, Argentina	Some evidence of increases (~15%), but attribution and cost-benefit uncertain; natural variability is large
Hail Suppression	Reduce hail damage to property/crops via modifying hailstone formation	Seeding clouds to alter ice formation (e.g. silver iodide)	U.S. hail suppression programs; also Alpine countries (Europe)	Mixed results; cost effectiveness unclear; monitoring hail damage has been used; uncertainty remains high
Fog Dissipation	Improve visibility (esp. aviation) by reducing or removing fog	Heaters, seeding, dispersion of nuclei, hygroscopic materials (ground generators or aircraft)	Salt Lake City International Airport (Delta Airlines program); other airports worldwide	Effectiveness depends on fog type (radiation vs advection); stable in some cases; cost can be high
Inadvertent / Unintentional Weather Modification	Effects unintentionally caused by human activities (pollution, land use)	Aerosols altering cloud microphysics; land surface changes; urban heat islands	Industrial/urban areas worldwide	Effects sometimes larger than intentional modification; hard to isolate; incomplete understanding

[5] https://www.ecfr.gov/current/title-15/subtitle-B/chapter-IX/subchapter-A/part-908
[6] https://apps.ipcc.ch/glossary/ – The definition is found in IPCC AR5 WG3.
[7] National Research Council. (2003). *Critical Issues in Weather Modification Research*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10829
[8] U.S. General Accounting Office. (1974). *Need for a national weather modification research program* (Report No. B-133202). Washington, D.C.: U.S. General Accounting Office.
Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change. (1975, December). *The Federal Role in Weather Modification*. Washington, D.C.: U.S. Government Printing Office.

Table 2. Examples of various forms of geoengineering. Source: Carnegie Europe 2025.[9] Note that not all experts agree on what falls under the umbrella concept of "geoengineering."

Geoengineering Method	Type	Deployment Location / Domain	Mitigation Potential / Readiness	Key Risks / Downsides
Carbon Dioxide Removal – Land-based (nature-based)				
Afforestation & Reforestation	CDR (Land)	Terrestrial (non-forest lands, deforested areas)	Relatively high removal potential; moderate readiness	Impermanence, land competition, albedo effects
Soil Carbon Sequestration (Carbon Farming)	CDR (Land)	Agricultural soils, rewilded lands	Moderate; relatively good readiness	Risk of re-release; N_2O emissions; trade-offs with farming
Biochar	CDR (Land)	Agricultural land (soil amendment)	Low to moderate; experimental	Cost; health impacts; uncertain permanence
Enhanced Weathering (on land)	CDR (Land)	Terrestrial application (crushed minerals)	High long-term potential; low readiness	Mining, energy costs, environmental impacts
Carbon Dioxide Removal – Ocean-based				
Blue Carbon (mangroves, seagrass, wetlands)	CDR (Ocean)	Coastal ecosystems	Moderate; restoration projects exist	Vulnerable to sea level rise; re-release; land/water rights issues
Seaweed Cultivation / Ocean Afforestation	CDR (Ocean)	Marine farms; sinking biomass	Moderate potential; readiness low	Ecosystem impacts; re-release; trade-offs with food systems
Artificial Ocean Fertilization	CDR (Ocean)	Nutrient-poor open ocean	Theoretically large; readiness very low	CO_2 re-release; oxygen depletion; ecosystem disruption
Artificial Upwelling	CDR (Ocean)	Cold water pumped to surface	Very limited; very low readiness	Brings CO_2 up; ecosystem risks
Artificial Downwelling	CDR (Ocean)	Moving surface waters to depth	Very limited; very low readiness	Permanence uncertain; ecological impacts
Ocean Alkalinity Enhancement	CDR (Ocean)	Surface ocean (alkaline minerals)	Promising; readiness early	Mining; chemical toxicity; uncertain dissolution
Electrochemical Direct Ocean Capture (eDOCCS)	CDR (Ocean/Engineered)	Seawater capture + geological storage	Very low scale; high energy costs	Infrastructure, energy, ecosystem disruptions
Carbon Dioxide Removal – Engineered				
Bioenergy with Carbon Capture & Storage (BECCS)	CDR (Engineered)	Biomass + CCS plants	Considerable potential; some plants exist	Land/water/food competition; biodiversity loss
Direct Air Capture (DACCS)	CDR (Engineered)	Industrial facilities	High cost; energy-intensive; readiness low	Cost, energy source, scale-up issues
Solar Radiation Management – Surface-				
Land Albedo Modification	SRM (Surface)	Deserts, cities, agriculture	Low to moderate; localized cooling	Ecosystem disruption; precipitation shifts
Ocean Albedo Modification (microbubbles, surfactants)	SRM (Surface/Ocean)	Ocean surface	Moderate potential; readiness low	Marine impacts; cost; uncertain longevity
Arctic / Antarctic Glacier Stabilization	SRM (Surface/Polar)	Polar regions	Regional/local only; high cost; low readiness	Geopolitical conflict; hydrological risks
Solar Radiation Management – Atmospheric				
Stratospheric Aerosol Injection (SAI)	SRM (Atmosphere)	Stratosphere (~20 km)	High potential, rapid cooling; low cost per degree cooled	Precipitation disruption; ozone loss; termination shock
Marine Cloud Brightening	SRM (Atmosphere)	Low marine clouds	Moderate potential; experimental	Teleconnection risks; uncertain net effect
Cirrus Cloud Thinning	SRM (Atmosphere)	Upper troposphere cirrus	Very uncertain; very low readiness	May cause warming; high uncertainty
Solar Radiation Management – Space-based				
Space Mirrors / Sunshades	SRM (Space)	Orbit / L1 point	Theoretically very large	Extremely high cost; vulnerability, governance risks

[9] Lazard, O., Bissett, M., & Dyke, J. (2025, July). *Geoengineering: Assessing Risks in the Era of Planetary Security.* Carnegie Endowment for International Peace. Retrieved from https://carnegie-production-assets.s3.amazonaws.com/static/files/Lazard,%20Bissett,%20Dyke_Geoengineering%20Planetary%20Risks.pdf

Figure 1. Nine states with active weather modification programs in 2024. Source: GAO 2024.[10]

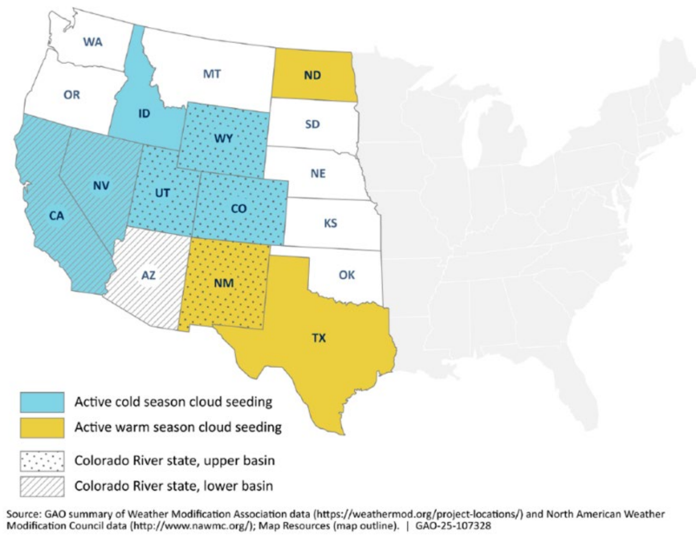


Figure 2. Countries (39) with weather modification programs during 2020-2024. Data source: GAO 2024, image created by me.

---

[10] U.S. Government Accountability Office. (2024, December 19). *Cloud Seeding Technology: Assessing Effectiveness and Other Challenges* (Report No. GAO-25-107328). https://www.gao.gov/assets/gao-25-107328.pdf

4. *Weather modification activities have been widely implemented in the United States and around the world for more than 70 years.*

According to a report of the White House Domestic Council in 1975[11]:

> An identifiable coordinated Federal research program in weather modification has been in existence at least since 1959 when the National Science Foundation, in response to Public Law 85-510, established a program to support studies, research, and evaluation in the field of weather modification. After a slow beginning, Federal funding for deliberate weather modification research increased steadily from $3.7 million in FY 1965 to a peak of $18.7 million in FY 1972. Support for the program decreased 34 percent to $12.4 million in FY 1975.

The table below, from that report, shows that approximately 7% of all federal funding for weather research was devoted to weather modification in FY1976.

Table 2. Agency Funding for Deliberate Weather Modification Research Compared with Total FY 1976 Funding for Meteorological Research[5/] (Millions of Dollars)

Agency	FY 72	FY 73	FY 74	FY 75	FY 76	Total FY 76 Meteorology Funding
Dept. of Agriculture	0.4	0.3	0.3	0.1	0.1	2.3
Dept. of Commerce	3.9	3.8	3.3	2.7	3.3	53.7
Dept. of Defense	1.8	1.2	1.2	1.3	0.5	26.1
Dept. of Interior	6.7	6.4	3.9	3.5	4.6	4.6
Dept. of Transportation	0.4	0.4	0.1	0.1	0.0	11.7
Nat'l Science Foundation	5.5	6.2	4.7	4.7	5.6	45.9
Other Federal Agencies	0.0	0.0	0.0	0.0	0.0	64.3
Totals	18.7	18.3	13.5	12.4	14.1	208.6

In the context of FY2025 federal funding for meteorological research across agencies, that would be roughly equivalent to $500 million in support for weather modification.[12] This indicates that in the 1970s weather modification was a significant research priority, and no longer is viewed as a priority.[13]

---

[11] Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change. (1975, December). *The Federal Role in Weather Modification*. Washington, D.C.: U.S. Government Printing Office. https://repository.library.noaa.gov/view/noaa/61052/noaa_61052_DS1.pdf

[12] Interagency Council for Advancing Meteorological Services. (2024, November). *The Federal Meteorological Enterprise: Fiscal Year 2025 Budget and Coordination Report*. Silver Spring, MD: Office of Science and Technology Policy. https://www.icams-portal.gov/resources/icams/fedrep/2024_fedrep.pdf

[13] For a comprehensive history of the early decades of weather modification in the U.S., see U.S. Department of Commerce. (1979, November). *National Weather Modification Policies and Programs: Submitted by the Secretary of Commerce in compliance with Public Law 94-490: A report to the President and the Congress.* Washington, D.C.: U.S. Government Printing Office. https://library.oarcloud.noaa.gov/noaa_documents.lib/Digitization_Scans/FY23_Scans/National_Weather_Modification_Policies_and_Programs_Submitted_by_the_Secretary_of_Commerce_in_Compliance_with_Public_Law_94-490.pdf

Over the past several decades, most weather modification efforts have been supported by the states. NOAA maintains a Congressionally-mandated database of required reports of weather modification projects. As of today, that database includes reports on 1,113 projects over the period 2001 to present.[14] This indicates that weather modification activities have been widely practiced over the past several decades, despite the relatively minor federal role.

There exists considerable opportunity to improve reporting and the presentation of those summaries to the general public in a manner that enhances transparency and understandability. In particular, such reports might be mandated to include project follow-on reports evaluating the effectiveness of the project, or whether no such evaluation was performed.

[14] https://library.noaa.gov/weather-climate/weather-modification-project-reports

5. *Despite the decades of implementation, the effectiveness of weather modifying activities for modifying the weather remains largely unknown.*

In 2010, the American Meteorological Society recognized that the effectiveness of cloud seeding programs was largely unknown and required greater attention to evaluation[15]:

> Rigorous attention to evaluation of both operational and research programs is needed to help develop more effective procedures and to improve understanding of the effects of cloud seeding. Research and operational programs should be designed in a way that will allow their physical and statistical evaluation. Any statistical assessment must be accompanied by physical evaluation to confirm that the statistical results can be attributed to the seeding through a well-understood chain of physical events.

A 2019 assessment by the World Meteorological Organization reinforced these conclusions[16]:

> The uncertainties that limit the scientific foundation for cloud seeding, especially for mixed-phase convective clouds, will be reduced through international analysis and model intercomparison workshops (McFarquhar et al. 2017; Grabowski 2015), promotion of best practices, and the publication of the data and results of relevant research in the international scientific literature.
>
> While water shortage has motivated cloud-seeding initiatives in the past, accelerating climate change has added a renewed urgency but also an additional complexity because of the uncertain regionalization of its effects.[17]
>
> The recommendations in the AMS Statement on Planned Weather Modification through Cloud Seeding are supported by the findings of this assessment.

A 2024 report by the Government Accountability Office similarly reinforced these findings[18]:

> 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.

Whatever effects that weather modification projects may have had on the weather, understandings remain elusive even after the better part of a century of weather modification projects.

---

[15] American Meteorological Society. (2010, November 2). *Planned Weather Modification through Cloud Seeding*. https://www.ametsoc.org/ams/about-ams/ams-statements/archive-statements-of-the-ams/planned-weather-modification-through-cloud-seeding/

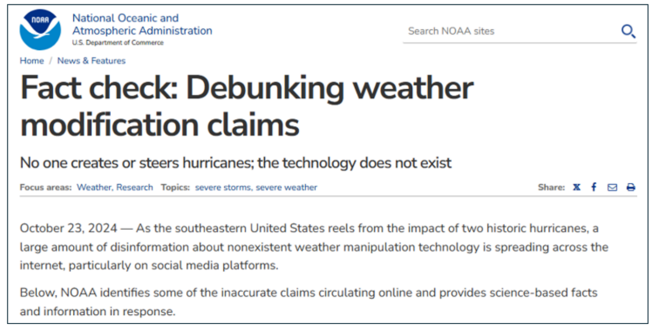
[16] Flossmann, A. I., Manton, M. J., Abshaev, A. M., Bruintjes, R., Murakami, M., Prabhakaran, T., & Yao, Z. (2019). *Review of advances in precipitation enhancement research*. *Bulletin of the American Meteorological Society*, 100(8), 1465-1480. https://doi.org/10.1175/BAMS-D-18-0160.1

[17] There is an interesting twist here: To the extent that weather modification efforts are successful in modifying they weather, they complexify efforts to detect and attribute changes in climate.

[18] GAO 2024, op. cit.

6. *There is no record of geoengineering being implemented anywhere in the world.*
7. *Due to (5) and (6) there is no basis for claims that governments or others are altering the weather, as sometimes claimed.*[19]

In 2024, in response to various online conspiracy theories, NOAA released a "fact check" on weather modification and geoengineering.[20]


National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Search NOAA sites
Home / News & Features

Fact check: Debunking weather modification claims

No one creates or steers hurricanes; the technology does not exist

Focus areas: Weather, Research Topics: severe storms, severe weather Share:

October 23, 2024 — As the southeastern United States reels from the impact of two historic hurricanes, a large amount of disinformation about nonexistent weather manipulation technology is spreading across the internet, particularly on social media platforms.

Below, NOAA identifies some of the inaccurate claims circulating online and provides science-based facts and information in response.

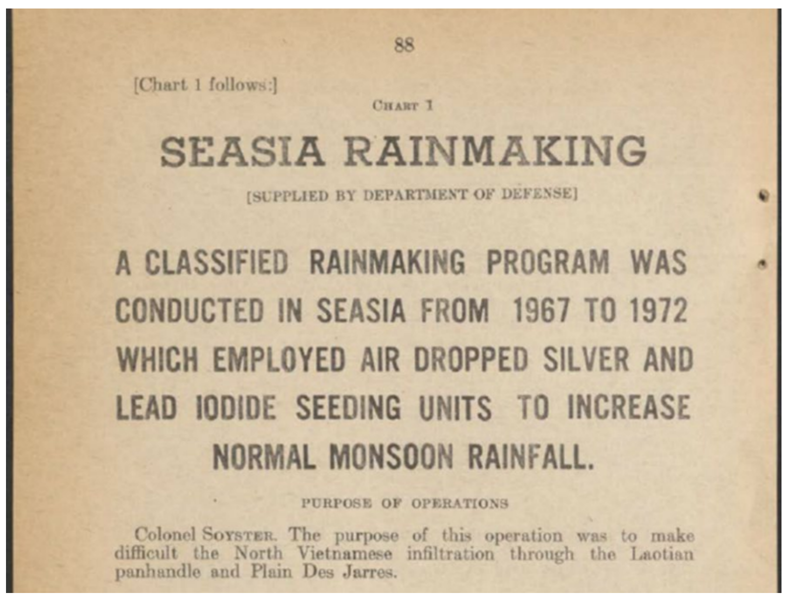
The simple facts are that:

- Despite many decades of weather modification efforts, published research offers no certainty that these projects even modify the weather;
- Geoengineering is not being implemented anywhere in the world.

The federal government would benefit from greater transparency and more effective communication related to the scope, effectiveness, purposes, and regulation of research, experiments, and projects focuses on weather modification.

It is important to acknowledge that the U.S. government has not always played things straight with respect to weather modification – However, these experiences took place a half century ago.

In the Vietnam War, the Department of Defense undertook secret efforts to modify the weather in Southeast Asia as a weapon of war.[21] Like other weather modification efforts these took place with no way to assess whether or not they were effective in any way.


88

[Chart 1 follows:]

CHART 1

SEASIA RAINMAKING

[SUPPLIED BY DEPARTMENT OF DEFENSE]

A CLASSIFIED RAINMAKING PROGRAM WAS CONDUCTED IN SEASIA FROM 1967 TO 1972 WHICH EMPLOYED AIR DROPPED SILVER AND LEAD IODIDE SEEDING UNITS TO INCREASE NORMAL MONSOON RAINFALL.

PURPOSE OF OPERATIONS

Colonel SOYSTER. The purpose of this operation was to make difficult the North Vietnamese infiltration through the Laotian panhandle and Plain Des Jarres.

There is little public information on the role of weather modification as a weapon of war around the world. If not already a priority, this should be a focus of U.S. intelligence.

---

[19] See for example: https://www.bbc.com/audio/play/p0m0chcz

[20] https://www.noaa.gov/news/fact-check-debunking-weather-modification-claims

[21] U.S. Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment. (1974). *Weather modification: Hearings before the Subcommittee on Oceans and International Environment of the Committee on Foreign Relations, United States Senate, Ninety-third Congress, second session, on the need for an international agreement prohibiting the use of environmental and geophysical modification as weapons of war and briefing on Department of Defense weather modification activity, January 25 and March 20, 1974*. Washington, DC: U.S. Government Printing Office.

8. *Supporters of geoengineering deployment experiments include those who believe that human-caused changes in climate are an emergency, those who believe that geoengineering is preferable to mitigation via emissions reductions, and those who support (or are involved in) geoengineering research.*

In 2022, on a bipartisan basis, the U.S. Congress passed the Global Catastrophic Risk Management Act of 2022 requiring the Department of Homeland Security to coordinate an expert assessment of global catastrophic and existential risks.[22] In 2024, the Department of Homeland Security published the first Global Catastrophic Risk Assessment.[23]

> An important dynamic of climate change effects is that any one mechanism by which climate change creates risk, such as those listed above, although potentially devastating on a local to regional scale, might not rise to the level of a global catastrophe or an existential risk.

The table below summarizes the DHS conclusions on risks posed by AI, asteroid and comet impacts, climate change, nuclear war, pandemics and super volcanoes. Of there, only climate change was judged to *not* pose an existential or catastrophic risk.

Summary of 2024 U.S. Global Catastrophic Risk Assessment	**existential risk**	**global catastrophic risk**	**global catastrophic and existential threats**
artificial intelligence	insufficient evidence	insufficient evidence	insufficient evidence
asteroid and comet impacts	yes	yes	yes
climate change	no	no	no
nuclear war	yes	yes	yes
pandemics	yes	yes	yes
supervolcanoes	insufficient evidence	insufficient evidence	insufficient evidence

The report explained that public characterizations of climate change found in climate advocacy do not line up with scientific assessments:

> A strong, international activist movement now exists that engages in advocacy for addressing climate change. That movement emphasizes the urgency of climate change; sponsors civic engagement efforts, including protest and civil disobedience, particularly among youths around the globe; and argues that climate change is a potential existential risk. . . although social movements reflect a genuine and legitimate concern about climate change's potential risks to society, they are not necessarily grounded in objective assessment of those risks.

Further, there is no evidence or claims found in the reports of the Intergovernmental Panel on Climate Change to suggest that the world's climate is presently in a state of emergency.[24]

---

[22] https://www.congress.gov/117/plaws/publ263/PLAW-117publ263.pdf

[23] https://www.rand.org/pubs/research_reports/RRA2981-1.html Note: The report is currently unavailable. The Rand Corporation informs me (11 Sept 2025) that it is undergoing additional review and is expected to be re-released very soon, unchanged.

[24] For instance, the phrases "climate emergency" or "existential threat" cannot be found in the reports of the IPCC.

9. *The U.S. Congress has options for improving research, understanding, and oversight of "weather modifying activities."*

GAO 2024 identified five policy options to address challenges faced by weather modification through cloud seeding or to potentially enhance benefits, summarized in the table below.[25] In 2010 the American Meteorological Society recommended against engaging in experiments seeking to modify extreme weather events[26] – I support this restriction.

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

Policy Option	Opportunities	Considerations
Maintain status quo efforts (report p. 21) *For example, cloud seeding operators, federal agencies, and researchers continue to apply technologies and approaches that are already tested and commercially available.*	• 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.	• Current efforts are not likely to address all challenges described in this report.
Encourage targeted research to reduce uncertainty (report p. 22) *For example, government entities, researchers, and operators could promote and support research partnerships to address uncertainties.*	• 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.	• 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.
Support more evidence-based operations (report p. 22) *For example, policymakers could use licensing and permitting requirements to ensure operations conduct evaluations.*	• Ensuring evaluations are done consistently across cloud seeding operations could help address standardization challenges.	• Required funding and expertise for evaluations may not be available.
Improve monitoring and oversight (report p. 23) *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.*	• 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.	• 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.
Expand education and outreach (report p. 24) *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.*	• Better understanding of definitions and differences can inform debate about potential risks and benefits of cloud seeding.	• Better understanding of definitions may not address some sources of negative public perception. • Additional funding would likely be required for larger outreach initiatives.

Source: GAO. | GAO-25-107328

[25] GAO 2024, op. cit.
[26] American Meteorological Society. (2010, November 2). *Planned Weather Modification through Cloud Seeding*. https://www.ametsoc.org/ams/about-ams/ams-statements/archive-statements-of-the-ams/planned-weather-modification-through-cloud-seeding/

10. I am a signatory to a call for a Solar Engineering Non-Use Agreement.[27] Others support solar geoengineering experiments in the atmosphere.[28]

An excellent 2023 report of the Congressional Research Service summarized the state of national and international policies governing geoengineering research (with a focus on solar geoengineering or SG)[29]:

> As of the publication of this report, Congress has not passed legislation that exclusively regulates or governs SG research or implementation; however, there are aspects of some U.S. statutes that may be relevant. . .
>
> Some scientists have stated that the scientific understanding of SG is not currently sufficient to consider implementation. Some commentators have raised the concern that the perceived availability of SG may be seen as an alternative to mitigation strategies, such as emissions reductions, and delay or reduce efforts at such reductions.
>
> Congressional deliberations on SG policy may include an evaluation of trade-offs between benefits and risks. On the one hand, SG may provide a cooling effect to offset global warming, reducing the risk of adverse climate change effects. On the other hand, risks associated with SG include possible damage to stratospheric ozone, reductions in precipitation, and reduction of ocean primary productivity. There is uncertainty about the climate response to SG, including the possibility of adverse impacts at global and regional levels. There may also be a risk of unilateral action on SG by countries or nonstate actors in the absence of U.S. law or an international agreement specifically addressing SG.

The fact that geoengineering could be practiced by individual countries, corporations, or even wealthy individuals increases the importance of developing a global governance regime. The U.S. government should consider implementing (or ensuring) adequate observational technology that would detect unauthorized geoengineering experimentation anywhere in the world. Such observational capabilities would have additional benefits in atmospheric science research.

With respect to weather modification, in 2010 the American Meteorological Society recommended that the community refrain from operation experiments on extreme weather events[30]:

> Research into modification of extreme weather systems, such as tornadic thunderstorms, tropical cyclones, etc., should be limited to numerical simulations until such time as there is sufficient knowledge to lay the foundation for safe experimentation in the atmosphere.

---

[27] https://www.solargeoeng.org/ – the call has more than 500 signatories.
[28] Seven geoengineering researchers have called for a "balanced approach" to research – https://www.call-for-balance.com/letter.
[29] Congressional Research Service. (2023, May 9). *Solar Geoengineering and Climate Change* (CRS Report No. R47551, Version 2). Prepared by Jonathan D. Haskett, Analyst in Environmental Policy. Washington, DC: Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47551
[30] AMS 2010, op. cit.

The 2010 AMS precaution foreshadowed more recent calls to ban geoengineering experiments. In 2022 I explained why I had signed a letter calling for an International Non-Use Agreement on Solar Geoengineering.[31] The remainder of this section reproduces much of that explanation.[32]

As a starting point, the main authors of an international non-use agreement explain that it "could begin with a coalition of like-minded governments that would jointly declare not to support the active development and potential future deployment of solar geoengineering technologies."[33]

Beyond that, nations participating in such an agreement might be more concrete in agreeing:

- to prohibit their national funding agencies from supporting the development of technologies for solar geoengineering, domestically and through international institutions.
- to ban outdoor experiments of solar geoengineering technologies in areas under their jurisdiction.
- to not grant patent rights for technologies for solar geoengineering, including supporting technologies such as for the retrofitting of airplanes for aerosol injections.
- to not deploy technologies for solar geoengineering if developed by third parties.
- to object to future institutionalization of planetary solar geoengineering as a policy option in relevant international institutions, including in assessments by the Intergovernmental Panel on Climate Change.

I endorse all of these concrete recommendations. Let me explain why.

In 2009, I participated in a project involving five Nobel Prize winners who endorsed the potential of geoengineering as a solution to climate change. My role in the project was to provide a critique of geoengineering as a solution to climate change.[34] My argument then, which I maintain today, is that solar geoengineering is a bad idea as well as a false solution to climate change.

In 2008, Dan Sarewitz and Richard Nelson proposed in *Nature* what has since come to be known as the Sarewitz-Nelson rules for a technological fix.[35] These rules, they explained, are necessary because:

> In a world of limited resources, the trick is distinguishing problems amenable to technological fixes from those that are not. Our rules provide guidance in making this distinction, be it for education, disease prevention or even climate change.

---

[31] https://www.solargeoeng.org/

[32] https://rogerpielkejr.substack.com/p/why-i-support-a-non-use-agreement

[33] Biermann, F., Oomen, J., Gupta, A., Ali, S.H., Conca, K., Hajer, M.A., Kashwan, P., Kotzé, L.J., Leach, M., Messner, D. and Okereke, C., 2022. Solar geoengineering: The case for an international non-use agreement. *Wiley Interdisciplinary Reviews: Climate Change*, *13*(3), p.e754. https://wires.onlinelibrary.wiley.com/doi/10.1002/wcc.754

[34] Pielke, R. A., Jr. (2009). *A Perspective Paper on Climate Engineering, Including an Analysis of Carbon Capture as a Response to Climate Change*. Copenhagen Consensus Center. https://copenhagenconsensus.com/sites/default/files/pp_climate_engineering_pielke_v.3.0.pdf

[35] Sarewitz, D., & Nelson, R. (2008). Three rules for technological fixes. *Nature*, *456*(7224), 871-872. https://www.nature.com/articles/456871a

In my response to the Nobel Prize winners, which I expanded upon in *The Climate Fix*,[36] I applied the Sarewitz-Nelson rules to solar geoengineering, which comprehensively fails to meet these criteria. Solar geoengineering is not a technological fix. Let's have a look at solar geoengineering under the three Sarewitz-Nelson rules to understand why.

Rule #1: The technology must largely embody the cause-effect relationship connecting problem to solution.

One reason that scientists wish to undertake small-scale deployment experiments in the Earth's atmosphere is to better understand the real-world effects of the deployment of solar geoengineering technologies. Another way to say this is that we really don't fully understand the consequence of such deployments — at any scale much less globally. It is generally understood that proposed solar geoengineering techniques would not simply and directly offset the effects of accumulating carbon dioxide emissions. Solar engineering would have effects on the climate system through direct and indirect radiative forcing, non-radiative forcings, and various feedbacks among these. Fully characterizing these effects, much less demonstrating accurate and reliable predictions of the consequences of solar engineering deployment, necessarily is theoretical.

Some researchers have argued to me that this creates a Catch-22 situation: how can we know that geoengineering does not work unless we conduct experiments in practice? And a ban on such deployments means that we cannot know that it might work. They are correct. Such an argument is similar to other arguments:

- We do not know if we can harvest organs from human clones unless we conduct experimental research. And if we ban research on human cloning for organ harvesting, how will we ever know?
- We do not know if we can prevent future pandemics by conducting so-called "gain-of-function" research on dangerous viruses. And if we ban certain types of gain-of-function research, how will we ever know?

Of course, both of these analogies highlight the importance of committing to non-use prior to establishment of mechanisms of regulation and oversight. In the case of human cloning the issues are mainly moral; in the case of gain-of-function mainly risk versus benefit. Geoengineering ticks both boxes — moral and risk.

Of course, apart for research governance, even most geoengineering champions will admit that there are far more direct ways to deal with increasing emissions — like reducing emissions, and their consequences — such as through vulnerability reduction and adaptation.

Sarewitz/Nelson Criterion #2: The effects of the technological fix must be assessable using relatively unambiguous or uncontroversial criteria.

Imagine that the world or an individual country decided to embark on a grand geoengineering effort by injecting particles into the stratosphere with a goal of lower global temperatures. Then

[36] Pielke Jr, R. (2010). **The climate fix: what scientists and politicians won't tell you about global warming**. Basic books.

assume that not long after, the United States experienced an extreme arctic cold wave similar to that which we saw impact the Texas electrical grid last year, with devastating result. What would happen next?

Obviously, some would blame the geoengineering itself for causing or contributing to the extreme weather and its impacts. Others would argue that such winters happen from time to time as part of climate variability. Scientifically, there would inevitably be multiple and conflicting explanations for what was observed. Rapid attribution studies would take place, perhaps with opposing results (just as happens today with such studies related to the influence of greenhouse gases on specific extreme weather events).

We actually don't have to imagine this scenario. We have experienced it. Efforts to modify the weather in the late to middle of the last century saw issues of responsibility for observed outcomes founder on establishing causality of outcomes.[37] William Travis, a disaster expert at the University of Colorado, explains that the more that atmospheric scientists learned about the complexities in attributing the effects of weather modification on the weather, the more difficult it became to demonstrate causality between the modification and the resulting weather. At the same time, those performing weather modification experiments were viewed by the public and policy makers to be responsible for whatever bad outcomes resulted from the weather, regardless of causality — which already happens today related to claims that climate change plays a role in every extreme event. The bottom line is that understandings of the effects of geoengineering on global weather and climate would be highly contested, with little means for resolving such controversies unambiguously and empirically through science.

Sarewitz/Nelson Criterion #3: Research and development is most likely to contribute decisively to solving a social problem when it focuses on improving a standardized technical core that already exists.

Solar geoengineering technologies do not exist. There is no practice planet Earth on which such technologies have already been implemented, evaluated, and improved. Even the most sophisticated climate models are but a simplistic facsimile of the real planet Earth. There is thus no technical core on which geoengineering technologies can be developed and improved. Developing such a technical core via trial and experience is limited by the inconvenient fact that we have only one planet. Sarewitz-Nelson rules 1 and 2 would prevent developing a technical core of sufficient quality to allow for reliable judgments of cause and effect. This might seem paradoxical: one reason for opposing implementation of geoengineering technologies is that they are poorly understood, but developing such understandings is limited because of obstacles to implementation. This paradox does not seem breakable.

Given that the world has finite resources to invest in technological development related to climate change, it would be fair to ask where geoengineering should rank among speculative, far-fetched technologies. Surely there are far more promising speculative technologies that might play a role in climate policy — such as carbon/air capture of carbon dioxide, nuclear fusion, advanced nuclear fission, utility-scale batteries or other areas that do not presently exist at scale but which have a

[37] Weiss, E. B. (1977). Principles for international agreement. *Futures*, *9*(6), 490-501. https://www.sciencedirect.com/science/article/abs/pii/0016328777900787

pre-existing technological core that offers potential for greater payoffs to achieving climate policy goals. Of course, such practicalities offer little solace to researchers who wish to explore geoengineering.

To sum, the hypothetical technologies of geoengineering, whatever their theoretical appeal, simply do not meet the basic Sarewitz-Nelson rules for an effective technological fix. In fact, they fail comprehensively. As such, solar geoengineering sits alongside nuclear weapons, human cloning, gain-of-function virology, gene drives, biological and chemical weapons, human subject experimentation, dual use and many other areas of research that have been subject to democratically accountable oversight, regulation, and in some cases, prohibition. Just because something can be researched does not mean that it must. And just because someone wishes to study something does not mean that we should.

I'll let the authors of the case for a non-use agreement have the last words here[38]:

> In sum, an International Non-Use Agreement on Solar Geoengineering would be timely, feasible, and effective. It would inhibit further normalization and development of a risky and poorly understood set of technologies that seek to intentionally manage incoming sunlight at planetary scale, and it would do so without restricting legitimate climate research. It would prevent a dangerous distraction from current climate policies by removing the false promise of a cheap and feasible alternative "Plan B" in the form of solar geoengineering. Decarbonization of our economies is feasible if the right steps are taken, leading also to innovation opportunities through economic transformation and ecological benefits beyond climate change mitigation. Solar geoengineering is not necessary. Neither is it desirable, ethical, or politically governable in the current context.

[38] Biermann et al. 2022, op. cit.

Biography of Roger Pielke Jr.

Roger Pielke Jr. is a senior fellow at the American Enterprise Institute (AEI), where he focuses on science and technology policy, the politicization of science, government science advice, energy and climate, and sports governance. He is concurrently a professor emeritus in the College of Arts and Sciences at the University of Colorado Boulder; a distinguished fellow at the Institute of Energy Economics, Japan; a research associate of Risk Frontiers (Sydney, Australia); and an honorary professor of University College London. In 2024, Roger was elected to membership in the Norwegian Academy of Sciences and Letters.

Roger also oversees a popular Substack —***The Honest Broker*** — where he is experimenting with a new approach to research, writing and public engagement. The Honest Broker has more than 37,000 subscribers in all 50 states and in more than 165 countries.

Roger is frequently called upon by governments, businesses, universities, sport governance organizations and others around the world as a speaker and policy advisor. His research at the intersection of science, policy, and politics is widely cited in multiple fields. Roger's most recent NSF grant (2021) focused on science advice in the COVID-19 pandemic across the world.

Roger holds degrees in mathematics, public policy, and political science, all from the University of Colorado Boulder. In 2012, Roger was awarded an honorary doctorate from Linköping University in Sweden and was also awarded the Public Service Award of the Geological Society of America. In 2006, Roger received the Eduard Brückner Prize in Munich, Germany in 2006 for outstanding achievement in interdisciplinary climate research.

Roger has been a Distinguished Fellow of the *Institute of Energy Economics, Japan* since 2016 and a Research Associate of *Risk Frontiers*, in Sydney, Australia, since 2017. Roger was a Fellow of the NOAA/CU Cooperative Institute for Research in Environmental Sciences from 2001 to 2016. He served as a Senior Fellow of *The Breakthrough Institute* from 2008 to 2018. In 2007, Roger served as a James Martin Fellow at Oxford University's Said Business School. Before joining the faculty of the University of Colorado, from 1993 to 2001 Roger was a Scientist at the National Center for Atmospheric Research.

At the University of Colorado Boulder, Roger founded and directed the Center for Science and Technology Policy Research (2002-2020) and the Sports Governance Center (2016-2019). He also created and led the university's Graduate Certificate Program in Science and Technology Policy (2003-2020), which has seen its graduates move on to faculty positions, Congressional staff, the White House, presidential political appointments, and to positions in business and civil society. Roger also led the development of the University of Colorado Boulder's graduate program in Environmental Studies that was focused on environmental policy (2002 to 2015).

His books include *Hurricanes: Their Nature and Impacts on Society* (with R. Pielke Sr., 1997, John Wiley), *Prediction: Science, Decision Making and the Future of Nature* (with D. Sarewitz and R. Byerly, 2001, Island Press), *The Honest Broker: Making Sense of Science in Policy and Politics*, (Cambridge University Press 2007), *The Climate Fix: What Scientists and Politicians Won't Tell you About Global Warming* (2010, Basic Books). *Presidential Science Advisors: Reflections on Science, Policy and Politics* (with R. Klein, 2011, Springer), and *The Edge: The War Against Cheating and Corruption in the Cutthroat World of Elite Sports* (Roaring Forties Press, 2016). His most recent book is *The Rightful Place of Science: Disasters and Climate Change* (2nd edition, 2018, Consortium for Science, Policy & Outcomes).