BAD POLICY RUNS DOWNHILL: HOW CLOUD SEEDING JURISPRUDENCE DISPROPORTIONATELY HARMS DISADVANTAGED COMMUNITIES

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ABSTRACT

Cloud seeding is the practice of altering the weather by injecting chemicals into clouds. The practice can be used to obtain a variety of desired outcomes such as more rain for farmers, hail suppression, hurricane suppression, fog mitigation, and increased snowfall which

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helps both summer runoff and ski resort tourism. While cloud seeding offers significant benefits to some, it inevitably imposes costs on others. Just as the negative consequences of climate change are disproportionately felt by those in disadvantaged communities, the costs of cloud seeding are likewise disproportionately experienced by those in disadvantaged communities, thus exacerbating economic and health inequalities. Another problem is that the unique nature of cloud seeding renders traditional legal remedies of effectively allocating costs largely ineffective, as causation is impossible to prove.

This Article comes at a critical time as there is currently a confluence of events converging around weather alteration. There is increased interest from the U.S. government in using weather modification to respond to the effects of climate change. Interstate riparian water rights have become exceedingly contentious. Proposals for large-scale geoengineering projects with potentially catastrophic consequences are being considered. In March 2024, the Tennessee Senate passed a bill barring the practice of releasing chemicals into the air to affect the weather. In 2023 the Bureau of Reclamation pledged $2.4 billion in cloud seeding projects. And the Supreme Court is predicted to issue a controversial decision blocking downwind EPA air pollution protections. This first-of-its-kind Article will hopefully serve as a powerful catalyst for positive change by promoting the implementation of equitable legal frameworks that take into account the underrepresented interests of disadvantaged communities.

INTRODUCTION

"[*W]e may eventually have almost complete control of rain and snow storms.*"

Quote from the first volume of the Stanford Law Review in 1948[1]

Cloud seeding is the practice of altering the weather by injecting chemicals into clouds.[2] The practice can be used to obtain a variety of desired outcomes such as more rain for farmers,[3] hail suppression,[4]

1. *Who Owns the Clouds?*, 1 STAN. L. REV. 43, 44 (1948).

2. *See Frequently Asked Questions*, TEX. DEP'T OF LICENSING & REGUL., https://www.tdlr.texas.gov/weather/weatherfaq.htm (last visited Apr. 2, 2024).

3. *See* Katie Brigham, *How States Across the West are Using Cloud Seeding to Make It Rain*, CNBC (Dec. 17, 2022, 9:44 AM), https://www.cnbc.com/2022/12/17/how-cloud-seeding-can-help-replenish-reservoirs-in-the-west.html.

4. *See* Gregory N. Jones, *Weather Modification: The Continuing Search for Rights and Liabilities*, 1991 BYU L. REV. 1163, 1163 (1991).

hurricane suppression,[5] fog mitigation,[6] and increased snowfall which helps both summer runoff and ski resort tourism.[7] While cloud seeding offers significant benefits to some, it inevitably imposes costs on others. Just as the negative consequences of climate change are disproportionately felt by those in disadvantaged communities, the costs of cloud seeding are likewise disproportionately experienced by those in disadvantaged communities, thus exacerbating economic and health inequalities.

The U.S. legal system has numerous methods for effectively allocating benefits and costs between parties, but the unique nature of cloud seeding renders these traditional legal theories largely ineffective, as but-for causation is nearly impossible to prove.[8] This first-of-its-kind Article advocates for the implementation of much needed federal regulation along with notice and comment to help mitigate the disproportionate harm from cloud seeding. The benefits of doing so are not just limited to the practice of cloud seeding. This will provide a valuable legal framework for other advancements in technology such as large-scale geoengineering which has the potential to do even greater harm.

This Article comes at a critical time as there is currently a confluence of events converging around weather alteration. There is increased interest from the U.S. government in using weather modification to respond to the effects of climate change.[9] Interstate riparian water rights have become exceedingly contentious.[10] Proposals for large-scale geoengineering projects with potentially

5. *See* Mike Wall, *Cloud Seeding Could Tame Hurricanes*, LIVE SCI. (Dec. 16, 2011), https://www.livescience.com/17524-cloud-seeding-hurricanes-global-warming.html.

6. *See Planned Weather Modification Through Cloud Seeding*, AMER. METEOROLOGICAL SOC'Y (Nov. 10, 2010), https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/planned-weather-modification-through-cloud-seeding/.

7. *See* Jay Adams, *Cloud Seeding's Role in the Winter Season*, DENVER WATER (Dec. 10, 2018), https://www.denverwater.org/tap/cloud-seedings-role-winter-season?size=n_21_n.

8. *See* Jones, *supra* note 4, at 1169.

9. *See* Manon Simon, *Enhancing the Weather: Governance of Weather Modification Activities of the United States*, 46 WM. & MARY ENV'T L. & POL'Y REV. 149, 149–50 (2021).

10. *See, e.g.*, Tristan Bove, *The Rules Governing the Colorado River Were Made for a 'Previous World' and the West Is Not Confronting a 21st Century Nightmare as It Runs Dry*, FORTUNE (Apr. 15, 2023, 5:00 AM), https://fortune.com/2023/04/15/colorado-river-shrinking-california-arizona-water-rights/.

catastrophic consequences are being considered.[11] In March 2024, the Tennessee Senate passed a bill barring the practice of releasing chemicals into the air to affect the weather.[12] In 2023, the Bureau of Reclamation pledged $2.4 billion in cloud seeding projects.[13] And the Supreme Court is predicted to issue a controversial decision blocking downwind EPA air pollution protections.[14]

Part I of this Article provides the background of cloud seeding and its expansive twenty-first century uses. Part II lists the potential harm from the practice including flooding, droughts, hail, and contamination from the chemicals used. Part III explains how climate change has disproportionately harmed those in disadvantaged communities and how these same people incur more of the costs and less of the benefits from cloud seeding. Part IV gives the limited case law relevant to cloud seeding. Part V discusses the near impossibility of proving causation by plaintiffs seeking compensation from harm by cloud seeding. Part VI shows how, under the current regime, regulation of the practice is very limited. Part VII argues for federal regulation of cloud seeding. Part VIII argues for adequate notice and comment for the practice. Finally, Part IX concludes by discussing how the increasing interest of using large-scale geoengineering to address climate change means it is imperative to establish equitable legal frameworks that takes into account disadvantaged communities.

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11. *See, e.g.*, Alejandro De La Garza, *A Controversial Technology Is Creating an Unprecedented Rift Among Climate Scientists*, TIME (Mar. 17, 2023, 1:14 PM), https://time.com/6264143/geoengineering-climate-scientists-divided/; Daisy Dunne, *Geoengineering Carries 'Large Risks' for the Natural World, Studies Show*, CARBON BRIEF (Jan. 22, 2018, 4:02 PM), https://www.carbonbrief.org/geoengineering-carries-large-risks-for-natural-world-studies-show/.

12. *See* Diana Leyva, *Tennessee Legislature Passes Bill Based on 'Chemtrails' Conspiracy Theory: What to Know*, THE TENNESSEAN (Apr. 2, 2024, 3:07 PM), https://www.tennessean.com/story/news/local/2024/03/20/tennessee-senate-passes-bill-banning-chemtrails-what-to-know/73027586007/.

13. *See* Julia Jacobo et al., *These Geoengineering Technologies Could Help Combat the Climate Crisis, Scientists Say*, ABC NEWS (Apr. 21, 2023, 6:04 AM), https://abcnews.go.com/US/geoengineering-technologies-combat-climate-crisis-scientists/story?id=98476205.

14. *See* Amy Howe, *Supreme Court Likely to Block EPA Ozone Regulation*, SCOTUSBLOG (Feb. 21, 2024, 3:50 PM), https://www.scotusblog.com/2024/02/supreme-court-likely-to-block-epa-ozone-regulation/. This is relevant to cloud seeding as there is likely interstate effects from the practice.

I. BACKGROUND

A. History and Science of Cloud Seeding

Cloud seeding, sometimes referred to as "weather resource management," "rain enhancement," and "artificial nucleation," is the practice of attempting to cause or increase precipitation by artificially injecting chemicals into cumulus clouds.[15] Modern cloud seeding operations spray silver iodide particles (or sometimes dry ice or liquid nitrogen) into the clouds, intending to cause droplets to form into snowflakes in the cloud which then fall to the ground.[16] Cloud seeding is generally conducted by airplane or by ground-based generators[17] but can also be conducted by ground-fired rockets.[18] Cloud seeding is a subset of geoengineering, which refers to practices that artificially manipulate the environment.[19] Large-scale geoengineering is thought by many to be an effective method for counteracting climate change.[20]

Humans have attempted to alter the weather for thousands of years. Early attempts included human and animal sacrifices,[21]

15. *See* TEXAS DEP'T OF LICENSING & REGUL., *supra* note 2.

16. *See id.*

17. *See Cloud Seeding Program*, DESERT RSCH. INST., https://www.dri.edu/cloud-seeding-program/what-is-cloud-seeding/ (last visited Apr. 2, 2024). The majority of cloud seeding in California is performed from ground-based generators. *See* Simon, *supra* note 9, at 166–67; The majority of cloud seeding in Utah is performed from ground-based generators. *See* Zak Podmore, *Utah Is a Leader in Cloud Seeding. Is It Working?*, THE SALT LAKE TRIB. (Apr. 9, 2021, 11:32 AM), https://www.sltrib.com/news/2021/03/28/utah-is-leader-cloud/.

18. *See* James Dinneen, *Can Cloud Seeding Help Quench the Thirst of the U.S. West?*, YALE ENV'T 360 (Mar. 3, 2022), https://e360.yale.edu/features/can-cloud-seeding-help-quench-the-thirst-of-the-u.s.-west.

19. *See The Harvard Solar Geoengineering Research Program*, THE SALATA INST. FOR CLIMATE & SUSTAINABILITY AT HARVARD UNIV., https://geoengineering.environment.harvard.edu/geoengineering (last visited Apr. 2, 2024).

20. *See Oxford Geoengineering Programme*, OXFORD MARTIN SCH., UNIV. OF OXFORD, https://www.oxfordmartin.ox.ac.uk/geoengineering#:~:text=The%20Oxford%20Geoengineering%20Programme%20seeks,systems%20to%20address%20climate%20change (last visited Apr. 2, 2024). For example, by artificially increasing the reflectiveness of clouds, the Sun's energy is partially reflected back into space, counteracting temperature increases. *See* THE SALATA INST. FOR CLIMATE & SUSTAINABILITY AT HARVARD UNIV., *supra* note 19.

21. *See, e.g.*, John M. Ingham, *Human Sacrifice at Tenochtitlan*, 26 COMPAR. STUD. IN SOC'Y & HIST. 379, 393, 396 (1984).

dances,[22] and prayer.[23] As early as the mid-1800s, the use of "pluviculture" techniques such as canon concussion were used as an attempt to alter the weather.[24] The persistent importance of controlling the weather is demonstrated by Congress's willingness to appropriate funds for rainmaking experiments in the 1800s.[25] The modern practice of introducing chemicals such as silver iodide into clouds to alter the weather—cloud seeding—has a long and diverse history. From the first cloud seeding operations in the 1940s, legal issues about the practice were debated. The 1948 inaugural volume of the *Stanford Law Review* published an article on cloud seeding titled, "Who Owns the Clouds?"[26]

These early attempts were more based on luck, and many in the scientific community at the time questioned the efficacy of the practice.[27] The notion of altering the weather by releasing chemicals into clouds was also met with fervent skepticism among lay people. Some of these skeptics even attempted to deter the practice by destroying radar dishes and shooting at airplanes.[28] The controversial use of cloud seeding as a military weapon was employed by the U.S. military in Vietnam and Laos over forty years ago.[29] Such

22. *See* Tamara Warta, *Native American Rain Dances*, LOVE TO KNOW, https://www.lovetoknow.com/life/lifestyle/native-american-rain-dances (last visited Apr. 5, 2024).

23. *See* Ralph W. Johnson, *Legal Implications of Weather Modification: The General Legal Setting, in* WEATHER MODIFICATION AND THE LAW, 76, 77 (Howard J. Taubenfeld ed., 1968). Arguably the first weather-modification case is that of *Dodd v. McLeod* involving prayer for rain. *See id.* at 76. A local minister organized a collective prayer service for rain which was followed by a severe thunderstorm. *See id.* at 77. The plaintiff, who had objected to the prayer service believing that it constituted an inappropriate tampering with nature, had his hay barn burned down after it was struck by lightning. *See id.* The case was dismissed because the minister had prayed only for rain, and the plaintiff was unable to prove that the prayers caused his hay barn to burn down. *See id.*

24. *See* Simon, *supra* note 9, at 156.

25. *See Who Owns the Clouds?*, *supra* note 1, at 43.

26. *See id.*

27. *See, e.g.*, Henry G. Houghton, *An Appraisal of Cloud Seeding as a Means of Increasing Precipitation*, 32 AM. METEOROLOGICAL SOC'Y 39, 39 (1951).

28. *See* Jack Queen, *How Cloud Seeding is Boosting Snowfall Totals at Colorado Ski Areas*, STEAMBOAT PILOT & TODAY (Oct. 5, 2017), https://www.steamboatpilot.com/news/how-cloud-seeding-is-boosting-snowfall-totals-at-colorado-ski-areas/.

29. *See* Seymour M. Hersh, *Rainmaking Is Used as Weapon by U.S.*, N.Y. TIMES, July 3, 1972, at A1.

meteorological warfare was then banned by the Environmental Modification Convention international treaty in 1978.[30]

B. Modern Day Uses

The twenty-first century has experienced a rapid increase in both private and state-funded cloud seeding projects.[31] Cloud seeding has expanded not only in volume, but also in purpose. Over fifty countries have cloud-seeding operations.[32] A French cloud-seeding company will guarantee a rain-free wedding for $150,000.[33] Ski resorts use cloud seeding to increase snowfall and therefore improve skiing conditions for its clientele.[34] China conducted extensive cloud seeding operations in an effort to reduce rainfall in Beijing during the 2008 Olympics.[35] Cloud seeding has been used in mountainous areas to increase winter snowpack with the end goal of increasing water levels in the summer to support rafting tourism.[36] Hurricanes can be seeded to reduce destructive wind force.[37] Cloud seeding can be used to

30. *See* Eleanor Cummins, *With Operation Popeye, the U.S. Government Made Weather an Instrument of War*, POPULAR SCI. (Mar. 20, 2018, 10:30 PM), https://www.popsci.com/operation-popeye-government-weather-vietnam-war/.

31. *See* Adriana Vélez-León, *Rain on Demand: Regulating Weather Modification Through the United States*, 8 GEO. WASH. J. ENERGY & ENV'T L. 148, 153 (2017).

32. *See id.* at 161.

33. *See* Bethany Hubbard, *Cloud Seeding Guarantees Perfect Wedding Weather*, DISCOVER MAG. (Nov. 19, 2019, 10:59 PM), https://www.discovermagazine.com/environment/cloud-seeding-guarantees-perfect-wedding-weather.

34. *See* Marshall Haworth, *Let It Snow: How Ski Resorts are Using Cloud Seeding to Boost Snowfall*, MARTIN & WOOD WEATER CONSULTANTS, INC. (Feb. 12, 2017), https://www.martinandwood.com/blog/2017/2/12/let-it-snow-how-ski-resorts-are-using-cloud-seeding-to-boost-snowfall.

35. *See* Clifford Coonan, *How Beijing Used Rockets to Keep Opening Ceremony Dry*, THE INDEP. (Aug. 11, 2008, 12:00 AM), https://www.independent.co.uk/sport/olympics/how-beijing-used-rockets-to-keep-opening-ceremony-dry-890294.html.

36. *See* Heather Sackett, *Vail Resorts' Cancellation of Cloud Seeding This Winter Could Mean Less Water in Streams*, VAIL DAILY (Nov. 27, 2020), https://www.vaildaily.com/news/vails-cancellation-of-cloud-seeding-this-winter-could-mean-less-water-in-streams/.

37. *See* Vélez-León *supra* note 31, at 151 ("In 1961, the National Oceanic and Atmospheric Administration ("NOAA"), along with the Department of Defense and the National Science Foundation seeded Hurricane Esther with silver iodide in an experiment called Project Stormfury, reducing its wind force by 10%. Approximately eight years later, on August 18, 1969, NOAA once again attempted to weaken a hurricane's wind force by cloud seeding Hurricane Debbie with silver iodide five times during an eight-hour period. As a result, winds decreased by 31% between the first seeding and five hours after the fifth seeding.").

augment clean energy by increasing the amount of water flowing through hydroelectric dams.[38]

When discussing the history of weather modification, it is important to note that this category includes inadvertent weather modification. For example, studies have found dramatic increases in precipitation, thunderstorms, and hailstorms from inadvertent weather modification.[39] Inadvertent weather modification is the result of a variety of activities such as greenhouse gas emissions, replacing vegetation with asphalt, and evapotranspiration.[40]

II. POTENTIAL FOR HARM

Unfortunately, altering the weather through cloud seeding may sometimes produce negative outcomes. A cloud seeding operation in China was followed by forty deaths and an estimated over $650 million in damages.[41] In 1972, a cloud seeding operation in South Dakota resulted in overflowing a creek which resulted in $160 million in property damage and 238 deaths.[42] A cloud seeding operation in Mongolia resulted in a death after a plane dropped a shell full of silver iodide that struck someone on the ground.[43] The previously mentioned use of cloud seeding as a military weapon illustrates the risk of intentional harm from the practice.[44] And, cloud seeding in one area can reduce desperately needed precipitation in another area, potentially exacerbating devastating droughts.[45]

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38. *See* Jack McNary, *What is Cloud Seeding, and Who is Doing It?*, GETSKITICKETS (Jan. 12, 2022), https://getskitickets.com/blog/what-is-cloud-seeding-and-who-is-doing-it/ .

39. *See* Ray Jay Davis, *Law and Urban-Induced Weather Change*, 25 U. TOL. L. REV. 379, 380–81 (1994).

40. *See id.* at 381–82.

41. *See Early Snowstorms Kill 40 Across North-Central China*, N.Y. TIMES (Nov. 14, 2009), at A10.

42. *See* Arnett Dennis, *Cloud Seeding and the Rapid City Flood of 1972*, 42 J. WEATHER MODIFICATION 124, 124 (2010); Dakota Water Science Center, *The 1972 Black Hills-Rapid City Flood Revisited*, U.S. GEOLOGICAL SERV. (Sept. 21, 2017), https://www.usgs.gov/centers/dakota-water-science-center/science/1972-black-hills-rapid-city-flood#overview.

43. *See* Virginia Simms, *Making the Rain: Cloud Seeding, the Imminent Freshwater Crisis, and International Law*, 44 INT'L LAW. 915, 921 (2010).

44. *See* Hersh, *supra* note 29, at A10; Cummins, *supra* note 30; and accompanying text.

45. *See*, *e.g.*, *Billion-Dollar Disasters: Calculating the Costs*, NAT'L CTRS. FOR ENV'T INFO., https://www.ncei.noaa.gov/access/monitoring/dyk/billions-calculations#:~:text=Since%201980%2C%20the%20U.S.%20has,400%20events%20exceeds%20%242.7%20trillion. (last visited Dec. 12, 2024) (explaining that droughts cost an average of $11.6 billion per event).

In addition to the potentially harmful end results of cloud seeding, the practice of releasing chemicals such as silver iodide into the atmosphere may have negative consequences. A 2022 study using twenty air quality ground-based stations and satellite imaging in the United Arab Emirates found significantly increased seeding agent levels during cloud seeding operations.[46] The court in *Pennsylvania Natural Weather Ass'n v. Blue Ridge Weather Modification Ass'n* held that some of these seeding agents are "poisonous."[47] The court went further and concluded that "possible harm can result from uncontrolled and unregulated weather modification activities."[48] Finally, it appears that silver iodine levels increase during warmer periods, creating a potential compounding effect with global warming.[49]

Current research on cloud seeding with silver iodide generally concludes that the increased levels of the particulate in the environment due to cloud seeding is nevertheless within permissible limits.[50] However, increases in cloud seeding could change this. And perhaps more of a threat to human safety, the currently unregulated nature of cloud seeding, and the lack of legal liability, could lead to experimentation with alternative cloud seeding chemicals that are more dangerous. Just one such example is in Texas, where operators have been experimenting with a new process called "dual seeding," which is seeding with a mix of both hygroscopic and glaciogenic materials.[51] Finally, the largely unregulated nature of cloud seeding could set a dangerous precedent for future geoengineering projects with the potential for catastrophic consequences.[52]

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46. *See* A. Farahat & A. Abuelgasim, *Effect of Cloud Seeding on Aerosol Properties and Particulate Matter Variability in the United Arab Emirates*, 19 INT. J. ENV'T SCI. & TECH. 951, 951 (2022).

47. Pa. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 761 (Pa. C.P. 1968).

48. *Id.*

49. *See* V. P. Korneev et. al., *Environmental Aspects of Cloud Seeding*, 42 RUSS. METEOROLOGY & HYDROLOGY 477, 481 (2017).

50. *See, e.g.*, Podmore, supra note 17; Matt Kretzschmar, *Cloud Seeding = More Snow, But Is It Worth Doing in the Long Run?*, NEW SCHOOLERS (2017), https://www.newschoolers.com/news/read/Cloud-Seeding-Snow-Worth-Long-Run#:~:text=At%20the%20moment%20these%20readings,Stanford%20Univeristy%20ecologist%2C%20Rob%20Jackson.

51. *See* Arquimedes Ruiz Columbié et. al, *Comments on Current Dual Cloud Seeding Operations in Texas*, 44 J. WEATHER MODIFICATION 96, 97 (2012).

52. *See, e.g.*, Chelsea Harvey, *Geoengineering Is Not a Quick Fix for the Climate Crisis, New Analysis Shows*, SCI. AM. (Apr. 3, 2023),

III. DISPROPORTIONATE POTENTIAL HARM TO DISADVANTAGED COMMUNITIES

This Part will discuss the disproportionate harm suffered by those in disadvantaged communities from environmental harm in general and cloud seeding specifically. Note that while this analysis focuses only on disadvantaged communities in the U.S., many of these environmental harms pose an even greater threat to those in developing countries.[53]

A. Disproportionate Environmental Harm in General

The various ways in which disadvantaged communities disproportionately suffer the harms from climate change are well documented. Those in disadvantaged communities are less likely to be able to combat the increasing frequency and severity of heat waves from climate change.[54] This problem is exacerbated by how the disadvantaged are more likely to live in communities with higher heat.[55] This is the product of how disadvantaged communities are more likely to live in environments with significant asphalt and concrete that retain heat and less likely to have vegetation that produces a cooling effect.[56] For example, in Denver, poor communities can be 8° hotter than the wealthy communities.[57] Naturally, the use of public transportation, which requires walking to and waiting for a bus, increases the risk of heat-related deaths when compared to the more affluent who have air conditioned cars. And those in disadvantaged communities are more likely to work in environments exposed to heat.[58]

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https://www.scientificamerican.com/article/geoengineering-is-not-a-quick-fix-for-the-climate-crisis-new-analysis-shows/.

53. *See* Pia Abeygunawardena, et al., *Poverty and Climate Change: Reducing the Vulnerability of the Poor Through Adaptation*, OECD 5 (2009), https://www.oecd.org/env/cc/2502872.pdf.

54. *See* Jesse Bedayn, *Record Heat Waves Illuminate Plight of Poorest Americans Who Suffer Without Air Conditioning*, AP NEWS (July 30, 2023, 6:55 PM), https://apnews.com/article/heat-wave-low-income-race-death-air-conditioning-f897e336d6d99ee2a53024f42ad7b8b5.

55. *See id.*

56. *See id.*

57. *See id.*

58. *See* Anna Wellenstein et al., *Climate Change and Poverty: The Perfect Storm*, WORLD BANK BLOGS (Feb. 2, 2022), https://blogs.worldbank.org/latinamerica/climate-change-and-poverty-perfect-storm#:~:text=When%20they%20work%20outside%20the,to%20heat%20extremes%20in%20LAC.

The disadvantaged are less likely to live in homes with air conditioning or less likely to be able to run their air conditioning.[59] And the harm to disadvantaged communities from heat waves is not just limited to death. Lack of access to air conditioning also produces ambient misery in disadvantaged communities.[60] And even those in disadvantaged communities who do have access to air conditioning incur significant tradeoffs when deciding to run it, as money spent on air conditioning cannot also be spent on food, medicine, doctor's visits, transportation, and cell phones needed to make emergency calls.[61]

Climate change results in higher food costs for numerous reasons. Increased greenhouse gas emissions results in degraded soil quality.[62] It also results in inefficiencies from inconsistent access to water due to droughts and more evaporation from higher temperatures.[63] Extreme heat in itself increases crop failures through disrupting the ideal growth cycle of crops.[64] Increased flooding and hail from climate change further reduces farming efficiencies.[65] These higher food costs from climate change disproportionately impact disadvantaged communities because food makes up a higher percentage of their expenses.[66]

Increased hurricanes from climate change disproportionately affect disadvantaged communities as they are more likely to live in homes susceptible to hurricane damage and less insulated against the economic shock that accompanies a hurricane.[67]

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59. *See* Bedayn, *supra* note 54.

60. *See id.*

61. *See id.*

62. Sinan Erdogan et al., *Does Climate Change Cause an Upsurge in Food Prices?*, 13 FOODS 154, 155 (2024).

63. *See id.*

64. *See id.*

65. *See Climate Change Impacts on Agriculture and Food Supply*, EPA (Sept. 23, 2024), https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply.

66. *See* David Soll, *How Food Prices Hit Low-Income Households Hardest*, CHI. SUN TIMES (July 18, 2022, 4:00 PM), https://chicago.suntimes.com/2022/7/18/23268537/food-prices-inflation-low-income-households-consumer-spending-david-soll-the-conversation-op-ed.

67. *See* Eleanor Krause & Richard V. Reeves, *Hurricanes Hit the Poor the Hardest*, BROOKINGS INST. (Sept. 18, 2017), https://www.brookings.edu/articles/hurricanes-hit-the-poor-the-hardest/#:~:text=First%2C%20lower%20income%20Americans%20are,effects%20of%20a%20severe%20storm.

These problems are made worse by the existence of compounding effects. Climate change not only disproportionately harms disadvantaged communities but also drives more people into disadvantaged status.[68] And those in disadvantaged communities are not only more likely to incur negative climate-related exposures, but they are also more likely to suffer from existing chronic medical conditions which are then exacerbated by climate-related health impacts.[69] Finally, in addition to harms incurred from climate change, disadvantaged communities are also more likely to suffer other environmental harms. For example, they are more likely to suffer harm from asbestos,[70] air pollution,[71] lead paint,[72] hazardous waste storage,[73] and the psychological harm from noise pollution.[74]

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68. *See Five Ways the Climate Crisis Impacts Human Security*, U.N., https://www.un.org/en/climatechange/science/climate-issues/human-security#:~:text=By%20hitting%20the%20poorest%20the,2030%20because%20of%20climate%20change (last visited Apr. 2, 2024) ("A World Bank report estimated that an additional 68 to 135 million people could be pushed into poverty by 2030 because of climate change.").

69. *See* Janet L. Gamble & John Balbus et al., *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, U.S. GLOB. CHANGE RSCH. PROGRAM 247, 252 (2016).

70. *See* Emily Walsh, *The Impact of Low-Income Neighborhoods on Health*, U.S. DEP'T OF HEALTH & HUM. SERVS. (Nov. 28, 2017), https://minorityhealth.hhs.gov/news/impact-low-income-neighborhoods-health#:~:text=If%20asbestos%20is%20still%20inside,higher%20risk%20of%20accidental%20exposure.

71. *See Disparities in the Impact of Air Pollution*, AMER. LUNG ASS'N (Nov. 2, 2023), https://www.lung.org/clean-air/outdoors/who-is-at-risk/disparities.

72. *See People at Increased Risk for Childhood Lead Poisoning*, CTR. FOR DISEASE CONTROL & PREVENTION (Apr. 10, 2024), https://www.cdc.gov/lead-prevention/risk-factors/index.html#:~:text=Children%20from%20low%2Dincome%20households%20and%20those%20who%20live%20in,more%20likely%20to%20contain%20lead.

73. *See* Jim Erickson, *Targeting Minority, Low-Income Neighborhoods for Hazardous Waste Sites*, U. OF MICH. (Jan. 19, 2016), https://news.umich.edu/targeting-minority-low-income-neighborhoods-for-hazardous-waste-sites/.

74. *See Urban Noise Pollution Is Worst in Poor and Minority Neighborhoods and Segregated Cities*, PBS (Oct. 7, 2017, 3:43 PM), https://www.pbs.org/newshour/nation/urban-noise-pollution-worst-poor-minority-neighborhoods-segregated-cities#:~:text=Neighborhoods%20with%20median%20annual%20incomes,communities%20with%20no%20black%20residents.

B. Disproportionate Harm from Cloud Seeding

Unfortunately for those in disadvantaged communities, the disproportionate harm they experience from environmental factors includes those from cloud seeding. Some experts believe that rain functions as a natural pollution mitigation mechanism.[75] Therefore, if cloud seeding focuses on increasing precipitation for ski resorts, agriculture, and winter snowpack, disadvantaged communities who are unlikely to be near these areas are less likely to receive precipitation, and therefore less likely to receive the pollution mitigation benefits of rain.[76] This is of particular concern because disadvantaged communities are more likely to live in high pollution environments.[77]

The previously mentioned risk of harm from silver iodide used in cloud seeding is likely to be disproportionately incurred by those in disadvantaged communities because of preexisting conditions and lack of access to health care.[78] Also, those in disadvantaged communities are more likely to live in flood-prone areas and therefore more likely to experience harm from flooding that occurs after some cloud seeding operations.[79]

Not only are the potential harms from cloud seeding disproportionately experienced in disadvantaged communities, but the benefits are disproportionately isolated to more affluent communities, creating an even more disparate cost-benefit outcome. Unfortunately for those in disadvantaged communities, politicians and those with political power are more likely to experience the benefits and be protected from the harms, thus creating a biased perspective from decisionmakers regarding cloud seeding.

For example, people in affluent communities are far more likely than those from disadvantaged communities to purchase a $299

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75. *See* Jennifer Chu, *Can Rain Clean the Atmosphere?*, MIT NEWS (Aug. 28, 2015), https://news.mit.edu/2015/rain-drops-attract-aerosols-clean-air-0828.

76. *See id.*

77. *See* AMER. LUNG ASS'N, *supra* note 71.

78. *See, e.g.*, Bob Hughes, *Pre-Existing Conditions: Is Poverty on the List?*, MO. FOUND. FOR HEALTH (Feb. 19, 2019), https://mffh.org/news/pre-existing-conditions-is-poverty-on-the-list/; Lillian Witting, *Limited Access: Poverty and Barriers to Accessible Health Care*, NAT'L HEALTH COUNCIL (Jan. 20, 2023), https://nationalhealthcouncil.org/blog/limited-access-poverty-and-barriers-to-accessible-health-care/.

79. *See* Leslie Kaufman, *The Truth About Flood Risk Can Worsen American Inequality*, BLOOMBERG (June 29, 2020, 6:00 AM), https://www.bloomberg.com/news/articles/2020-06-29/the-truth-about-flood-risk-can-worsen-american-inequality.

single-day lift ticket at Vail Ski Resort and benefit from the increased snowfall from the cloud seeding conducted there.[80] These people are also more likely to engage in white-water rafting vacations that benefit from melting snowpack as a result from cloud seeding.[81] And large farms run by large corporations are more likely to conduct cloud seeding operations when compared to smaller, family-run farms.

Finally, those in disadvantaged communities are unlikely to have the resources necessary to alter these disparate outcomes. Under the current regime, cloud-seeding projects are often funded through cost-sharing agreements between state and local governments and private parties such as large farmers and ski resorts.[82] Members of disadvantaged communities likely do not have the political connections to foster such funding. And what political capital they do have is likely to be spent on more pressing, and more salient matters.

IV. CASE LAW

Despite the relatively unregulated nature of cloud seeding, its widespread use for over eighty years, and the potential for catastrophic harm, there is little case law on the practice.[83] This is perhaps due to the awareness that attempts to impose liability for cloud seeding operations are nearly impossible because of the difficulty of proving causation. The following is the relevant case law directly and indirectly related to cloud seeding:

Dodd v. McLeod: While not a cloud seeding case, this is arguably the first weather-modification case, and it illustrates the problem of proving causation.[84] The case is from the 1800s and involves a defendant minister who organized a collective prayer service to pray for rain amidst a severe drought.[85] The prayer service was followed by a severe thunderstorm.[86] The plaintiff—who had objected to the prayer service, believing that it constituted an inappropriate tampering with nature—had his hay barn burned down after it was struck by

80. *See Lift Tickets*, VAIL, https://www.vail.com/plan-your-trip/lift-access/tickets.aspx?startDate=03%2F07%2F2024&numberOfDays=1&ageGroup=Adult (last visited Apr. 2, 2024); David O. Williams, *Cloud Seeding Study Validates Ski Industry Staple*, ASPEN JOURNALISM (Feb. 25, 2020), https://aspenjournalism.org/cloud-seeding-study-validates-ski-industry-staple/.

81. *See Cloud Seeding*, COLO. RIVER DIST., https://www.coloradoriverdistrict.org/cloud-seeding/ (last visited Apr. 5, 2023).

82. *See* Dinneen, *supra* note 18.

83. *See* Jones, *supra* note 4, at 1167.

84. *See* Johnson*, supra* note 23, at 76.

85. *See id.* at 76–77.

86. *See id.* at 77.

lightning.[87] The case was dismissed because the minister had prayed only for rain, not lightning, and the plaintiff was unable to prove that the prayers caused his hay barn to burn down.[88]

Adams v. California: Plaintiff was unable to prove that snowpack augmentation seeding was the cause of a flooding that resulted in death and millions of dollars in damage.[89] Plaintiff lost at trial due to an inability to prove causation.[90]

Slutsky v. City of New York: This case involved the owners of a year-round vacation resort who sought a temporary injunction preventing the City of New York from cloud seeding, arguing that rainfall would be harmful to their business.[91] The court held that plaintiffs failed to prove that cloud seeding would cause irreparable injury and that plaintiffs "clearly have no vested property rights in the clouds or the moisture therein . . . ."[92] The court went further and maintained that the balance of interests is in favor of how the cloud seeding would promote the general welfare and public good against the purely speculative dangers alleged by the plaintiffs.[93]

Reinbold v. Sumner Farmers, Inc.: Plaintiff who was downwind from a precipitation enhancement project sued the operator and sponsor.[94] Plaintiff ultimately lost because testimony did not establish that the cloud seeding materials used were found on plaintiff's property, and therefore, there was no physical, causal connection proven.[95]

Claims against the City of San Diego: San Diego hired Charles M. Hatfield to engage in cloud seeding operations which were followed by torrential rain, washing out a dam, resulting in death and property damage.[96] Multiple lawsuits were filed against the city

87. *See id.*

88. *See id.*

89. *Adams v. California*, Civil No. 10112 (Super. Ct. Sutter Cnty., Cal. Apr. 6, 1964).

90. *See id.*

91. *See Slutsky v. New York*, 97 N.Y.S.2d 238, 239 (Sup. Ct. 1950).

92. *Id*.

93. *Id.* at 240.

94. *See* Reinbold v. Sumner Farmers, Inc. No. 2734-C (Cir. Ct. Tuscola Cnty., Mich., 1974).

95. *See* Ray J. Davis & Pierre St.-Amand, *Proof of Legal Causation in Weather Modification Litigation: Reinbold v. Sumner Farmers, Inc., and Irving P. Krick, Inc.,* 7 J. WEATHER MODIFICATION 127, 140 (1975).

96. *See Who Owns the Clouds?*, supra note 1, at 43–44.

totaling almost one million dollars.[97] The city was successful in having the cases dismissed on the grounds "that the rain was an act of God."[98]

First English Evangelical Lutheran Church v. County of Los Angeles: In this, the only Supreme Court case involving cloud seeding, plaintiffs purchased church land in 1957.[99] In 1977, a forest fire denuded upstream hills, resulting in plaintiff's land becoming a serious flood hazard.[100] The very next year, following a cloud seeding operation, a storm produced eleven inches of rain in two days, flooding the church and destroying the buildings.[101] In response to the flooding, Los Angeles adopted an ordinance barring the construction of buildings in the interim flood protection area.[102] Plaintiff's lawsuit includes two claims. The first cause of action alleges that the defendants are liable for dangerous conditions on their upstream land.[103] The second cause of action sought an inverse condemnation and a tort action for the cloud seeding operation.[104] The Supreme Court reversed and remanded the case based primarily on the issue of whether the just compensation clause requires the government to pay for temporary regulatory takings.[105] But the California Court of Appeals did grant a motion for nonsuit by the defense, dismissing the attempt to apply strict liability for cloud seeding.[106]

Saba v. City of Bismarck: Plaintiff was unable to prove that weather modification was the cause of their flooded property.[107] While the court initially granted Plaintiff's temporary restraining order, it was not made permanent as expert testimony led the court to conclude that Plaintiff failed to prove causation.[108]

Southwest Weather Research, Inc. v. Rounsaville: Plaintiffs were cattle ranchers who alleged that hail suppression operations occurring

97. *See id.* at 44.

98. *Id*.

99. *See* First Eng. Evangelical Lutheran Church v. County of Los Angeles, 482 U.S. 304, 307 (1987).

100. *See id.*

101. *See id.*

102. *See id.*

103. *See id.* at 308.

104. *See First Eng. Evangelical Lutheran Church*, 482 U.S. at 308.

105. *See id.* at 317–18, 322.

106. *See id.* at 309, n.3.

107. *See* Saba v. City of Bismarck, Civil No. 25379 (4th Jud. Dist. Ct., N.D. 1974).

108. *See id.*

over their property denied them valuable rain.[109] The court granted a temporary injunction, explaining that "the landowner is entitled to such precipitation as Nature deigns to bestow. . . . It follows, therefore, that this enjoyment of or entitlement to the benefits of Nature should be protected by the courts if interfered with improperly and unlawfully."[110] While the injunction only pertained to the airspace directly over the plaintiff's property,[111] it is a unique case in that Plaintiffs successfully proved causation against cloud seeding operators.[112] However, it is important to note that this finding was only used to acquire a very limited injunction, not to impose any liability on the cloud seeding operation.

Pennsylvania National Weather Ass'n v. Blue Ridge Weather Modification Ass'n: Plaintiffs sought an injunction against the defendant's hail suppression operations arguing that it resulted in severe drought.[113] While the court maintained that "[i]t seems to us that one of the elements of land in its 'natural condition' must be weather in its natural form, including all forms of natural precipitation. . . . If we conclude that weather in its natural form is a natural incident of land ownership, it also follows that we must conclude that a landowner has some 'right' in the clouds, or more specifically, in the moisture in the clouds."[114] It nevertheless denied the injunction based on a lack of causation, holding that the plaintiffs could not prove "more than the *possibility* of future harm."[115]

Lunsford v. U.S.: After a flash flood in South Dakota in 1972 led to property damage and over 200 deaths, Plaintiffs filed suit alleging that the cloud seeding that preceded the flood, conducted by a contractor working for the Bureau of Reclamation of the U.S. Department of the Interior, was inherently dangerous and negligently

109. Sw. Weather Rsch., Inc. v. Rounsaville, 320 S.W.2d 211, 212–14 (Tex. Civ. App. 1958).

110. *Id.* at 216.

111. The court explicitly explained, "We do not mean to say or imply . . . that the landowner has a right to prevent or control weather modification over land not his own." *Id.*

112. *See id.* at 216 (stating "[t]here is ample evidence here to sustain the fact findings of the trial court that clouds were destroyed over property of appellees by operations of the appellants."); *see also* Sw. Weather Rsch., Inc. v. Jones, 327 S.W.2d 417, 417 (Tex. 1959).

113. *See* Pa. Nat'l Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 749, 751–52 (Ct. Com. Pl. Pa. 1968).

114. *Id.* at 756.

115. *Id.* at 762 (emphasis in original).

conducted under threatening weather conditions.[116] Regarding an interlocutory appeal, the court rejected Plaintiffs' motion to strike the government's immunity defense based on the Flood Control Act of 1928, 33 USC § 702.[117] The case was ultimately dismissed on class action procedural grounds.[118]

Center for Biological Diversity v. U.S. Bureau of Land Mgmt.: The court recognized cloud seeding programs as a reasonable method by the Bureau of Land Management to enhance groundwater recharge, thus concluding that the Bureau did not violate the National Environmental Policy Act by inadequately considering mitigation measures.[119]

V. CAUSATION

As demonstrated in the previous case law section, causation in weather-modification cases is "exceedingly difficult, if not impossible, to prove."[120] This is because causation in this context would require the following: "(1) the weather-modification attempt in question actually altered the weather, (2) the modification of the weather was, in fact, the cause of the plaintiff's damage, and (3) the damage would not have occurred otherwise."[121]

This inability to prove causation applies to nearly every conceivable theory of civil liability including trespass, private nuisance, negligence, res ipsa loquitur, strict liability, and negligence per se.[122] It is well settled in the scientific community that cloud seeding operations increase precipitation in the long run.[123] Unfortunately for plaintiffs, these longitudinal studies are

116. Lunsford v. U.S., 570 F.2d 221, 222–23 (8th Cir. 1977).

117. *See id.* at 570 F.2d at 227, 227–31.

118. *Id.* at 230.

119. *See* Ctr. for Biological Diversity v. U.S. Bureau of Land Mgmt., No. 2:14-cv-00226, 2017 U.S. Dist. LEXIS 137089, at *10 (D. Nev. Aug. 23, 2017).

120. Johnson, *supra* note 23, at 85.

121. Jones, *supra* note 4, at 1170.

122. *See* MacKenzie L. Hertz, *It's Raining, It's Pouring, Weather Modification Regulation is Snoring: A Proposal to Fill the Gap in Weather Modification Governance*, 96 N.D. L. REV. 31, 38–45 (2021). However, note that the two states of Wisconsin and Colorado maintain that unauthorized cloud seeding operations—including operations that violate the terms of a cloud seeding permit—constitute negligence per se. *See* WIS. STAT. ANN. § 93.35(14)(d) (West 2024); COLO. REV. STAT. ANN. § 36-20-123(2) (West 2024).

123. *See* Koh Ewe, *How Cloud Seeding Works and Why It's Wrongly Blamed for Floods From Dubai to California*, TIME (Apr. 17, 2024, 7:45 AM), time.com/6967836/dubai-floods-cloud-seeding-rain-blame-climate-change/.

insufficient.[124] Plaintiffs need to demonstrate that but-for a specific cloud seeding incident, the damages in question would not have happened.[125] This is nearly impossible because cloud seeding can only increase the likelihood of producing a given weather outcome; it does not guarantee it.[126] This probabilistic nature of cloud seeding is further illustrated in the variability of the estimates of the effectiveness of the practice which include increasing precipitation over various time periods from 2 to 5%,[127] 3% to 10%,[128] 7%,[129] 5 to 10%,[130] 5 to 15%,[131] 10% or more,[132] 8 to 15%,[133] 14%,[134] 3 to 21%,[135] up to 25%,[136] and "6.3 to nearly 29 percent."[137] Notice that none of these

124. Simon, *supra* note 9, at 215 ("[T]he complexity of weather modification science is such that, in practice, it would be impossible to demonstrate that a single seeding operation has increased precipitation to a degree that contributed to a particular damage."); Sho Sato, *The Role of Local Governmental Units in Weather Modification: California*, *in* CONTROLLING THE WEATHER: A STUDY OF LAW AND REGULATORY PROCEDURE 221, 239 (Howard J. Taubenfeld ed., 1970) ("[W]hen the state of the art is such that the complainant faces a virtually impossible task of carrying his burden of proving the amount of augmentation at a given place at a given time, a complainant is effectively denied relief.").

125. *See* Melissa Currier, Note, *Rain, Rain, Don't Go Away: Cloud Seeding Governance in the United States and a Proposal for Federal Legislation*, 48 U. PAC. L. REV. 949, 958 (2017).

126. Jones, *supra* note 4, at 1171.

127. *See* Heather Sackett, *Vail Resorts' Cancellation of Cloud Seeding This Winter Could Mean Less Water in Streams*, VAIL DAILY (Nov. 27, 2020), https://www.vaildaily.com/news/vails-cancellation-of-cloud-seeding-this-winter-could-mean-less-water-in-streams/.

128. *See* Alex Cabrero, *Cloud Seeding Efforts in Utah Will Increase to Bring More Snow*, KSL TV 5 (Sept. 29, 2023, 5:40 AM), https://ksltv.com/590072/cloud-seeding-efforts-in-utah-will-increase-to-bring-more-snow/.

129. *See* Podmore, *supra* note 17.

130. *See* Jerd Smith, *As Pandemic Hammers Its Finances, Vail Pulls Out of State Cloud Seeding Program*, THE COLO. SUN (Nov. 11, 2022, 4:54 PM), https://coloradosun.com/2020/11/27/vail-finances-colorado-cloud-seeding/.

131. *See* Vélez-León, *supra* note 31, at 150.

132. *See* DESERT RSCH. INST., *supra* note 17.

133. *See* Jonathan A. Jennings & Ronald T. Green, *Rain Enhancement of Aquifer Recharge Across the West Texas Weather Modification Association Target Area*, 46 J. WEATHER MODIFICATION 45, 52 (2014).

134. *See* DESERT RSCH. INST., *supra* note 17.

135. *See* Don A. Griffith et al., *30+ Winter Seasons of Operational Cloud Seeding in Utah*, 41 J. WEATHER MODIFICATION 23, 23 (2009).

136. *See* Jack Queen, *How Cloud Seeding is Boosting Snowfall Totals at Colorado Ski Areas*, STEAMBOAT PILOT & TODAY (Oct. 5, 2017), https://www.steamboatpilot.com/news/how-cloud-seeding-is-boosting-snowfall-totals-at-colorado-ski-areas/.

137. *Id.*

estimates are close to 51%, which would be needed for but-for causation.

The difficulty of proving causation in such a probabilistic practice is made even more difficult when one considers the practical aspects of attempting to do so. Expert witnesses would no doubt need to be employed. Not only is this costly, but such witnesses may be hesitant to testify for a plaintiff who suffered harm from a cloud seeding operation out of fear that such testimony may harm advances in the area of study.[138] And even in the event that an expert was willing to testify for the prosecution, the defense would more easily be able to obtain a competing witness. Given the scientific and probabilistic nature of the competing testimonies, juries are likely to be confused, and this confusion is likely to be interpreted as the plaintiff not having met his burden of proof.[139]

Attempting to prove causation by presenting historical statistics on rainfall, hail, or snowpack is likewise problematic for potential plaintiffs. For example, simply showing that a weather event was abnormal does little to prove that a cloud seeding operation caused the event because abnormal weather events also happen in the absence of cloud seeding. Furthermore, such statistics are generally inadmissible as evidence because they are evidence of out-of-court experiments.[140] In order to be admissible at trial, experiments generally need to be conducted under a controlled environment similar to those that instigated the litigation.[141] And it is impossible to perfectly recreate the exact temperature, air pressure, moisture content of the clouds, windspeed, wind direction, and seeding insertion point that was originally present.

An additional causation hurdle exists when multiple cloud seeding operators are in operation. This is because it would be even more difficult to prove which operator caused the plaintiff's damages. Potentially, such a plaintiff could attempt to use the theory of market share liability to impose liability on all operators based on their market

138. *See* Jones, *supra* note 4, at 1172.

139. *See id.* at 1173 ("After all of this has gone on, the defendants will have their own statistician testify, and more likely than not, the jury will become confused or unconvinced. Unless the plaintiff convinces the jurors, they must find for the defendant.") (quoting R. DEWSNUP & D. JENSEN, LEGAL ASPECTS OF WEATHER MODIFICATION IN UTAH 3, 27 (1977)).

140. *See* Ray Jay Davis, *Special Problems of Liability and Water Resources Law*, *in* WEATHER MODIFICATION AND THE LAW 103, 107 (Howard J. Taubenfeld ed., 1968) (citing Hammons v. Schrunk, 305 P.2d 405, 410 (Or. 1956)).

141. *See id.*

share of cloud seeding in the area.[142] However, such an attempt would likely be viewed as increasing the already tenuous causal link between defendant's actions and plaintiff's harm.

Some have proposed a burden-shifting framework to get around the near-fatal causation hurdle.[143] Such proposals are often comparable to the National Vaccine Injury Compensation Program, but conducted at the state level.[144] For example, a state would set up a Weather Modification Trust Fund to compensate those harmed.[145] A table could proscribe specific weather modification operations compared to associated injuries, such as a specific time period after hail-mitigation efforts during which certain types of enumerated injuries would be covered.[146] Such an injured party would receive a presumption that their injury was caused by weather modification, shifting the burden to the weather modifier to prove otherwise.[147] However, this burden-shifting framework is ill-advised as it only negates the causation issue as applicable to potential plaintiffs; the defendant cloud seeding operators now shoulder the causation burden. Just as the nature of weather and probabilistic effects of cloud seeding makes it nearly impossible to prove a weather outcome was caused by cloud seeding, it would be nearly impossible for a cloud seeding operator to prove that cloud seeding efforts did not cause the weather that led to injury.

Another proposed solution for the causation issue is to implement a lesser standard of proof for civil suits against those who engage in cloud seeding.[148] For example, a "benefit of the doubt" burden of proof could be statutorily proscribed for these cases.[149] Under such a framework, if the plaintiff could show that the evidence weighs equally in favor of both sides, he would prevail.[150] This is similar to the lesser standard currently applied to the Veterans Benefits

142. *Id.* at 108; *see, e.g.*, Frank J. Giliberti, *Emerging Trends for Products Liability: Market Share Liability, Its History and Future*, 15 TOURO L. REV. 719, 720 (1999) (defining market share liability as the theory that "permits a products liability cause of action to be stated where the plaintiff cannot identify either one or a small group of defendants potentially responsible for the harm and cannot join all or substantially all of the defendants in the action.").

143. *See* Hertz, *supra* note 122, at 56.

144. *See id.*; Simon, *supra* note 9, at 193.

145. *See* Hertz, *supra* note 122, at 58.

146. *See id.*

147. *See id.*

148. *See id.* at 59.

149. *See id*.

150. *See* Hertz, *supra* note 122, at 59.

Program.[151] While this is less petitioner-friendly than the previously mentioned burden-shifting framework, it would lead to some of the same problems. It may disincentivize those wanting to engage in cloud seeding as the potential harms from weather related disasters that could correspond to cloud seeding have the potential to be hundreds of millions of dollars.[152]

VI. CURRENT REGULATORY ENVIRONMENT

Given the lack of liability for cloud seeding and its widespread use, there is unfortunately little regulation of the practice.[153] Because cloud seeding is controlled at the state rather than federal level,[154] there is no centralized regulatory regime for the practice.[155] And even at the individual state level, most states' reporting requirements are minimal.[156] In only one state, Montana, are all weather modification operations required to conduct an Environmental Impact Assessment.[157]

This lack of comprehensive recordkeeping regarding cloud seeding potentially exacerbates the harm to disadvantaged communities due to the potential negative effects of climate change which these communities already face.[158] Human efforts to alter the weather have likely had some effect on climate change—for better or worse.[159] Therefore, to better understand climate change, we must be able to analyze weather modification efforts. This requires a central regulatory regime and a central repository for records of the practice.

VII. COMPARISON TO WATER RIGHTS

The lack of federal oversight in current regulation of traditional water rights in the United States serves as a cautionary tale. Much like current cloud seeding and geoengineering law, regulation of

151. *See id.*

152. *See id.*

153. *See* Karen Bradshaw & Monika U. Ehrman, *Cloud Seeding, Wildfire Smoke Emissions, and Solar Geoengineering: Why is Climate Modification Unregulated?*, 35 GEO. ENV'T L. REV. 459, 459 (2023).

154. *See* Simon, *supra* note 9, at 151.

155. *See* Bradshaw & Ehrman, *supra* note 153, at 467.

156. *See* Jianlin Chen, *Optimal Property Rights for Emerging Natural Resources: A Case Study on Owning Atmospheric Moisture*, 50 U. MICH. J.L. REFORM 47, 74 (2016).

157. *See* MONT. CODE ANN. § 85-3-202 (WEST 2023).

158. *See* Harvey, *supra* note 52.

159. *See* Bradshaw & Ehrman, *supra* note 153, at 468.

traditional water rights is governed almost exclusively by state law.[160] Largely due to differences in water scarcity, states have developed different regulatory systems to govern access to water resources.[161] This has led to a complex patchwork of legal access to water in the United States, which, because water is a necessary resource for human existence and frequently crosses state boundaries, creates problems including inequities in water use and access.

In the eastern United States, where water has historically been plentiful, use of surface water is typically governed by riparian rights systems.[162] While the precise contours of riparian rights can vary by state, the basic notion is that an owner of property that abuts a body of water has the right to have that body of water continue to flow across the land, subject to the rights of other landowners to make reasonable use of the water.[163] What constitutes a "reasonable" use of the water is an intensely fact-based inquiry determined by the circumstances of each case.[164] As uses for water have increased, and as climate change has impacted access to water, many eastern states have moved to a system commonly called "regulated riparianism."[165] This system maintains many of the same principles of the common-law riparian system, but administers the water rights through an administrative permitting system that is intended to protect the public interest in surface water as well as the rights of the property owners.[166]

In the western United States, where scarcity of water has always been an issue, water rights developed on a different trajectory, and a system called "appropriative rights" or "prior appropriation" developed.[167] This system developed largely from large mining settlements that rapidly grew in California due to the gold rush.[168] Miners needed water both for mining and to live, but did not have title to the land the water was on, as most of the land was at that time owned by the government.[169] However, the location of the mine frequently

160. *See* Joseph W. Dellapenna, *The Evolution of Riparianism in the United States*, 95. MARQ. L. REV. 53, 53 (2011).
161. *See id*.
162. *See id*.
163. *See id.* at 55.
164. *See id.* at 82.
165. Dellapenna, *supra* note 160, at 85–86.
166. *See id.* at 86–87.
167. *Id.* at 53–54.
168. *See id.* at 77.
169. *See id.* at 78.

did not abut a waterway.[170] Thus, miners simply diverted waterways or used water as needed, and a legal system developed whereby the senior user of water had dominant rights to water use, as long as the water was being put to a beneficial use.[171] While the prior appropriation doctrine has certainly evolved over time, its basic principles remain a bedrock of water rights in many western states.[172]

To add to this complexity, groundwater rights are often regulated differently than surface water rights. In most states, groundwater rights have historically been considered property rights, allowing for virtually unlimited pumping by property owners who own the property above the groundwater source.[173] Common-law groundwater rights developed at a time when the scientific understanding of groundwater was very limited.[174] Since scientific understanding at the time did not contemplate how groundwater moved, exploiting it as a resource was not limited in the same way that surface water was under riparian rights.[175] While the law has evolved to restrict groundwater pumping in ways that it wasn't previously in the common law, many commentators note that this history of unlimited pumping of groundwater still affects modern groundwater law, resulting in an overuse of this valuable resource.[176]

This complex and inconsistent regulation of water rights throughout the United States creates problems. At the time these laws developed, society did not have a full understanding of the water cycle, weather, and how groundwater and surface water sources interact with each other.[177] Additionally, water is an inherently interstate, and in some ways a global resource. Thus, how one state regulates the use of water may affect access to water in another state, whether through the depletion of an interstate aquifer, pollution, or redirection of surface

170. *See* Dellapenna*, supra* note 160, at 79.

171. *See* Lawrence J. MacDonnell, *Prior Appropriation: A Reassessment*, 18 U. DENV. WATER L. REV. 228, 242 (2015).

172. *See generally id.* at 262–80 (discussing the evolution of prior appropriation water rights); *see also Water Rights*, COLO. DIV. OF WATER RES., https://dwr.colorado.gov/services/water-administration/water-rights (last visited May 17, 2024) (discussing the prior appropriation of water rights system).

173. *See* Dave Owen, *Taking Groundwater*, 91 WASH. U. L. REV. 253, 266 (2013) (discussing the evolution of groundwater rights in the U.S.).

174. *See id*.

175. *See id.* at 267–68 (referencing older water law opinions describing the movement of groundwater as secret and occult).

176. *See id.* at 255, 266.

177. *See id.* at 266–67 (discussing the lack of scientific understanding in the development of water law, particularly groundwater).

water.[178] Under the United States' federalist legal system, states are often rightfully touted as "laboratories of democracy" that are allowed great latitude in experimenting with different forms of regulation.[179] However, when the subject of that regulation is water, this experimentation can result in an inconsistent, sub-optimal race-to-the-bottom regulatory environment that pits the states against each other.[180]

The current state of water use in the United States, and the world, highlights the problem with this piecemeal regulatory environment. Groundwater in the United States is being depleted at a rate that many argue is unsustainable.[181] Discharge into interstate waterways, oftentimes from agriculture, is causing environmental problems, including a "dead zone" in the Gulf of Mexico.[182] In addition to these problems caused from misuse of resources, many argue that climate change has led to altered weather patterns that will affect the use of water, including droughts in some areas and unusual flooding in others.[183] These problems are an inherently difficult problem to address from a regulatory standpoint, and are made all the more difficult when regulated at the state level.

These nuanced problems with water regulation and the potential for inequitable outcomes highlight why it is important to regulate

178. *See, e.g.*, Chiara Kalogjera-Sackellares, *Reviving the Mississippi River: Riparianism and Equitable Remedies*, 34 TUL. ENV'T. L.J. 61, 70–72 (2021) (discussing the history of equitable apportionment litigation, in which one state sues another before the Supreme Court of the United States to apportion water rights).

179. New State Ice Co. v. Liebmann, 285 U.S. 262, 279 (1932) (stating that the states have authority to "indulge in experimental legislation . . . ."); *id.* at 311 (Brandeis, J., dissenting) (reiterating that "[i]t is one of the happy incidents of the federal system that a single courageous state may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country.").

180. *See* Kalogjera-Sackellares, *supra* note 178, at 70–72; *see also* Jamison E. Colburn, *Rethinking the Supreme Court's Interstate Water Jurisprudence*, 33 GEO. ENV'T L. REV. 233, 234–36 (2021) (providing an overview of interstate water disputes for the Supreme Court).

181. *See* Mira Rojanasakul et al., *America Is Using Up Its Groundwater Like There's No Tomorrow*, N.Y. TIMES (Aug. 28, 2023), https://www.nytimes.com/interactive/2023/08/28/climate/groundwater-drying-climate-change.html (discussing that 90% of the water systems in the United States are severely depleted).

182. *See* Kalogjera-Sackellares, *supra* note 178, at 63–64 (discussing how agricultural run-off in the Midwest travels down the Mississippi to the Gulf of Mexico, creating environmental problems).

183. *See Water – at the Center of the Climate Crisis*, U.N., https://www.un.org/en/climatechange/science/climate-issues/water (last visited May 17, 2024).

cloud seeding and geoengineering at the federal level. Like the movement of water, weather patterns are not contained within state boundaries. If the law regarding cloud seeding and geoengineering is allowed to continue to evolve at the state level virtually unchecked at the federal level, the already inconsistent and inequitable standards will continue to grow more disparate.

VIII. FEDERAL REGULATION SOLUTION

Given that lack of regulation and lack of recordkeeping are significant problems, comprehensive federal regulation is needed for cloud seeding operations. Such regulation would provide numerous benefits over the existing regime of minimal state regulation.[184] Most of these benefits stem from the ineffective nature of state regulation, improved recordkeeping, and uniformity that would take place under a federal regime. Congress clearly has the authority to regulate weather alteration practices among the states under the current, expansive interpretation of the Commerce Clause.[185] Activities that have a substantial effect on interstate commerce are covered under the Commerce Clause.[186] Weather alteration operations affect farming, winter and summer recreation, hydroelectric energy production, and natural disasters that require a national response.

Because state lines are completely ineffective at containing weather, state regulations are not ideal, as one states' laws on cloud seeding may affect another state. There are already cloud seeding operations that are very close to state lines.[187] And cloud seeding has been demonstrated to affect the weather 100 miles away.[188] This is similar to how the often intra-state nature of riparian water rights

184. *See* Currier, *supra* note 125, at 965–68; Hertz, *supra* note 122, at 45 (stating "though an analysis of states' governance shows variation in type and comprehensiveness, all states have one thing in common: none offer an adequate avenue for relief from harm that may arise from weather modification.").

185. *See* Brendan Woodruff, *When It Rains, It Pours: Weather Modification Law in the United States and a Proposal for Federal Control*, 41 PACE ENV'T L. REV. 406, 421 (2024).

186. *See* Wickard v. Filburn, 317 U.S. 111, 124 (1942) (citing United States v. Wrightwood Dairy Co., 315 U.S. 110, 119 (1942)).

187. *See, e.g.*, *Cloud Seeding Operations*, DRI, https://www.dri.edu/cloud-seeding-program/current-cloud-seeding-operations/ (last visited Jan. 15, 2025) (showing cloud seeding operations on the California / Nevada border and the Nevada / Oregon border).

188. *See Weather Modification Frequently Asked Questions*, TEX. DEP'T OF LICENSING & REGUL., https://www.tdlr.texas.gov/weather/weatherfaq.htm (last visited Dec. 12, 2024).

requires federal involvement.[189] There is even precedent for contentious interstate disputes as when the Idaho Attorney General threatened to file suit in the Supreme Court if Washington moved forward with a modest cloud seeding program.[190] Federal regulation is further supported by the federal government's ownership of large amounts of land in states that engage in cloud seeding,[191] and the existing role of the federal government in negotiating water rights disputes involving Indian reservations.[192] Federal regulation of the matter would not only address such disputes between states when they arise but help avoiding such disputes altogether by providing a valuable framework for settling disputes, thus providing valuable legal predictability. Finally, cloud seeding is increasingly being performed by drones,[193] and the usage of drones is already regulated by the federal government.[194]

Creating a centralized repository for cloud seeding data would provide the ability for more thorough investigations into the practice. This would allow for a more evidence-based approach leading to increased efficiencies. This would also provide more data to measure specifically the effects of the practice on disadvantaged communities. Finally, increased recordkeeping requirements and a centralized repository would help provide data to make determinations regarding causation and potential legal liability. With the following increased knowledge regarding cloud seeding, a more robust cost-benefit analysis could be conducted. This is also needed to accurately assess potential effects—harmful or beneficial—that the practice may have on climate change. For example, Texas is currently experimenting

189. *See, e.g.*, Texas v. New Mexico, 602 U.S. __ (2024).

190. *See* Ray Jay Davis, *Weather Modification Interstate Legal Issues*, 15 IDAHO L. REV. 555, 556 (1979).

191. *See Federal Land Ownership by State*, BALLOTPEDIA, https://ballotpedia.org/Federal_land_ownership_by_state (last visited Apr. 22, 2024). For example, the federal government owns over 45 million acres in California, over 24 million acres in Colorado, over 33 million acres in Utah, and over 56 million acres in Nevada. *See id.*

192. *See* Leonard R. Powell, *The Supreme Court and Tribal Water Rights*, AM. BAR ASS'N (Jan. 22, 2024), https://www.americanbar.org/groups/crsj/publications/human_rights_magazine_home/native-american-issues/supreme-court-and-tribal-water-rights/.

193. *See* Andrew Craft, *Making It Rain: Drones Could be the Future for Cloud Seeding*, FOX NEWS (Mar. 2, 2017, 11:25 PM), https://www.foxnews.com/tech/making-it-rain-drones-could-be-the-future-for-cloud-seeding.

194. *See Drones*, FED. AVIATION ADMIN., https://www.faa.gov/uas (last visited Oct. 26, 2024).

with using new chemicals in cloud seeding.[195] It is important that information regarding potential externalities from such experimentation are disseminated throughout the United States and not just limited to Texas.

The increased uniformity by moving from the current, state-based regime to a federal one would also provide numerous benefits. It would help reduce the current regulatory uncertainties which function to prevent progress in weather modification.[196] With more regulatory certainty, cloud seeding businesses would be more likely to invest in research and development which could lead to improvements in efficiency and safety.[197] It would reduce the risk of a potential "race to the bottom" whereby states are incentivized to produce as much precipitation as possible from clouds while over their state, leaving less potential precipitation for other states. Uniformity in permitting and recordkeeping would also create inefficiencies in cloud seeding operators who work in multiple states. Increased uniformity would help reduce the risk from cloud seeding operators experimenting with alternative chemicals that could potentially cause great harm.[198] Finally, relief efforts such as compensation programs would likely be more efficient at the federal level. This is because such efforts would be similar to an insurance program whereby geographic diversity would help dissipate risk.[199]

The federal agency could either be created as a standalone agency or an extension of an existing federal entity such as the National Science Foundation. The latter option would likely produce efficiencies in both information sharing and cost savings as the purpose of this new agency would be consistent with the stated purpose of the National Science Foundation which is "to [p]romote the progress of science; [to a]dvance the national health, prosperity,

195. *See, e.g.*, *Cloud Seeding Pilot Program Passes First Committee*, N.M. POL. REP. (Jan. 24, 2024), https://nmpoliticalreport.com/2024/01/24/cloud-seeding-pilot-program-passes-first-committee/.

196. *See* Alan W. Witt, Note, *Seeding Clouds of Uncertainty*, 57 JURIMETRICS 105, 105 (2016).

197. *See, e.g.*, Brooke Wilson, *Past the Tipping Point, But with Hope of Return: How Creating a Geoengineering Compulsory Licensing Scheme Can Incentivize Innovation*, 27 WASH. & LEE J. C.R. & SOC. JUST. 791, 807 (2021).

198. *See* Witt, *supra* note 196, at 130–31.

199. In other words, if a catastrophic event happened in one state in a given year, the costs would be spread out among the whole national program, rather than just the program in that one state.

and welfare; [to s]ecure the national defense."[200] Additionally, the data compiled from this new agency would likely compliment other federal climate change research programs. This is especially true now that audacious geoengineering projects are being considered to combat climate change.[201]

Federal regulation is further needed because existing federal legislation was not made with cloud seeding in mind. For example, an experimental cloud seeding operator that dispersed potentially harmful chemicals would likely not be liable under the Clean Air Act or the Clean Water Act as both require dispersal from a stationary source.[202]

There have been two major attempts in Congress at passing comprehensive federal weather modification regulation. In 2004, the Weather Modification Research and Technology Transfer Authorization Act was introduced.[203] The bill was audacious, aiming "to develop and implement a comprehensive and coordinated national weather modification policy and a national cooperative Federal and State program of weather modification research and development."[204] The bill ultimately failed, yes, it appears they both died in committee likely due to how the co-chairs of the Committee on Commerce, Science, & Transportation argued that more research into weather modification was needed before federal regulation should be implemented.[205] Just five years later in 2009, a similar bill, the Weather Mitigation Research and Development Policy Authorization Act of 2009 was introduced.[206] This bill also ultimately failed.

The failure of these two bills by wide margins at a time when the efficacy of cloud seeding is largely agreed upon is somewhat puzzling. It may be the result of how politicians are beholden to how their constituents perceive the practice, not the actual evidence behind the

200. *About NSF*, NAT'L SCI. FOUND., https://new.nsf.gov/about (last visited Sept. 22, 2024).

201. *See* Wilson, *supra* note 197, at 800–03.

202. *See* 42 U.S.C.A. §§ 7411(a)(3), (b)(1)(A) (West 2018); 33 U.S.C.A. § 1311(a) (West 2019); 33 U.S.C.A. §§ 1362(12), (14) (West 2019).

203. *See* Weather Modification Research and Technology Transfer Authorization Act, S. 2170, 108th Cong. (2004).

204. *Id.* § 2.

205. *See* Currier, supra note 125, at 961–62.

206. *See* Weather Mitigation Research and Development Policy Authorization Act of 2009, S. 601, 111th Cong. (2009). The language of the Bill would have clearly covered cloud seeding as it included "changing or controlling, or attempting to change or control, by artificial methods the natural development of atmospheric cloud forms or precipitation forms in the troposphere." *Id.* § 4.

practice. For example, if constituents believe the practice is junk science, does more harm than good, or violates their religious principles, a politician is unlikely to embark on an extensive reeducation campaign to change their minds. While it is outside the primary scope of this Article to discuss legislative pragmatism, perhaps a future bill which includes as its stated purpose the equal administration of weather modification operations to protect members of disadvantaged communities would be more successful.

IX. PUBLIC NOTICE AND COMMENT

Public participation in the process of cloud seeding regulation is another key factor in protecting the rights of disadvantaged groups. This includes both the ability for public comment before proposed cloud seeding operations are permitted and the access to information regarding cloud seeding so that the effects can be better measured. Notice requirements regarding cloud seeding operations are nonexistent in most states.[207] And some of the states that do require notice do not allow for any public input.[208]

Providing notice and comment requirements will help ensure that cloud seeding projects are implemented with an equitable cost benefit analysis, rather than just considering the best interest of the operators and wealthy paying customers. While those in disadvantaged communities themselves likely do not have the time nor technical know-how to assess and respond to proposed cloud seeding operations, groups that represent their interests could do so.

This increase in transparency afforded by public notice and participation may provide the additional benefit of mitigating conspiracy theories regarding weather modification. This is important to the advancement of science in a democracy as there is much false information surrounding related issues. For example, many mistakenly believe conspiracies regarding "chemtrails," whereby entities are allegedly releasing hazardous chemicals from airplanes to enact harmful results such as sterilization, reduced life expectancy, or mind control.[209]

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207. *See* Hertz, *supra* note 122, at 49.

208. *See id.* at 50.

209. *Chemtrails Conspiracy Theory*, HARVARD UNIV.: DAVID KEITH'S RSCH. GRP., https://keith.seas.harvard.edu/chemtrails-conspiracy-theory (last visited Apr. 2, 2024).

CONCLUSION

This first-of-its-kind Article provides the case for federal regulation along with notice and comment requirements for cloud seeding operation on the basis of how the practice disproportionately harms those in disadvantaged communities. This is not an anti-cloud seeding Article nor does it argue for the complete cessation of the practice. Cloud seeding provides numerous benefits such as more rain for farmers, hail suppression, hurricane suppression, fog mitigation, and increased snowfall which helps both summer runoff and ski resort tourism.[210] Furthermore, it provides environmentally friendly advantages, such as the ability to boost the water supply compared to alternatives such as building dams, reservoirs, and pipelines.[211] And the implementation of legal frameworks that result in advantageous and equitable results from cloud seeding could prove valuable for the future implementation of large-scale geoengineering to combat the effects of climate change. Given the potential for cataclysmic harm, it is even more important that such large-scale geoengineering projects implement an equitable cost-benefit analysis and utilize a balanced legal framework such as the one presented in this Article.

210. *See* Brigham, *supra* note 3; Jones, *supra* note 4; Wall, *supra* note 5; AMER. METEOROLOGICAL SOC'Y, supra note 6; Adams, *supra* note 7.

211. Podmore, *supra* note 17.