William & Mary Environmental Law and Policy Review

Volume *46 (2021-2022)*
Issue 1

Article 5

10-1-2021

Enhancing the Weather: Governance of Weather Modification Activities of the United States

Manon Simon

ENHANCING THE WEATHER: GOVERNANCE OF WEATHER MODIFICATION ACTIVITIES IN THE UNITED STATES

MANON SIMON*

ABSTRACT

In the context of climate change, weather modification by cloud seeding, and in particular, precipitation enhancement techniques, has gained a renewed attention from governments. In the United States, several states run weather modification programs to secure freshwater resources and increase both crop and hydroelectricity production. Weather modification techniques were developed post–World War II, and so were the legal arrangements that govern them. Since then, weather modification law has undergone little to no reform. California and Texas are two active users of cloud-seeding technologies but employ very different governance frameworks. This Article assesses the effectiveness of weather modification governance in these two states and argues that reforms are needed to align weather modification legal regimes to principles of environmental governance.

INTRODUCTION

Climate change is likely going to increase the frequency and intensity of extreme weather events, such as droughts and severe storms.[1] To alleviate these risks, states will have to develop adaptation measures to adjust to changing conditions. Weather modification techniques have been utilized for decades to mitigate weather hazards by stimulating precipitation or suppressing hail.[2] In recent years, the United States government

* University of Tasmania, Faculty of Law, Center for Marine Socio-ecology.

[1] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, GLOBAL WARMING OF 1.5 OC: AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5° C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS, IN THE CONTEXT OF STRENGTHENING THE GLOBAL RESPONSE TO THE THREAT OF CLIMATE CHANGE, SUSTAINABLE DEVELOPMENT, AND EFFORTS TO ERADICATE POVERTY 254–55 (Valérie Masson-Delmotte et al. eds., 2018).

[2] Howard T. Orville, *Final Report of the Advisory Committee on Weather Control: Importance of Weather and its Modification*, 39 BULL. AM. METEOROLOGICAL SOC'Y 583, 584,

has shown a renewed interest in the potential for weather modification, like precipitation enhancement, to assist in responding to climate change impacts.[3] In 2003, the National Research Council ("NRC") published a report, *Critical Issues in Weather Modification Research*, calling "for a coordinated national program [to be developed] to conduct a sustained research effort in the areas of cloud and precipitation microphysics, cloud dynamics, cloud modeling, and cloud seeding."[4] However, no such research program has been developed, and weather modification projects are conducted in several states without a comprehensive national framework.[5]

Weather modification by cloud seeding was first experimented in 1946 by scientists working for General Electric.[6] Following this discovery, the U.S. government invested heavily in various weather modification techniques as a means to mitigate weather hazards and increase the production of goods.[7] Precipitation enhancement is a cloud seeding technique developed to increase rainfall and snowfall, to secure freshwater resources, and to increase crop and hydroelectricity production.[8] Today, over fifty countries use cloud-seeding techniques to ensure water, food, and energy security.[9] In the United States, thirty-six active operational programs are conducted in nine states, representing the second largest investment in weather modification techniques in the world, after China.[10] Throughout the 1960s and 1970s, American states have passed legislation to regulate weather modification by cloud seeding.[11] Most of these laws are still in force today.[12]

589, 595 (1957).

[3] ANDREA I. FLOSSMANN ET AL., PEER REVIEW REPORT ON GLOBAL PRECIPITATION ENHANCEMENT ACTIVITIES, at iii (2018).

[4] NAT'L RSCH. COUNCIL, CRITICAL ISSUES IN WEATHER MODIFICATION RESEARCH 4 (2004).

[5] *Id.* at 2.

[6] *See generally* Irving Langmuir, *The Production of Rain by a Chain Reaction in Cumulus Clouds at Temperatures Above Freezing*, 5 J. METEOROLOGY 175–92 (1948).

[7] *See* Vaughn C. Ball, *Shaping the Law of Weather Control*, 58 YALE L.J. 213, 217 (1949).

[8] N. AM. WEATHER MODIFICATION COUNCIL, CLOUD SEEDING: THE ENVIRONMENT & THE CLIMATE, 2 [hereinafter NAWMC], http://www.nawmc.org/publications/Environment%20r11%20press_final.pdf [https://perma.cc/2RVU-675B].

[9] WORLD METEOROLOGICAL ORG., WMO STATEMENT ON WEATHER MODIFICATION 1 (2015) [hereinafter WMO].

[10] ROELOF BRUINTJES, REPORT FROM WMO EXPERT TEAM ON WEATHER MODIFICATION RESEARCH FOR 2012/2013 5 (2013); Wolfgang Gasser, Let it Rain—Weather Modification in Europe, USA, and with a Special Focus on China (Mar. 2016) (study project) (on file with the Technical University of Munich).

[11] *See generally* Ray Jay Davis, *State Regulation of Weather Modification*, 12 ARIZ. L. REV. 35, 43, 49, 52 (1970).

[12] WIS. STAT. § 93.35 (1991); 3 PA. CONS. STAT. § 1101 (1968); COLO. REV. STAT. § 24-33.5

Legal scholars have considered some aspects of weather modification activities, particularly questions of proprietary rights over cloud water[13] as well as liability for detrimental diversion of atmospheric water and for production of harmful weather events.[14] However, few studies have addressed current weather modification governance in the United States, usually focusing on federal laws, whereas weather modification activities are mainly regulated at the state level.[15] This Article fills some of the gaps in the legal literature by identifying essential elements of weather modification regulatory regimes in two states actively engaged in weather modification: California and Texas. As past studies have been essentially doctrinal, this Article also fills research gaps addressing weather modification governance at a project level to assess the effectiveness of weather modification law in practice.

The topic is important for two reasons. First, weather modification is likely to form an increasingly important part of our adaptation to climate impacts. With climate change straining freshwater resources worldwide, there is a renewed interest in developing cloud-seeding programs to prevent water shortage.[16] The United States has been a pioneer and leader in designing legal frameworks to regulate cloud-seeding activities, but in past decades weather modification governance has received little academic scrutiny.[17] An effectiveness evaluation of American weather-modification laws is thus necessary to assess their ability to govern the

---

-714 (2012); TEX. AGRIC. CODE ANN. § 302.003 (2003).

[13] *See generally Who Owns the Clouds?*, 1 STAN. L. REV. 43, 45–46 (1948); Paul Binzak et al., *Rights of the Private Landowner As Against Artificial Rainmakers*, 34 MARQ. L. REV. 262, 264–65 (1951); Ralph M. Wade, *Are There Individual Property Rights in Clouds*?, 15 WYO. L.J. 92, 92–93 (1960); James N. Corbridge Jr. & Raphael J. Moses, *Weather Modification: Law and Administration*, 8 NAT. RES. J. 207, 213 (1968).

[14] *See generally* Stanley Brooks, *The Legal Aspects of Rainmaking*, 37 CAL. L. REV. 114, 115 (1948); Donald D. Stark, *Weather Modification: Water—Three Cents Per Acre-Foot?*, 45 CAL. L. REV. 698, 699, 704–05 (1957); Jack C. Oppenheimer, *The Legal Aspects of Weather Modification*, 1958 INS. L.J. 314, 318, 320 (1958); *Legal Remedies for "Cloud-Seeding" Activities: Nuisance or Trespass?*, 1960 DUKE L.J. 305, 306 (1960).

[15] *See generally* Alan W. Witt, *Seeding Clouds of Uncertainty*, 57 JURIMETRICS 105, 115, 117 (2016); Melissa Currier, *Rain, Rain, Don't Go Away: Cloud Seeding Governance in the United States and a Proposal for Federal Regulation*, 48 U. PAC. L. REV. 949, 956 (2016); Adriana Vélez-León, *Rain on Demand: Regulating Weather Modification Throughout the United States*, 8 GEO. WASH. J. ENERGY & ENV'T L. 148, 149 (2017).

[16] FLOSSMANN ET AL., *supra* note 3, at 2.

[17] 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, 45–46 (2021).

multiplicity of weather-modification projects in a changing climate. Second, the governance of weather modification offers a valuable starting point for potential governance of solar geoengineering—a far more controversial form of climate intervention.[18] It is beyond the scope of this Article to draw lessons from weather modification law for the governance of climate intervention, but this contextual background gives a new impetus to evaluate U.S. weather modification laws.

This Article proceeds in six parts. Part I explains cloud-seeding technologies and associated risks. Part II outlines the history of cloud-seeding research and deployment in the United States, providing the necessary context for the development of law and governance. Parts III and IV present different approaches to cloud-seeding governance, in California and Texas, respectively. Drawing on this analysis, Part V identifies common features in the two states' weather modification regimes and issues that require renewed attention. The conclusion states that a reform of weather modification regulatory frameworks is required, especially if the United States is to move forward with climate intervention.

I. WEATHER MODIFICATION BY CLOUD SEEDING

Precipitation enhancement by cloud seeding refers to deliberate human intervention in the atmosphere to enhance the volume of rainfall.[19] As far back as 1946, American scientists working under the supervision of the Nobel Prize Laureate, Irving Langmuir, discovered that injecting substances like dry ice and silver iodide into certain types of clouds could enhance precipitation processes.[20] Within a few years of this discovery, several states have considered the "obvious" economic and social benefits

---

[18] Solar geoengineering—also known as solar radiation management—is a set of technologies designed to counteract the effects of climate change by reflecting sunlight and decreasing global temperatures. Solar geoengineering schemes are fraught with uncertainties and carry significant environmental risks. Because it is not covered under existing regulatory frameworks, deployment of these emerging technologies will require governance mechanisms that address these risks and uncertainties. Weather modification and solar geoengineering bear many similarities and legislation on weather modification laws have been proposed to regulate research and development of these schemes. *See generally* NAT'L ACADS. SCIS., ENG'G & MED., REFLECTING SUNLIGHT: RECOMMENDATIONS FOR SOLAR GEOENGINEERING RESEARCH AND RESEARCH GOVERNANCE 256 (2021), https://doi.org/10.17226/25762 [https://perma.cc/BW2Y-3YY5].

[19] NAWMC, *supra* note 8, at 2.

[20] *See* Vincent J. Schaefer, *The Early History of Weather Modification*, 49 BULL. AM. METEOROLOGICAL SOC'Y 337, 339–40 (1968).

of modifying the weather.[21] The development of weather modification promised to reduce billions of dollars of losses from personal injury and property damage caused by weather disasters in sectors such as agriculture, industry, and commerce.[22] Moreover, enhancing rainfall could increase agricultural and hydroelectricity production at a relatively low cost.[23] Precipitation enhancement was just one of a number of weather-modification techniques researched as a means to limit damage from severe weather events (along with fog dispersion, hail suppression, or hurricane modification).[24] However, as the only technique that has been demonstrated to work,[25] this Article focuses on the governance of rain- and snow-enhancement techniques.

Scientists have developed a number of cloud-seeding techniques that aim to stimulate or enhance precipitation from different cloud formations.[26] Glaciogenic cloud seeding was developed from the original General Electric's experiments and aims to enhance precipitation from clouds that contain supercooled water droplets (water below 0°C that has not yet frozen).[27] It is mainly applied in mountainous areas, such as in the Sierra Nevada, from ground generators or airplanes, to increase snowpack.[28] Hygroscopic seeding, on the other hand, is conducted in warm clouds (above 0°C) that contain water droplets, rather than ice, and is therefore more suited to clouds in warmer climates.[29] It is increasingly used to enhance rainfall from summertime clouds in Texas.[30] Because cloud seeding

---

[21] Ball, *supra* note 7, at 214; Corbridge & Moses, *supra* note 13, at 207; Donald Frenzen, *Weather Modification: Law and Policy*, 12 B.C. INDUS. & COM. L. REV. 503, 506 (1970); Lawrence A. Weirs, *Weather Modification: A Modest Proposal*, 4 GA. J. INT'L & COMP. L. 159, 160 (1974).

[22] Ball, *supra* note 7, at 217–18.

[23] *See, e.g.*, Ball, *supra* note 7, at 221; Joe Gelt, *Weather Modification: A Water Resource Strategy to be Researched, Tested Before Tried*, 6 ARROYO 1, 3 (Mar. 1992), https://wrrc.arizona.edu/publications/arroyo-newsletter/weather-modification-water-resource-strategy-be-researched-tested-tri [https://perma.cc/Y7L8-3PFB].

[24] *See generally* WMO, *supra* note 9, at 1 (providing up-to-date scientific information on fog dispersion, hail suppression, lightning suppression and hurricane modification).

[25] WMO, *supra* note 9, at 1; FLOSSMANN ET AL., *supra* note 3, at 2.

[26] NAWMC, *supra* note 8, at 2.

[27] WILLIAM R. COTTON & ROGER A. PIELKE, SR., HUMAN IMPACTS ON WEATHER AND CLIMATE 9–11 (2007).

[28] CAL. DEP'T WATER RES., RESOURCE MANAGEMENT STRATEGIES: CH. 11—PRECIPITATION ENHANCEMENT 1, 5 (2013).

[29] COTTON & PIELKE, *supra* note 27, at 32–33.

[30] *See generally* Kendell LaRoche et al., *An Overview of the 2016 Rainfall Enhancement Activities in Texas: A More Intensive Use of Hygroscopic Material*, 49 J. WEATHER

is only efficient in the presence of clouds, it is best used as a long-term water management tool rather than an emergency response in times of drought.[31] To that extent, cloud seeding has progressively evolved into an adaptation measure to climate change impacts.[32]

The effectiveness of cloud-seeding techniques has long been questioned because irreducible uncertainties prevent scientists from accurately estimating the amount of precipitation attributed to a specific operation.[33] The natural variability of atmospheric processes makes the determination of how much rain would have fallen "but for" the seeding highly speculative.[34] However, research over the past seventy years has increased confidence levels in the effectiveness of precipitation enhancement in certain types of clouds: under specific conditions, both glaciogenic and hygroscopic seeding have been demonstrated to work.[35] Recently, for instance, the use of radar and gauges has enabled better quantification of artificially induced snowfall in the United States.[36] Questions surrounding the effectiveness of cloud seeding are thus more quantitative (e.g., how to measure the effects of a seeding operation) than qualitative (e.g., whether it works or not).[37] Yet, despite progress in weather modification science and technology, considerable uncertainties remain in understanding aerosol-cloud interactions—that is the impact of particles on cloud formation and weather patterns.[38]

Cloud seeding also raises socio-economic and environmental concerns. The World Meteorological Organization ("WMO") recognizes, "[u]nintended consequences of cloud seeding, such as downwind effects, persistent effects of silver iodide in soil, and environmental and ecological impacts, have not been demonstrated but cannot be ruled out."[39]

MODIFICATION 38, 38 (2017).

[31] WMO, *supra* note 9, at 4.

[32] FLOSSMANN ET AL., *supra* note 3, at 1.

[33] NAT'L SCI. FOUND., *Scientists Demonstrate that Cloud Seeding Can Generate Snowfall* (Feb. 26, 2020), https://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=300089 [https://perma.cc/HC55-2SJ5].

[34] "The complexity and natural variability of clouds result in significant challenges and difficulties in understanding and detecting the effects of attempts to modify them artificially." WMO, *supra* note 9, at 4.

[35] FLOSSMANN ET AL., *supra* note 3, at 2.

[36] *See generally* Katja Friedrich et al., *Quantifying Snowfall from Orographic Cloud Seeding*, 117 PROC. NAT'L ACADEMY SCIS. 5190, 5190 (2020).

[37] WORLD METEOROLOGICAL ORG., EXECUTIVE COUNCIL app. 3 at 263 (2017).

[38] FLOSSMANN ET AL., *supra* note 3, at 24.

[39] WMO, *supra* note 9, at 7.

Major uncertainties persist concerning potential "extra-area" effects, notably downwind of cloud-seeding target areas. There have long been concerns from both states and private landowners that cloud-seeding activities deprived or "robbed" downwind areas of their natural precipitation.[40] However, recent studies have shown that the dispersion of seeding materials can seed clouds and enhance rainfalls up to two hundred kilometers from the target area.[41] Yet, there are still risks of operation failure where interventions could have adverse effects to those intended, such as reducing precipitation or causing hail.[42] Under certain conditions, cloud seeding can also increase the risks of severe weather events, such as floods.[43] However, uncertainties remain in attributing particular weather events to a cloud-seeding operation, and further research is required to improve our understanding of seeding agents' effects on precipitation processes.

Some scientists also continue to hold concerns about the environmental impacts of seeding agents, such as silver iodide.[44] Fajardo et al., for instance, warn that silver iodide may have accumulative properties and, in high concentrations, creates risks of ecotoxicity for soil biota, in both terrestrial and aquatic environments.[45] The WMO considers the amounts used in current weather modification projects to be safe for human health and the environment.[46] However, it recommends evaluating the potential

---

[40] "It is . . . a realistic concern considering that Cho and List (1980) showed that producing stronger convection by seeding may lead to a greater moisture convergence, thus reducing moisture available at other locations of a synoptic field." Roland List, *Weather Modification—A Scenario for the Future*, 85 BULL. AM. METEOROLOGICAL SOC'Y 51, 57 (2004).

[41] *See generally* T.P. DeFelice et al., *Extra Area Effects of Cloud Seeding—An Updated Assessment*, 135–36 ATMOSPHERIC RSCH. 193, 195, 200 (2014).

[42] "[I]t should not be ignored that, under certain conditions, seeding may cause more hail or reduce precipitation." WMO, *supra* note 9, at 2, 6, 7.

[43] COTTON & PIELKE, *supra* note 27, at 250.

[44] CHARLES F. COOPER & WILLIAM C. JOLLY, ECOLOGICAL EFFECTS OF WEATHER MODIFICATION: A PROBLEM ANALYSIS 64 (1969).

[45] *See generally* C. Fajardo et al., *Potential Risk of Acute Toxicity Induced by AgI Cloud Seeding on Soil and Freshwater Biota*, 133 ECOTOXICOLOGY & ENV'T SAFETY 433, 434, 439–40 (2016).

[46] Published studies have shown no significant impacts on human health and the environment due to silver iodide and hygroscopic salts used in past weather modification operations. However, any plans to use either a massive quantity of such a product or a different seeding agent should be accompanied with a preliminary evaluation of its potential effects on both environment and human health.

effects of a massive quantity of silver iodide and other agents on human health and the environment, leaving to the discretion of states what constitutes a "massive" amount.[47] The Environmental Protection Agency ("EPA") considers silver a nuisance chemical and sets the maximum contaminant level for safe drinking water at 0.1 mg/L.[48] It appears that silver concentration from past weather modification operations is far below national standards:[49] the U.S. Weather Modification Association confirmed that the annual dispersion of three tons of silver iodide in Canada and the United States is environmentally safe.[50] Nevertheless, the governance of weather modification ought to take into account uncertainties and potential risks.

II. A BRIEF OVERVIEW OF WEATHER MODIFICATION GOVERNANCE IN THE UNITED STATES

The United States has a long history of weather-modification governance that predates the discovery of modern cloud seeding.[51] Since the mid-1800s, there have been many attempts at influencing the weather using various "pluviculture" techniques, including the concussions of cannons and the dispersal of chemical mixtures.[52] Early on, these tentative modifications of the atmosphere raised complex legal issues.[53] However,

---

WMO, *supra* note 9, at 12.

[47] *See id.* at 12.

[48] *See* EPA, SECONDARY DRINKING WATER STANDARDS: GUIDANCE FOR NUISANCE CHEMICALS, https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals [https://perma.cc/K2N8-A42X].

[49] *See id.*

[50] *See generally* WEATHER MODIFICATION ASS'N, POSITION STATEMENT ON THE ENVIRONMENTAL IMPACT OF USING SILVER IODIDE AS A CLOUD SEEDING AGENT 4 (2009).

[51] *See generally* JAMES RODGER FLEMING, FIXING THE SKY: THE CHECKERED HISTORY OF WEATHER AND CLIMATE CONTROL 173 (2010).

[52] Inspired by Edward Powers' *War and the Weather* (1871), the "concussionists," were the first rainmakers to gain financial support from the U.S. federal government to demonstrate that loud explosions could artificially trigger rainfalls. However, with the failure of the experiments conducted in Texas, by a certain Robert Dyrenforth, both the federal government and a large part of the public dismissed rainmaking theories altogether. The disapproval of the concussion theory coincided with the beginning of chemical rainmaking. *See id.* at 61–62. *See also* Jeff A. Townsend, Nineteenth and Twentieth Century Rainmaking in the United States 13, 33 (1974) (unpublished Ph.D. dissertation, Texas Tech Univ.) (on file with Texas Digital Library).

[53] In 1916, the city of San Diego, California, hired Charles Mallory Hatfield to increase rainfall over the city using secret chemicals dispersed from a tower. His activities coincided with a flash flood that destroyed a dam, two bridges and killed dozens of people.

it was only after 1946 that weather modification became the object of legal and regulatory developments both at the federal and state levels.[54]

A. Federal Involvement in Weather Modification Research

Federal agencies have long been the main sponsor of weather-modification research in the United States, but the first federal law—the *Weather Modification Reporting Act*—was not passed until the 1970s.[55] The early involvement of the military in weather-modification research can partly explain delays in regulating weather modification at the federal level.[56] The military has always shown a great interest in understanding and controlling weather conditions: soon after the discovery of cloud seeding, the Department of Defense ("DoD") became the first federal agency to invest in weather-modification technologies.[57] In 1951, bills were introduced before Congress,[58] but the DoD opposed regulation as "a threat to its autonomy."[59] Delays in the development of a legal framework can also be explained by the position of the Weather Bureau, which, since the 19th century, had always been skeptical about rainmaking's efficacy.[60] Yet, by 1953, private and public cloud-seeding activities covered close to ten percent of the U.S. territory.[61] Thus, Congress mandated a temporary Advisory Committee on Weather Control ("the Committee") to investigate the viability of weather-modification activities, report to Congress, and recommend policy.[62]

The city of San Diego denied the contract with Hatfield and refused to pay his due $10,000. Hatfield sued the city, which dismissed the case in 1938 "on the basis that the rain was an act of God." *Who Owns the Clouds?*, *supra* note 13, at 43–44.

[54] Mason T. Charak & Mary T. DiGiulian, *A Review of Federal Legislation on Weather Modification*, 55 BULL. AM. METEOROLOGICAL SOC'Y 755, 755 (1974).

[55] Weather Modification Reporting Act, Pub. L. No. 92-205, 85 Stat. 735 (1971).

[56] FLEMING, *supra* note 51, at 173.

[57] *Id.*

[58] *See, e.g.*, T.E. Watts, Jr., *Weather Modification Legislation—A Survey*, 8 VAND. L. REV. 897, 898 n.8; *Weather Control*, CONG. REC.—DAILY DIG., Apr. 5, 1951.

[59] FLEMING, *supra* note 51, at 173.

[60] "Professional integrity, an institutional self-concept which visualized the role of public protector, and the instinct for institutional self-preservation had conducted the Weather Bureau to reject the idea of weather modification research." Townsend, *supra* note 52, at 7, 40, 136, 138.

[61] TOM RYAN, METRO. WATER DIST. S. CAL., WEATHER MODIFICATION FOR PRECIPITATION AUGMENTATION AND ITS POTENTIAL USEFULNESS TO THE COLORADO RIVER BASIN STATES 1 (2005).

[62] Pub. L. 83-256, § 2, 67 Stat 426 (1953). *See, e.g.*, Townsend, *supra* note 52, at 120.

In 1957, Congress terminated the Committee, for want of conclusive answers, and designated the National Science Foundation ("NSF") as the central agency in charge of weather modification research and development.[63] Several federal agencies had started to invest in applied research and, because other programs were growing, Congress decided to terminate the NSF's coordination role in 1968.[64] Several agencies were developing mission-oriented programs—specializing in either rain augmentation, hail suppression, or other applications—and weather-modification governance became fragmented. Since the 1960s, precipitation enhancement has been the privileged field of the U.S. Bureau of Reclamation ("USBR") under the Department of Interior. The USBR, for instance, received more funding than any other agency with Skywater, a project conducted in the western states, along with many agencies, universities, and private companies.[65] These policies left federal weather-modification research without a coordinating agency and without regulation. It was not until the 1970s, and the creation the National Oceanic and Atmospheric Administration ("NOAA") under the Department of Commerce (replacing the Weather Bureau), that the federal government started to regulate weather modification activities.[66]

The Weather Modification Reporting Act ("WMRA") was passed in 1971 to prohibit nonfederal weather modification activities unless reported to the federal government.[67] It requires all persons engaging in weather modification activities to submit a report to the Secretary of Commerce.[68] The Secretary delegated to NOAA the responsibility to specify the information required in the report.[69] In 1973, the reporting requirement was extended to federal agencies as well.[70] The WMRA is still in force today and NOAA maintains a record of weather-modification activities, which is available online.[71] Violators of the WMRA's provisions can be

---

[63] Townsend, *supra* note 52, at 119, 124–26.
[64] Stanley A. Changnon, Jr. & W. Henry Lambright, *The Rise and Fall of Federal Weather Modification Policy*, 19 J. WEATHER MODIFICATION 1, 1 (1987).
[65] *See* JEDEDIAH S. ROGERS, U.S. BUREAU OF RECLAMATION, PROJECT SKYWATER, 1, 2, 13 (2009).
[66] *See* Bernard Silverman, *Project Skywater*, 8 J. WEATHER MODIFICATION 107, 120 (1976).
[67] Weather Modification Reporting Act, Pub. L. No. 92-205, § 2, 85 Stat. 735 (1971).
[68] *Id.*
[69] Maintaining Records and Submitting Reports on Weather Modification Activities, 15 C.F.R. §§ 908.1, 908.5 (1976).
[70] Charak & DiGiulian, *supra* note 54, at 756.
[71] WEATHER MODIFICATION PROJECT REPS., NOAA, https://library.noaa.gov/Collections/Digital-Collections/Weather-Modification-Project-Reports [https://perma.cc/JCV9-3689]

fined up to $10,000.[72] Later, Congress also passed the National Weather Modification Policy Act of 1976, recommending that the Secretary of Commerce "develop a comprehensive and coordinated national weather modification policy and a national program of weather modification research and development."[73] However, no such policy was developed.

About the same time, the press shed light on "Operation Popeye," a series of cloud-seeding operations conducted by the DoD over North Vietnam between 1967 and 1972 to hinder access of the Vietcong troops to the Ho Chi Minh Trail.[74] In the context of the Cold War, international tensions over weather warfare led the United States and Soviet Union to negotiate the 1976 Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques ("ENMOD Convention").[75] The ENMOD Convention prohibits "[1] military or any hostile use of environmental modification techniques [2] having widespread, long-lasting or severe effects [3] as a means of destruction, damage or injury to any other State Party."[76] The Convention also encourages the use of environmental modification—including weather modification—for peaceful purposes.[77] The United States ratified the ENMOD Convention in 1980,[78] but has not taken any proactive measure to implement the provisions of the Convention. International law is part of the domestic law of the United States, and treaties are directly enforceable in U.S. courts as supreme federal law.[79] However, American courts recognize a distinction between self-executing and non-self-executing agreements.[80] Because the provisions of the Convention have never been brought before a court, the question of their direct applicability remains unsettled.

(last visited Oct. 14, 2021).

[72] Weather Modification Reporting Act, Pub. L. 92-205, § 1, 85 Stat. 735 (1972).

[73] National Weather Modification Policy Act, Pub. L. 94-490, § 2(b), 90 Stat. 2359–2361 (1976).

[74] FLEMING, *supra* note 51, at 179–80.

[75] *Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques*, May 18, 1977, 31 U.S.T. 333, 1108 U.N.T.S. 151.

[76] *Id.* art. I.

[77] *Id.* art. III.

[78] U.S. DEP'T. STATE, CONVENTION ON THE PROHIBITION OF MILITARY OR ANY OTHER HOSTILE USE OF ENVIRONMENTAL MODIFICATION TECHNIQUES (May 18, 1977), https://2009-2017.state.gov/t/isn/4783.htm#:~:text=The%20President%20ratified%20the%20Convention%20December%2013%2C%201979.,instrument%20of%20ratification%20was%20deposited%20in%20New%20York [https://perma.cc/4A4W-ECCB].

[79] *See, e.g.*, The Paquete Habana, 175 U.S. 677, 677 (1900).

[80] *See generally* Carlos Manuel Vazquez, *The Four Doctrines of Self-Executing Treaties*, 89 AM. J. INT'L L. 695, 695–96 (1995).

The United States is also party to one bilateral agreement with Canada that fosters cooperation in "weather modification activities of mutual interest."[81] The agreement creates a reporting mechanism between the two parties but does not create any standing institution.[82] Under this agreement, NOAA must consult and exchange information with its Canadian counterpart,[83] as designated under Canadian law.[84] In addition, the United States long participated in a voluntary reporting mechanism established in 1975 to report weather-modification activities to the WMO.[85] Before 2000, the United States had consistently contributed to the WMO National Registers on Weather Modification, but not since then.[86] The reasons why the United States has stopped reporting on its weather modification activities are unclear. In 2007, the WMO stopped compiling the registers, notably due to budget cuts that resulted in the creation of a trust fund for weather modification.[87] The United States has not contributed to this trust fund, but it is beyond the scope of this Article to address the international governance issues arising from weather modification activities.

---

[81] "[C]arried out in or over the territory of a Party within 200 miles of the international boundary; or such activities wherever conducted, which, in the judgment of a Party, may significantly affect the composition, behaviour, or dynamics of the atmosphere over the territory of the other Party." Agreement Between Canada and the United States of America Relating to the Exchange of Information on Weather Modification Activities, Can.-U.S., art. I(b), Mar. 26, 1975, 26 U.S.T. 540.

[82] *Id.* art. II.

[83] "The responsible agencies shall consult with a view to developing compatible reporting formats, and to improving procedures for the exchange of information." *Id.* art. III.

[84] *See* Weather Modification Information Act, R.S.C. 1985, c. W-5 (Can.); Weather Modification Information Regulations, C.R.C., c 1604 (Can.).

[85] "Congress agreed that an inventory of activities within Member countries related to weather modification should be initiated and maintained." World Meteorological Organization, Abridged Report with Resolutions 28, WMO No. 416 (7th World Meteorological Congress, Geneva, Apr. 1975). "States should gather and record technical and scientific information on weather modification activities. They should ensure that such information is made available to the World Meteorological Organization, which should continue to prepare and distribute appropriate reports on weather modification activities . . . ." *See also* UNEP Governing Council, *Provisions for Co-Operation between States in Weather Modification*, U.N. Doc. 8/7/A (1980).

[86] *See, e.g.*, WORLD METEOROLOGICAL ORG., REGISTER ON NATIONAL WEATHER MODIFICATION PROJECTS (1999), https://library.wmo.int/index.php?lvl=notice_display&id=8188#.YGPTYB1xXUo [https://perma.cc/3N2F-GG4K].

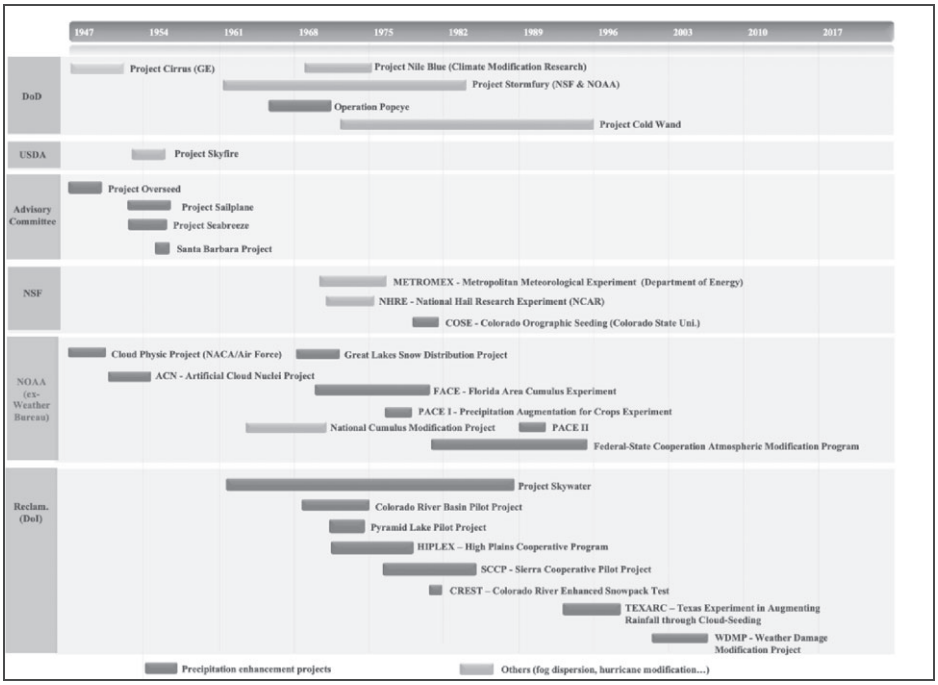
[87] WORLD METEOROLOGICAL ORG., STRATEGIC PLAN FOR THE IMPLEMENTATION OF WMO'S WORLD WEATHER RESEARCH PROGRAMME (WWRP): 2009–2017 (2009).

Between 1960 and 1985, the U.S. government spent about $300 million on weather modification research and development.[88] However, federal funding started to decline dramatically after 1978–79,[89] from $15 million in fiscal year 1971 to $8.1 million in 1984.[90] By the early 2000s, funding had dropped to less than $500,000.[91] The reasons behind this shift are complex, and most of the literature attributes this decrease to overestimated results, difficulties in overcoming scientific uncertainty, and lack of evidence to support efficacy claims.[92] Changnon and Lambright also mention a number of "policy failures" in the 1960s, and the lack of a coordinating agency following the termination of the NSF's leadership.[93] In addition, Cotton and Pielke point out the Reagan administration's cuts in federal expenditures, relatively drought-free years, and a decreasing interest from both the government and the public in favor of other issues, and in particular, climate change.[94] In turn, governance issues have greatly impacted weather modification research and development at the federal level. The table below summarizes the major research projects conducted by U.S. federal agencies since 1946—with a particular focus on projects conducted in California and Texas—and shows the decrease in federal research efforts.

---

[88] "Federal funding for weather modification [research and development] grew from $2.7 million in [fiscal year 1963] to $18.7 million by [fiscal year 1972], a six-fold increase in ten years." Changnon & Lambright, *supra* note 64, at 1.
[89] FLEMING, *supra* note 51, at 185.
[90] Changnon & Lambright, *supra* note 64, at 2.
[91] NAT'L RSCH. COUNCIL, *supra* note 4, at 2.
[92] *See generally* David Atlas, *Selling Atmospheric Science*, 56 BULL. AM. METEOROLOGICAL SOC'Y 688, 688–90 (1975). *See also* Changnon & Lambright, *supra* note 64, at 1; List, *supra* note 40, at 52.
[93] Changnon & Lambright, *supra* note 64, at 1.
[94] COTTON & PIELKE, *supra* note 27, at 68.

TABLE 1—TABLE OF THE FEDERALLY FUNDED WEATHER MODIFICATION PROGRAMS[95]



Despite the decline in activity, the USBR and NOAA have remained involved in weather modification research and pursued cloud-seeding experiments, often in joint-funding projects between the federal government, states, localities, and private companies.[96] From 1986 through 1995,

---

[95] *See generally* Changnon & Lambright, *supra* note 64; Corbridge & Moses, *supra* note 13; ROBERT G. FLEAGLE ET AL., METEOROLOGICAL SOC'Y, WEATHER MODIFICATION IN THE PUBLIC INTEREST 10 (1974); Stanley A. Changnon, *The Paradox of Planned Weather Modification*, 56 AM. METEOROLOGICAL SOC'Y 27, 33 (1975); George W. Bomar et al., *The Texas Weather Modification Program: Objectives, Approach, and Progress*, 31 J. WEATHER MODIFICATION 9, 10 (1999); RYAN, *supra* note 61; James Rodger Fleming, *The Pathological History of Weather and Climate Modification: Three Cycles of Promise and Hype*, 37 HIST. STUD. PHYSICAL & BIOLOGICAL SCIS. 3, 25 (2006).

[96] In 1972, private companies spent about $8 million—or 25% of the total U.S. expenditure—on weather modification, half of which directed to research and development in foreign areas. Stanley A. Changnon, *Weather Modification in 1972: Up or Down?*, 54 BULL. AM. METEOROLOGICAL SOC'Y 642, 642 (1973).

NOAA was involved in the Federal-State Atmospheric Modification Program ("AMP"), which funded research in six states.[97] More recently, in 2002, Congress provided $2 million for the Weather Damage Modification Program ("WDMP") to be administered by the USBR in collaboration with seven states.[98] The WDMP included three projects—in Colorado, Utah, and Nevada (in the Sierra Nevada near the Californian border)—to investigate wintertime cloud seeding; and two projects using summertime cloud seeding—one in North Dakota and one overlapping Texas, New Mexico, and Oklahoma.[99] The federal government has not funded weather modification research and operations since. Nevertheless, the withdrawal of federal support has set the stage for states and private companies to pursue weather-modification operations.[100]

B. State Weather-Modification Regulations

In the United States, states have traditionally had primary carriage of weather-modification regulations.[101] In 1953, the Council of State Governments recommended that states develop legislation for weather modification.[102] By 1958, twenty-two states had passed laws "specifically regulating or otherwise dealing with weather modification."[103] A few lawsuits arose from weather disasters allegedly resulting from cloud seeding activities, especially floods, and in some cases, suppression of beneficial rain from hail suppression activities.[104] By 1968, seven states had passed regulations explicitly recognizing their rights over atmospheric moisture,

---

[97] RYAN, *supra* note 61, at 6. *See also* Arlin B. Super, *Summary of NOAA/Utah Atmospheric Modification Program: 1990–1998*, 31 J. WEATHER MODIFICATION 51, 51–52 (1999).
[98] RYAN, *supra* note 61, at 6.
[99] *See generally* STEVEN M. HUNTER ET AL., U.S. BUREAU OF RECLAMATION, THE WEATHER DAMAGE MODIFICATION PROGRAM, *in* 16TH CONFERENCE ON PLANNED AND INADVERTENT WEATHER MODIFICATION (2005).
[100] "Despite this decline in support for weather modification research and over the same time period, operational weather modification programs in the United States and the rest of the world have grown in number." Michael Garstang et al., *Weather Modification: Finding Common Ground*, 86 BULL. AM. METEOROLOGICAL SOC'Y 647, 654 (2005).
[101] *See generally* Stark, *supra* note 14; Corbridge & Moses, *supra* note 13; Ray Jay Davis, *Legal Response to Environmental Concerns about Weather Modification*, 14 J. APPLIED METEOROLOGY 681, 682 (1975); Gregory N. Jones, *Weather Modification: The Continuing Search for Rights and Liabilities*, 1991 BYU L. REV. 1163, 1163–65 (1991).
[102] Orville, *supra* note 2, at 595.
[103] Oppenheimer, *supra* note 14, at 314.
[104] Frenzen, *supra* note 21, at 513.

thereby preventing private disputes over cloud water.[105] State courts have attempted to define proprietary rights over cloud water but have produced contradictory decisions.[106] Moreover, in most cases, uncertainties in establishing causation barred courts from apportioning liability for damage. Scholars commenting on these decisions advocated for the law to be clarified, especially with respect to "diversion of air-borne moisture and precipitation of harmful rain."[107] However, according to Bomar, "[d]espite approximately a dozen court cases filed since 1950, none have resolved the most important issues surrounding the practice of weather modification."[108] Today, proprietary rights over artificial precipitation still remain unclear in several jurisdictions.

Most states have put in place weather-modification regulations that require a license for cloud-seeding operators or a permit for operations.[109] In these states, for a project to take place, operators must comply with a number of conditions, including competence, public notice, reporting, proof of financial responsibility (or insurance), and potential liability.[110] Some twenty-three states regulate weather modification and six states allow weather modification as an emergency management measure, without regulating it per se.[111] The table below summarizes how states and territories have regulated weather modification. At the time of writing, however, only nine states are actively engaged in cloud-seeding activities: California, Colorado, Idaho, Kansas, Nevada, North Dakota, Texas, and Utah (in grey in the table).

---

[105] Corbridge & Moses, *supra* note 13, at 218.

[106] *Compare* "[the plaintiffs] clearly have no vested property rights in the clouds or the moisture therein." Slutsky v. City of New York, 97 N.Y.S.2d 238, 238 (N.Y. Misc. 2d 1950), *with* "clouds and the moisture in the clouds, like air and sunshine, are part of space and are common property belonging to everyone who will benefit from what occurs naturally in those clouds." Pa. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass., 44 Pa. D. & C.2d 749, 759 (1968).

[107] Brooks, *supra* note 14, at 114; *see also* Stark, *supra* note 14, at 705; Oppenheimer, *supra* note 14, at 88; Wade, *supra* note 13, at 95.

[108] George W. Bomar, *Weather Modification and the Law*, 6 SW. HYDROLOGY: RES. FOR SEMI-ARID HYDROLOGY 22, 22 (2007).

[109] HOWARD J. TAUBENFELD, CONTROLLING THE WEATHER: A STUDY OF LAW AND REGULATORY PROCEDURES 21 (1970).

[110] Jianlin Chen, *Optimal Property Rights for Emerging Natural Resources: A Case Study on Owning Atmospheric Moisture*, 50 U. MICH. J. L. REFORM 47, 60 (2016).

[111] Alaska, Arkansas, Rhode Island, Tennessee, Virginia, and the District of Columbia. *See* ALASKA STAT. § 26.23.150 (2021); ARK. CODE ANN. § 12-75-115 (2021); tit. 30 R.I. GEN. LAWS § 30-15-7 (2021); TENN. CODE ANN. § 58-2-116 (2021); VA. CODE ANN. § 44-146.22 (2021); D.C. CODE § 7-2305 (2021).

TABLE 2—CLOUD-SEEDING LEGISLATION IN THE USA—WITH PROJECT REGULATIONS (LICENSE OR PERMIT), NOTICE, REPORTING OF PROJECT, LIABILITY, AND PARTICIPATION PROVISIONS[112]

States in grey represent states that are actively engaged in weather modification.

States	License	Permit	Notice	Report-ing	Liability	Partic-ipation
Arizona	X			X		
California			X	X		
Colorado		X	X	X	X	X
Virgin Islands						
Florida	X		X	X		
Idaho						
Illinois						X
Kansas	X	X	X	X	X	X
Maryland	X			X		
Montana	X	X	X	X	X	X
Nebraska						
Nevada	X	X	X	X	X	
New Hampshire						
New Mexico	X			X		
North Dakota	X	X	X	X	X	X
Oklahoma	X	X	X	X	X	
Oregon	X		X	X	X	X
Pennsylvania	X		X	X	X	
Texas	X	X	X	X	X	X
Utah	X			X	X	
Washington	X	X	X	X	X	X
Wisconsin	X	X		X	X	

[112] This table was made following a review of the current legislation in states regulating weather modification. For more information see AM. SOC'Y ENG'RS, GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 58 (Conrad G. Keyes et al. eds., 3rd ed. 2016).

States	License	Permit	Notice	Report-ing	Liability	Partic-ipation
Wyoming		X		X	X	

The states of California and Texas make excellent case studies of the operationalization of these laws. California is the state that currently conducts the most cloud-seeding projects.[113] However, California's legislation is not representative of most U.S. states' regulatory systems that require a license or a permit.[114] Texas, on the other hand, is representative and is regarded as having the "most sophisticated and well-regulated activities in the U.S."[115] Given contrasts in both climates and political contexts, it is interesting to compare the governance of weather-modification activities in these two states. The Colorado River Basin states also constitute interesting case studies but would require further research to address complex interstate and potential transboundary implications.[116] The following parts outline the legal and governance structures in California and Texas, with a focus on two projects: the Tahoe-Truckee project and the West Texas Weather Modification Association's program.

III. CALIFORNIA

A. Context

California is the American state that is the most active in weather modification, with sixteen programs conducted in the past ten years (see Figure 4 below).[117] California has been running cloud-seeding programs for over fifty-five years.[118] For the most part, cloud-seeding operations are

---

[113] *See, e.g.*, Bernard A. Silverman, *An Evaluation of Eleven Operational Cloud Seeding Programs in the Watersheds of the Sierra Nevada Mountains*, 97 ATMOSPHERIC RSCH. 526, 526 (2010).
[114] *See* Figure 2; Currier, *supra* note 15, at 959–60.
[115] JOHN FORREST, HARVESTING THE SKIES 8 (2002), https://www.parliament.vic.gov.au/images/stories/committees/enrc/future_water_supply/Submissions_57_110/084_Attachment9.pdf [https://perma.cc/S4PG-HPA7].
[116] *See generally* Steven M. Hunter, *Potential Water Augmentation from Cloud Seeding in the Colorado River Basin*, 38 J. WEATHER MODIFICATION 51, 51–53 (2006).
[117] WEATHER MODIFICATION PROJECT REPS., *supra* note 71.
[118] STEVEN M. HUNTER, U.S. BUREAU OF RECLAMATION, OPTIMIZING CLOUD SEEDING FOR WATER AND ENERGY IN CALIFORNIA 5 (2007).

conducted from ground-based generators located in the Sierra Nevada to augment snowfall for "hydroelectric power, agriculture, municipal and industrial needs, recreation, and endangered species habitat."[119] In past decades, California has suffered from serious droughts that significantly compromised its water security.[120] The Department of Water Resources ("DWR") is now considering precipitation enhancement to offset some of the snowpack loss expected from climate change and potentially delay forest fire seasons.[121] Cloud seeding is used to secure water supply in anticipation of drought (adaptation) and to generate hydroelectricity, thereby decreasing reliance on fossil fuels (mitigation).[122] All of the Californian projects are conducted by municipalities and water utilities to increase water supply or energy production.[123] Cloud seeding is considered more effective in Northern California due to its cooler climate, so most Californian projects take place in the Sierra Nevada, including two major projects at the border with Nevada (see map below).[124]

---

[119] *Id.* at 1.

[120] *See generally* ALI MIRCHI ET AL., CLIMATE CHANGE IMPACTS ON CALIFORNIA'S WATER RESOURCES 301–19 (Kurt Schwabe et al. eds., 2013).

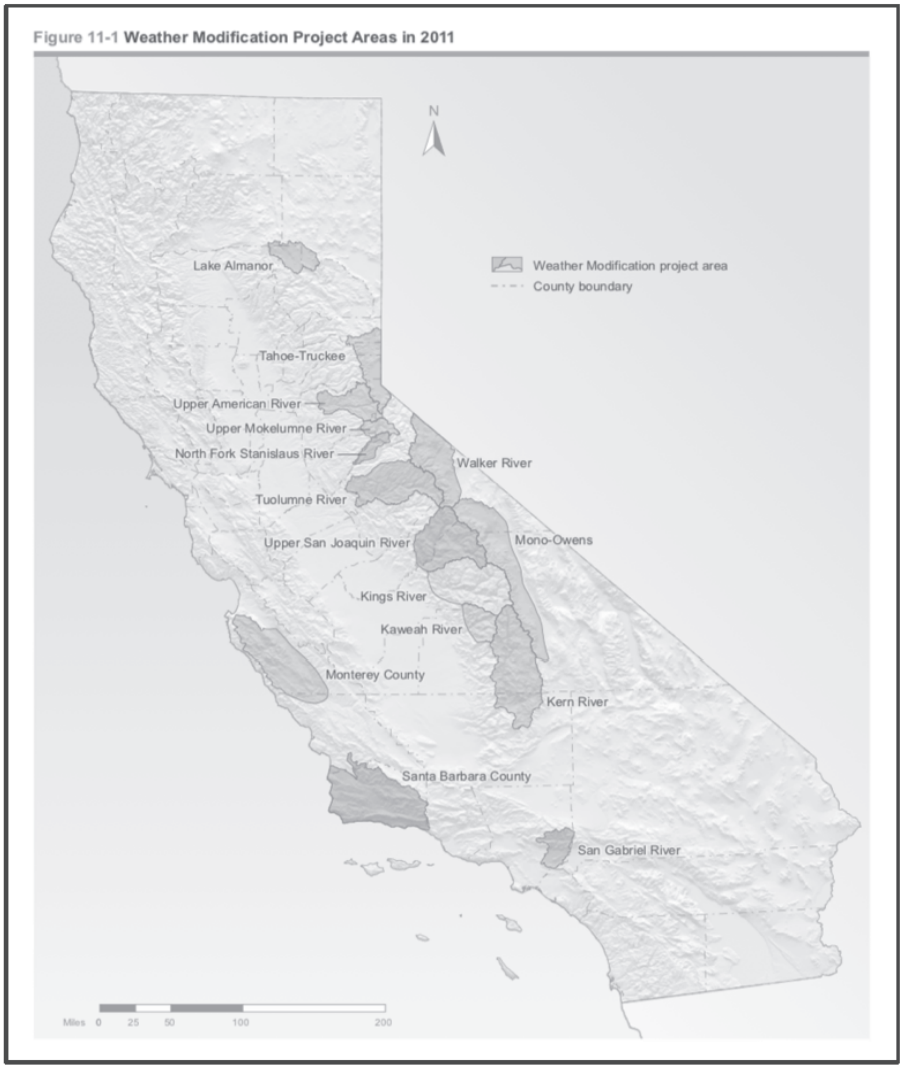
[121] CAL. DEP'T WATER RES., *supra* note 28, at 9.

[122] For more information on adaptation and mitigation, see INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION SUMMARY FOR POLICY MAKERS AND TECHNICAL SUMMARY, at 44, 86–87 (Leonidas O. Girardin & Mattia Romani eds., 2011).

[123] CAL. DEP'T WATER RES., *supra* note 28, at 8.

[124] CAL. DEP'T WATER RES., PRECIPITATION ENHANCEMENT A RESOURCE MANAGEMENT STRATEGY OF THE CALIFORNIA WATER PAN 2 (2016), https://cawaterlibrary.net/wp-content/uploads/2016/07/CWP-RMS-Ch-10-Precipitation_Enhancement_July2016.pdf [https://perma.cc/38YC-RT59].

Figure 1—Weather Modification Target Areas in California in 2011[125]



[125] *Id.* at 2 fig.1. This image was reproduced with the permission of the California Department of Water Resources.

B. Legislation

California was one of the first states to legislate on weather modification in 1951, requiring licenses for operators and permits for projects.[126] The California legislature then gave local agencies the authority to conduct weather modification activities in the following terms:

> Any county, city, city and county, district, authority or other public corporation or agency which has the power to produce, conserve, control or supply water for beneficial purposes shall have the power to engage in practices designed to produce, induce, increase or control rainfall or other precipitation for the general benefit of the territory within it.[127]

In 1978, California passed a new law making the license/permit system discretionary.[128] However, in 1982–83, the state terminated support to the Weather Resources Management program, leaving the DWR with no other funds than permit and license fees to administer the program.[129] Roos considers this decision a de facto deregulation.[130] Indeed, the DWR attempted to increase the fees in order to increase its budget, but eventually, the regulations were rejected and the DWR repealed the weather modification law.[131] The new California Weather Resources Management Act of 1984 further deregulated state control over weather modification.[132]

The California Weather Resources Management Act does not expressly use the term "weather modification" but instead refers to "weather resources management," which is defined as "attempting to produce by physical means any of the following: cloud water conversion, light adjustment, or weather hazard suppression."[133] Although the terminology is slightly different, the technologies regulated under these provisions are essentially the same. Most provisions from the 1978 law have been repealed, but project operators are still required to file with the DWR, publish

---

[126] Stark, *supra* note 14, at 709.
[127] CAL. GOV'T CODE § 53063 (West 1955).
[128] Maurice Roos, *De Facto Deregulation of Weather Modification in California*, 15 J. WEATHER MODIFICATION 74, 74 (1983).
[129] Maurice Roos, *How California Handled Two Weather Modification Permit Applications from Nevada, an Adjoining State*, 18 J. WEATHER MODIFICATION 127, 127 (1986).
[130] Roos, *supra* note 128, at 74.
[131] *Id.*
[132] *Id. See also* Maurice Roos, *Status of Weather Modification Regulation in California*, 17 J. WEATHER MODIFICATION 71, 71 (1985).
[133] CAL. WATER CODE § 402 (West 1984).

a notice of intention in a newspaper having a general circulation, and send it to the board of supervisors within affected counties.[134] The operator must also keep records of operations and submit a report to the DWR on the evaluation of the project results at least once every two years for ongoing projects, or within a year of the termination of a project.[135] However, nothing in the law specifies what information the notice of intention or the report must contain.[136] The DWR used to compile Reports on Weather Modification Operations in California,[137] but the new reporting mechanism does not provide for public access to information.

Public agencies involved in weather modification projects must comply with the California Environmental Quality Act ("CEQA")[138] and the CEQA guidelines,[139] especially those related to Environmental Impact Assessments (generally referred to as "EIA").[140] CEQA provisions are fairly detailed and require the public agency with primary responsibility for a proposed project to prepare an Environmental Impact Report ("EIR").[141] If, in the initial study, the lead agency finds no substantial evidence that the proposed project may cause a significant impact on the environment, it can file a negative declaration or mitigated negative declaration.[142] A negative declaration is adopted when there is no substantial evidence that a project may have a significant environmental impact, and a mitigated negative declaration when there may be significant environmental impacts that can be mitigated.[143] In those cases, the agency in charge of the project is not required to conduct a full EIR.[144] A few weather modification projects in California have required a full EIR, back in the 1990s,[145] but more recent projects have only required a negative declaration or mitigated negative declaration.[146] Private projects, however, are only

---

[134] CAL. WATER CODE §§ 410–412 (West 1984).
[135] CAL. WATER CODE § 420 (West 1984).
[136] Roos, *supra* note 132, at 71.
[137] *See, e.g.*, CAL. DEP'T WATER RES., REPORT ON WEATHER MODIFICATION OPERATIONS IN CALIFORNIA, JULY 1952–JUNE 1956 (1957), cited in Stark, *supra* note 14, at 710.
[138] CAL. PUB. RES. CODE §§ 21000–21177 (West 2009).
[139] CAL. CODE REGS. tit. 14, §§ 15000–15387 (2009).
[140] *Id.*
[141] CAL. PUB. RES. CODE § 21061 (West 2009).
[142] CAL. PUB. RES. CODE §§ 21064–21064.5 (West 2009).
[143] *Id.*
[144] CAL. CODE REGS. tit. 14, § 15371.
[145] *See, e.g.*, U.S. DEP'T AGRIC. & CAL. DEP'T WATER RES., JOINT ENVIRONMENTAL IMPACT STATEMENT ENVIRONMENTAL IMPACT REPORT: PROTOTYPE PROJECT TO AUGMENT SNOWPACK BY CLOUDSEEDING USING GROUND BASED DISPENSERS IN PLUMAS AND SIERRA COUNTIES (1990).
[146] *See, e.g.*, CNTY. L.A. DEP'T PUB. WORKS, CNTY L.A. WEATHER MODIFICATION PROJECT,

subject to CEQA requirements if the action includes governmental participation, financing, or approval.[147] Thus, CEQA requirements do not apply to all cloud-seeding projects.

C. Litigation

There have been two reported cloud seeding judicial decisions in California.[148] In 1955, a severe storm caused a flood that was particularly severe in Yuba City: flood levees burst, killing thirty-seven people and damaging thousands of homes.[149] Pacific General & Electric ("PG&E") had been conducting cloud seeding in nearby areas, but the public had not been informed of the ongoing operations.[150] PG&E had foreseen the severity of the storm and suspended cloud-seeding operations three days before the flood.[151] The 170 plaintiffs sued PG&E and their operator for negligence and strict liability for ultrahazardous activities, as well as the State of California for negligence in the design, construction, and maintenance of the levee system.[152] The court held that the plaintiffs failed in their burden of proof to demonstrate that the cloud-seeding operations had contributed to the disaster.[153] They lost against the cloud seeders but won against the State for inverse condemnation (just compensation for the taking of their private property).[154] In another case, a cloud-seeding operation conducted by the County of Los Angeles' Flood Control District allegedly caused a flood that destroyed a church's property.[155] Following the flood, the County enacted a temporary flood-zoning ordinance that depreciated the value of the church's land.[156] The church sued the County in inverse condemnation and tort liability for the cloud-seeding activities.

FINAL MITIGATED NEGATIVE DECLARATION (2009); SAN LUIS OBISPO CNTY. FLOOD CONTROL AND WATER CONSERVATION DIST. Res. 2019-233 (2019).

[147] CAL. CODE REGS. tit. 14, §§ 15002(c), 15378(a)(2) (2009).

[148] *See, e.g.*, Adams v. California, 176 F. Supp. 456, 457 (N.D. Cal. 1959); First English Evangelical Lutheran Church of Glendale v. Cnty. of L.A., 482 U.S. 304,308 (1987).

[149] *See generally* Dean E. Mann, *The Yuba City Flood: A Case Study of Weather Modification Litigation*, 49 BULL. AM. METEOROLOGICAL SOC'Y 690, 691 (1968).

[150] *Id.* at 690, 692, 694.

[151] *Id.* at 694.

[152] *Id.* at 690, 709.

[153] *Adams*, 176 F. Supp. at 458.

[154] Mann, *supra* note 149, at 690, 709.

[155] First English Evangelical Lutheran Church of Glendale v. Cnty. of L.A., 482 U.S. 304, 308 (1987).

[156] *Id.* at 304.

The U.S. Supreme Court granted the defense a motion for nonsuit on the account of strict liability for cloud seeding.[157] The Court further held that there was no valid claim of compensable taking for cloud seeding, but the case did not address liability for negligence or trespass,[158] nor did it address strict liability.[159] Accordingly, liability regimes for cloud seeding under California law remain unclear.

D. Projects

Cloud seeding is now part of the state's Integrated Regional Water Management.[160] In 2013, the DWR's Water Plan estimated that the combined cloud-seeding projects had increased runoff up to four hundred thousand acre-feet annually (or four percent).[161] Cloud-seeding programs are sponsored and operated by different actors. One project has long been funded and operated by the public sector (e.g., Sacramento Municipal Utility District), and some entirely by the private sector (e.g., PG&E). Most projects, however, are sponsored by local public entities (water districts, cities, and counties), which contract with private operators to run their cloud-seeding activities (see table below). Four companies work alone or jointly on the different projects: Atmospheric Inc. ("AI"), RHS Consulting ("RHS"), North American Weather Consultants ("NAWC") and Weather Modification Inc. ("WMI"), the "world's largest private aerial cloud-seeding company."[162] Finally, two projects are conducted by the Nevada-based Desert Research Institute ("DRI"), a non-profit organization that conducts cloud-seeding operations for partner agencies at the local, state, and federal levels.[163] The following section examines in more detail the Tahoe-Truckee project, conducted by DRI in California for the benefit of Nevada.

---

[157] Ray Jay Davis, *Atmospheric Water Resources Development and International Law*, NAT. RES. J. 11, 35 (1991).
[158] *First English Evangelical Lutheran Church of Glendale*, 482 U.S. at 313.
[159] *Id.* at 309–10.
[160] "Operational funding support for new projects may be available through the IRWM program." CAL. DEP'T WATER RES., *supra* note 28, at 12.
[161] CAL. DEP'T WATER RES., *supra* note 28, at 8.
[162] Amanda Little, *Weather on Demand: Making It Rain Is Now a Global Business*, BLOOMBERG BUSINESSWEEK (Oct. 28, 2015), https://www.bloomberg.com/features/2015-cloud-seeding-india/ [https://perma.cc/DG6H-68LW].
[163] *Cloud Seeding Program*, DRI, https://www.dri.edu/cloud-seeding-program/ [https://perma.cc/AA8F-8CR6] (last visited Oct. 14, 2021).

TABLE 3—SPONSORS AND OPERATORS OF THE DIFFERENT CLOUD-SEEDING PROJECTS IN CALIFORNIA (IN THE LAST TEN YEARS)[164]

Project	Years	Sponsor	Operator	EIA
Upper Tuolumne River Weather Modification Project	1991–2019	Turlock and Modesto Irrigation Districts	AI, WMI	Yes
Mokelumne	1954–2018	Pacific Gas & Electric Company (PG&E)	PG&E	Yes
Kings River	1955–2018	Kings River Conservation District	AI, NAWC	N/I
Upper American River Project	1969–2020	Sacramento Municipal Utility District (SMUD)	WMI	Yes
Lake Almanor	1954–2017	Pacific Gas & Electric Company	PG&E	N/I
Upper San Joaquin Cloud Seeding Program	1951–2017	Southern California Edison Company	NAWC, AI, RHS	N/I
Kaweah River Project	1976–2016	Kaweah Delta Water Conservation District	AI	N/I

[164] Table made following a review of National Oceanic and Atmospheric Administration ("NOAA") Weather Modification Project Reports. *See* WEATHER MODIFICATION PROJECT REPS., *supra* note 71; Silverman, *supra* note 113, at 526–39.

Project	Years	Sponsor	Operator	EIA
Kern River Project	1977–2016	North Kern Water Storage District	AI, RHS	N/I
Stanislaus Weather Modification Program	2007–2018	Northern California Power Agency	WMI	Yes
San Gabriel Mountains	2015–2016	Los Angeles County Department of Public Works	NAWC	Yes
Santa Barbara and San Luis Obispo Counties	2001–2018	Santa Barbara County	NAWC	Yes
Pit River–McCloud River	2008–2009	Pacific Gas & Electric Company (abandoned)	PG&E	No
Tahoe-Truckee	1978–2020	Nevada State & Western Regional Water Commission	DRI	No
Mono-Owens (Eastern Sierra)	1987–	Los Angeles Department of Water & Power	AI	N/I
Walker River	1980–	Desert Research Institute (DRI)	DRI	Yes (NEPA)
Monterey County	2004–2005	Monterey County	AI	N/I

1. The Tahoe-Truckee Project

The Desert Research Institute has been conducting cloud-seeding experiments in the Tahoe-Truckee basin since the 1950s to increase freshwater supply in Nevada's reservoirs.[165] When the 1978 law passed, the DRI applied for a permit to conduct wintertime cloud seeding in the area.[166] Permits were to be granted automatically to existing projects that had been operated continuously for a period of ten years and an exemption was granted to the DRI in November 1979.[167] Because CEQA requirements do not apply to adjoining state agencies, the DRI was not considered a "public agency" under the California weather modification law, and therefore was not required to prepare an EIR.[168] Instead, the DWR was granted a functional equivalent process, originally designed for private applications, to replace the EIA.[169] When the 1984 law passed, no remaining legal requirements applied to the Tahoe-Truckee project.[170]

At that time, the USBR also became involved in weather-modification research in the Sierra Nevada under Project Skywater.[171] The 1977–87 Sierra Cooperative Pilot Project was conducted to investigate cloud seeding in the Sierra Nevada region of both California and Nevada.[172] Following a programmatic environmental impact statement, the USBR conducted a NEPA Environmental Assessment ("EA") for the Sierra Cooperative Pilot Project in 1981 which extended to parts of the Truckee-Carson River Basin.[173] The EA provided for suspension criteria and notably stated that "the DRI will be contacted for assessment of flood potential for the Tahoe-Truckee Basin."[174] It is the only mention to the DRI's project in the assessment.[175] More recently, the DRI obtained a federal grant from the

---

[165] *See generally* J. A. Warburton et al., *Assessment of Seeding Effects in Snowpack Augmentation Programs: Ice Nucleation and Scavenging of Seeding Aerosols*, 34 J. APPLIED METEOROLOGY 121, 121–30 (1995).
[166] Roos, *supra* note 129, at 127–28.
[167] Out of fourteen permits granted between 1978 and 1984, eight qualified for an exemption. *Id.* at 128.
[168] *Id.*
[169] *Id.*
[170] *See* CAL. WATER CODE §§ 400–401 (West 1984).
[171] *See generally* David W. Reynolds & Arnett S. Dennis, *A Review of the Sierra Cooperative Pilot Project*, 67 BULL. AM. METEOROLOGICAL SOC'Y. 513, 513–23 (1986).
[172] HUNTER, *supra* note 118, at 13.
[173] EDWARD R. HARRIS, SIERRA COOPERATIVE PILOT PROJECT, ENVIRONMENTAL ASSESSMENT AND FINDING OF NO SIGNIFICANT IMPACT iii–v (1981).
[174] *Id.* at 16.
[175] *Id.*

USBR under the WDMP to evaluate cloud seeding in the Walker River Basin, with part of the project conducted over the Tahoe Basin.[176] However, the author is not aware of any formal EIA conducted for the Tahoe-Truckee Basin project, although the DRI has offered to do so under state funding.[177]

The DRI has continued its cloud-seeding operations over the Tahoe-Truckee basin with the sponsor of various public entities.[178] Since 1994, the State of Nevada had contributed to the funding of the State of Nevada Cloud Seeding Program along with the Western Regional Water Commission ("WRWC") under the Regional Water Management Fund.[179] In 2009, however, the state cut funding to weather modification, threatening the future of the program.[180] The DRI requested support from the Truckee River Fund and the Truckee Meadows Water Authority, from year to year.[181] In 2018, the DRI secured new funding from the Nevada state legislature through the Northern Nevada Water Planning Commission, in partnership with the WRWC.[182] The DRI estimates that the project has created an additional fourteen thousand acre-feet of water a year over the last thirty years.[183] The DRI has contracted with WMI for aircraft and equipment and, more recently, with private companies to develop "unmanned aerial systems," for drone-based cloud-seeding technologies.[184]

---

[176] CAL. DEP'T WATER RES., *supra* note 28, at 11.

[177] If one or more EAs are required, DRI will submit a separate proposed budget to cover the costs for their preparation, which usually requires hiring an outside consultant to assist DRI in certain aspects of the assessment. Preparation of an EA costs between a few thousand dollars to as much as $60,000.

MARC PITCHFORD, DRI, PROPOSAL AND SCOPE OF WORK CLOUD SEEDING PROJECT FOR THE STATE OF NEVADA FOR WY2016, at 2 (2014), http://dcnr.nv.gov/uploads/documents/StateConsortiumCloudSeedingProposal.pdf [https://perma.cc/6F2J-73D6].

[178] W. REGIONAL WATER COMM'N, STAFF REPORT (Oct. 11, 2018), http://www.wrwc.us/meetings_go_here/files/2018-10-17/Item%209%20Cloud%20Seeding%202018-2019%20Staff%20Report.pdf [https://perma.cc/P7BX-SZGW].

[179] *Id.*

[180] *Id.*

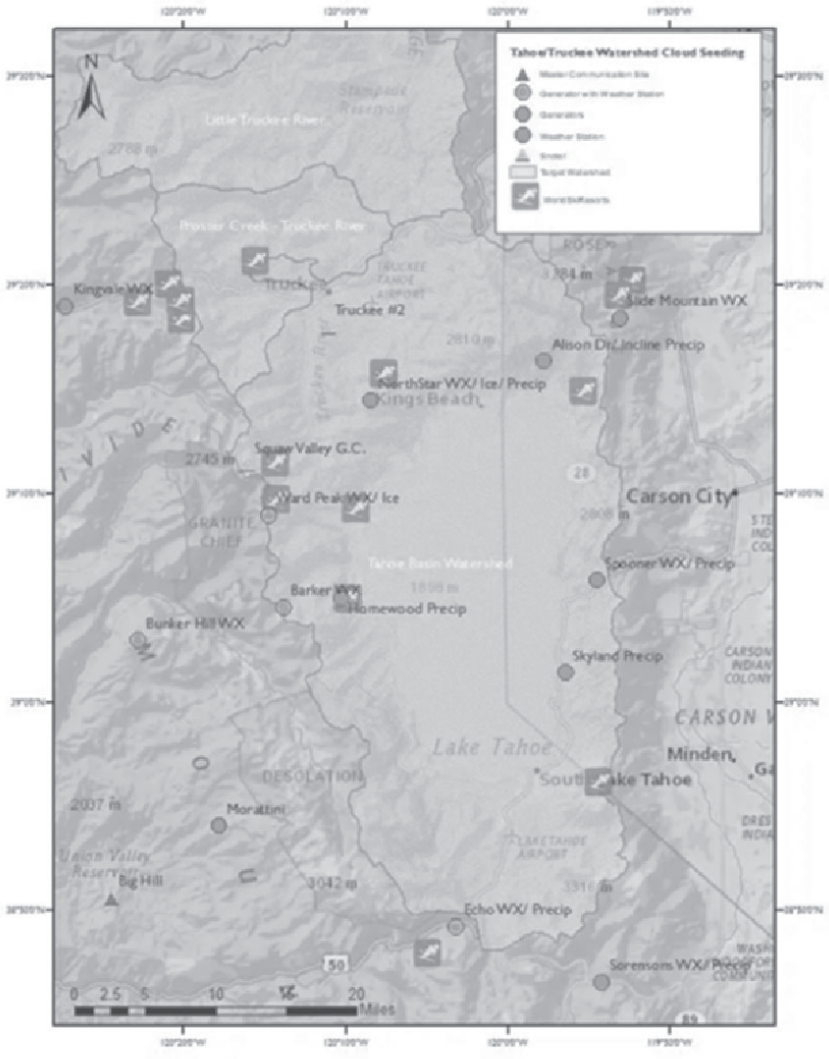
[181] *See, e.g.*, TRUCKEE RIVER FUND, CLOUD SEEDING PROJECT FOR TAHOE & TRUCKEE BASINS, GRANT #92, http://truckeeriverfund.org/projects/cloud-seeding-project-for-tahoe-truckee-basins/ [https://perma.cc/K4KU-8UDQ] (last visited Oct. 14, 2021).

[182] N. NEV. WATER PLANNING COMM'N, STAFF REPORT (Sept. 27, 2018), http://www.nnwpc.us/meetings_go_here/files/2018-10-03/Item%206%20Cloud%20Seed%20stf%20rpt%20jp.pdf [https://perma.cc/J69Q-E4HW].

[183] W. REGIONAL WATER COMM'N, *supra* note 178.

[184] UAS Editors, *UAS Project to Increase Snowpack in Nevada Mountains*, UAS VISION, https://www.uasvision.com/2016/02/12/uas-project-to-increase-snowpack-in-nevada-mountains/ [https://perma.cc/AR3P-3BT7] (last visited Oct. 14, 2021).

Figure 2—Tahoe-Truckee Cloud Seeding Target Areas for 2018–19[185]



[185] *See Cloud Seeding Program*, *supra* note 163. This image was reproduced with the permission of DRI Cloud Seeding Program.

Interestingly, the Tahoe-Truckee project mostly takes place in the territory of California, for the benefit of Nevada, as part of the Nevada State Cloud Seeding Program.[186] Under Nevada's weather modification law, the state Department of Conservation and Natural Resources ("DCNR") is responsible for overseeing weather-modification operations.[187] The DCNR "shall utilize to the fullest possible extent the facilities and technical resources of the Desert Research Institute of the Nevada System of Higher Education."[188] The law requires a permit and a license, but the DCNR can grant an exemption from license, permit, and liability requirements for "research and development and experiments by State and federal agencies, institutions of higher learning and bona fide non-profit research organizations."[189] It appears that, under Nevada law, the Tahoe-Truckee project is exempt from a license or permit, but it is unclear whether it is due to the DRI's status or because the project takes place in California territory. Moreover, the law does not regulate operations conducted in an adjoining state.[190] Thus, operations have continued in the Tahoe-Truckee River Basin, bypassing both states' environmental laws.[191] In 1969, California and Nevada signed the Tahoe Regional Planning Compact administered by the Tahoe Regional Planning Agency.[192] However, it appears that the Tahoe-Truckee cloud-seeding project is not regulated under the agreement.

IV. TEXAS

A. Context

The weather in Texas is characterized by its diversity, severity, and mutability.[193] Due to climate change, Texas' mean temperatures have increased, and weather extremes have become more and more frequent.[194] Recurrent episodes of drought have impacted surface and groundwater resources, and over the past twenty years, Texas has increasingly used weather modification for agricultural production and aquifer replenishment, especially in the arid and semi-arid areas of the

---

[186] N. NEV. WATER PLANNING COMM'N, *supra* note 182, at 2.
[187] NEV. REV. STAT. ANN. § 544.030 (West 1961).
[188] *Id.* § 544.060.
[189] *Id.* § 544.130.
[190] *Id.*
[191] *See, e.g.*, Roos, *supra* note 128, at 74.
[192] Tahoe Regional Planning Compact, Pub. L. 96-551, 94 Stat. 3233 (1980).
[193] *See* GEORGE W. BOMAR, WEATHER IN TEXAS: THE ESSENTIAL HANDBOOK? 1–2 (2017).
[194] *Id.* at 16–21 (discussing the effects of climate change on Texas' weather).

state.[195] Unlike snowpack enhancement operations conducted in California, cloud seeding in Texas is targeted at summertime thunderstorms: silver iodide flares are mounted on aircraft and targeted at warm clouds during the growing season (April to October).[196] In recent years, Texas programs have also experimented with "dual seeding," a mix of both glaciogenic and hygroscopic materials (using calcium chloride or salt).[197] Parts of Texas also use cloud seeding for hail suppression, but the use of these techniques has been highly controversial amongst the scientific community as well as the public.[198] In 2019, there were only two hail suppression projects in Texas.[199] Other techniques are being developed to stimulate rainfall in the region, such as cloud ionization for precipitation enhancement and reduction of air pollution responsible for rain suppression,[200] but their efficacy is still debated in the international scientific community.

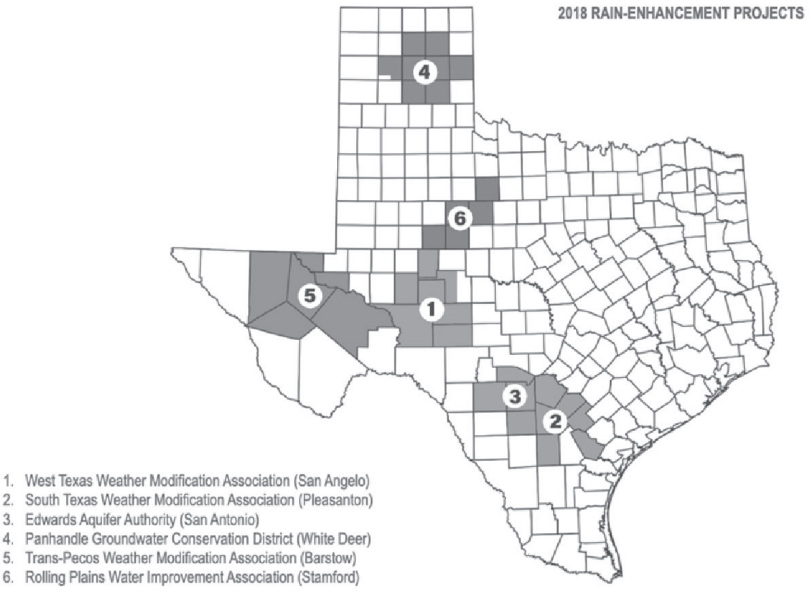
There have been several federally funded projects in Texas.[201] These include the High Plains Cooperative Program ("HIPLEX") as part of Project Skywater, conducted between 1974–80 to evaluate the potential for cloud seeding in warm clouds.[202] Joint projects have also been conducted, with the 1986–94 Southwest Cooperative Program ("SWCP") between Texas and Oklahoma,[203] and the 1995–98 Texas Exercise in Augmenting Rainfall Through Cloud-Seeding Project ("TEXARC") (as part of NOAA's Federal-State AMP).[204] Since then, water districts and public associations composed of counties have sponsored and conducted cloud-seeding operations (e.g., the Colorado River Municipal Water District

---

[195] *Id.* at 215–24.
[196] *Id.* at 215–24 (discussing weather modification in Texas).
[197] Arquímedes Ruiz Columbié et al., *Comments on Current Dual Cloud Seeding Operations in Texas*, 44 J. WEATHER MODIFICATION 96, 96–100 (2012).
[198] Richard Peterson, *Caprock Chronicles: West Texas Rainmaking and Hail Suppression*, LUBBOCK AVALANCHE-J. (Oct. 12, 2019, 12:04 AM), https://www.lubbockonline.com/news/20191012/caprock-chronicles-west-texas-rainmaking-and-hail-suppression [https://perma.cc/H9P2-TFN5].
[199] TEX. DEP'T LICENSING & REGUL., STAFF REPORT (June 6, 2019), https://www.tdlr.texas.gov/weather/agendas/StaffReports060619.pdf [https://perma.cc/VD7V-5Z9S].
[200] *See generally* PHILLIP KAUFFMAN & ARQUÍMEDES RUIZ-COLUMBIÉ, ARTIFICIAL ATMOSPHERIC IONIZATION: A POTENTIAL WINDOW FOR WEATHER MODIFICATION 1, 4, *in 16th Conference on Planned and Inadvertent Weather Modification* (Jan. 2005).
[201] TEX. DEP'T LICENSING & REGUL., HARVESTING THE TEXAS SKIES IN 2020—A SUMMARY OF RAIN ENHANCEMENT OPERATIONS IN TEXAS [hereinafter TDLR], https://www.tdlr.texas.gov/weather/summary.htm [https://perma.cc/23PN-YG8G] (last visited Oct. 14, 2021).
[202] Bomar et al., *supra* note 95, at 10.
[203] Sponsored by the Texas Water Commission, the USBR, the Colorado River Municipal Water District (Big Spring), and the City of San Angelo. *Id.* at 10.
[204] *Id.* at 11.

was the first district to use cloud seeding in 1971).[205] It was not until 1995, and the termination of most federal projects, that Texas developed an interest in a state program and contracted with counties to develop cloud seeding.[206] Today, counties continue to sponsor and operate cloud-seeding activities through weather-modification associations, supported by taxpayer money.[207] The West Texas Weather Modification Association ("WTWMA"), for instance, has been operating cloud seeding with its own aircraft, equipment, and personnel since 1998, and has been used as a prototype for the design of other Texas weather-modification programs.[208]

Figure 3—Texas Weather Modification Program as of 2018[209]



[205] *Id.* at 12.
[206] *See* TDLR, *supra* note 201.
[207] Jack Manhire, *Unknowable Unknowns of Tax Reform: Wicked Systems, Cloud Seeding, and the Border Adjustment Tax*, TEXAS A&M UNIV. SCH. L. LEGAL STUD. RSCH. PAPER No. 17-19, at 3 (2017).
[208] TEX. WEATHER MODIFICATION ASS'N, *About Us*, http://www.texasweathermodification.com/history.htm [https://perma.cc/3N5R-MTFT] (last visited Oct. 14, 2021).
[209] TEX. DEP'T LICENSING & REGUL. ADVISORY COMM. ON WEATHER MODIFICATION, STAFF REPORT 1 (2018), https://www.tdlr.texas.gov/weather/agendas/WXM%20111518%20Staff%20Reports.pdf [https://perma.cc/2CXY-BYEA]. This image was reproduced with the permission of the Texas Department of Licensing and Regulation.

B. Legislation

The Texas Weather Modification Act of 1967 is one of the most sophisticated weather-modification laws in the United States. It was developed following a review of weather-modification governance in other states.[210] Originally part of the Texas Water Code, the law was long administered by the Texas Water Development Board.[211] In 2003, the Texas legislature transferred the weather-modification program to the Texas Department of Licensing and Regulation ("TDLR").[212] The law is now part of the Agricultural Code and gives authority to the TDLR to administer the "weather modification and control program."[213] It defines weather modification as "changing or controlling, or attempting to change or control, by artificial methods the natural development of atmospheric cloud forms or precipitation forms that occur in the troposphere."[214] It requires licenses for operators and permits for projects, unless an exemption is granted.[215] The state agency in charge, currently TDLR, develops rules to determine the conditions of the license and permit system.[216]

The one-year license requires the payment of a fee and proof of the operators' competence (i.e., degree in meteorology, physical science, or relevant experience).[217] A four-year permit is also granted for each program, upon payment of a permit fee, publication of a notice of intention, and proof of financial responsibility.[218] License holders must keep record of operations and report in writing to the TDLR, which keeps reports open for public inspection, "or on a publicly-accessible website," since a 2019 amendment.[219] The law also created an Advisory Committee on Weather Modification ("the Committee"), which meets quarterly to review the

---

[210] INT'L CTR. ARID & SEMI-ARID LAND STUD.: TEX. TECH UNIV., WEATHER MODIFICATION STUDIES 40–41, 47 (Donald Haragan ed., 1974).
[211] Rodney Gerik, *Legal Aspects of Weather Modification in Texas*, 25 BAYLOR L. REV. 501, 506 (1973).
[212] S. 1175, 77th Leg., Reg. Sess. (Tex. 2001). It was transferred to the Texas Department of Agriculture that assumed sponsorship up until 1997, and to the Natural Resource Conservation Commission until 2001.
[213] *See, e.g.*, TEX. DEP'T LICENSING & REGUL., *Weather Modification*, https://www.tdlr.texas.gov/weather/weathermod.htm [https://perma.cc/MZV6-E2QB] (last visited Oct. 14, 2021).
[214] TEX. AGRIC. CODE ANN. § 301.002 (West 2003).
[215] TEX. AGRIC. CODE ANN. §§ 301.101–102 (West 2003).
[216] 16 TEX. ADMIN. CODE §§ 79.01–80 (2019).
[217] TEX. AGRIC. CODE ANN. § 301.103 (West 2003); 16 TEX. ADMIN. CODE § 79.13 (2019).
[218] TEX. AGRIC. CODE ANN. §§ 301.107–109 (West 2003).
[219] TEX. AGRIC. CODE ANN. § 301.117 (West 2003); 16 TEX. ADMIN. CODE § 79.33 (2019).

licenses and permits.[220] The Committee is composed of a board of five experts: an atmospheric scientist, a farmer, an engineer, a businessman, and a lawyer. The TDLR has the authority to suspend or revoke a permit or a license following public notice and hearing.[221] Finally, a county or part of a county included in the target area can file an "Application for Election to Disapprove a Weather Modification Permit" within thirty days of the publication of the notice of intention.[222] If a majority votes against the issuance of the permit, the TDLR can deny the permit or exclude an area from the coverage of the permit.[223] This system sets a strict regulatory framework, and in recent years, no permit has been denied.

In 2004, Texas stopped funding weather-modification projects, only providing to the TDLR funding to administer the Act and evaluate projects.[224] In 2020, the Texas Sunset Advisory Commission reviewed the TDLR and recommended the deregulation of weather modification to eliminate the weather-modification program as "unnecessary to protect the public."[225] Because the TDLR does not assess the need for or effectiveness of proposed projects, the Commission determined that the regime did not advance the public interest.[226] In light of districts' experience and expertise, it deemed the TDLR's oversight redundant to the NOAA reporting system and the submission of the water management plan to the Texas Water Development Board.[227] Despite this recommendation, the law has not yet been dismantled, and it seems unlikely that the Sunset Advisory Commission will recommend the deregulation of the Texas weather-modification programs to the legislature.

---

[220] TEX. AGRIC. CODE ANN. §§ 301.053 (West 2003). *See also* TEX. DEP'T LICENSING & REGUL., *Weather Modification Advisory Committee*, https://www.tdlr.texas.gov/weather/weathercmte.htm [https://perma.cc/WSC8-UVR9] (last visited Oct. 14, 2021).
[221] TEX. AGRIC. CODE ANN. §§ 301.252–254 (West 2003).
[222] TEX. AGRIC. CODE ANN. § 301.155 (West 2003).
[223] TEX. AGRIC. CODE ANN. § 306.163 (West 2003).
[224] TEX. DEP'T LICENSING & REGUL., *Frequently Asked Questions*, https://www.tdlr.texas.gov/weather/weatherfaq.htm [https://perma.cc/2DLP-GKAP] (last visited Oct. 14, 2021).
[225] TEX. DEP'T LICENSING & REGUL., TEX. SUNSET COMM'N, STAFF REPORT WITH FINAL RESULTS 28–29 (2020), https://www.sunset.texas.gov/public/uploads/files/reports/Texas%20Department%20of%20Licensing%20and%20Regulation%20Staff%20Report%20with%20Final%20Results_6-30-21.pdf [https://perma.cc/XWU8-R2KF].
[226] *Id.*
[227] TEX. WATER CODE ANN. § 36.1071(a)(7) (West 2011).

C. Litigation

Texas does not claim sovereign rights over atmospheric water, but Texas courts have recognized a private right to the use of rainfall.[228] In a case litigated prior to the enactment of the Texas law, cattle ranchers alleged that hail suppression operations over their lands deprived them of beneficial rainfall.[229] Ranchers sought a permanent injunction against the cloud seeders, and the court recognized that a natural right to use precipitation was attached to land ownership: "[w]e believe that under our system of government the landowner is entitled to such precipitation as Nature deigns to bestow."[230] The court granted a temporary injunction and prohibited operations in the airspace directly over the plaintiffs' land.[231] It remains the only American case where plaintiffs managed to prove causation, based on eyewitnesses' testimony, and win against cloud seeding operators.[232] In a later case, a Texas court considered that "plaintiff's lay opinion evidence and visual observation evidence was not sufficient to counter the expert testimonies of the defendant's witnesses."[233] However, this case did not clarify liability for harm.[234] Today, the difficulty for a plaintiff to prove the causal nexus between a weather damage and a particular cloud seeding operation would still considerably limit access to remedies.[235] Moreover, these controversies relate to hail suppression techniques and there has been no litigation over rain enhancement projects in Texas.

---

[228] Southwest Weather Research, Inc. v. Rounsaville, 320 S.W.2d 211, 213–15 (Tex. Civ. App. 1958); Southwest Weather Research, Inc. v. Duncan, 319 S.W.2d 940, 941 (Tex. Civ. App. 1958); Southwest Weather Research, Inc. v. Jones, 327 S.W.2d 417, 419 (Tex. 1959).
[229] *Southwest Weather Research, Inc. v. Rounsaville*, 320 S.W.2d at 212–14.
[230] *Id.* at 216.
[231] *Id.* at 216–17. The case went all the way to the Texas Supreme Court, which confirmed the injunction. Corbridge & Moses, *supra* note 13, at 215.
[232] *Southwest Weather Resources, Inc. v. Jones*, 327 S.W.2d at 417, 422.
[233] Farmers and Ranchers for Nat. Weather v. Atmospherics, Inc., Civ. No. 7594 (D. Ct. Lamb Cnty., Tex., May 3, 1974), discussed *in* G. N. Heilbronn, *Some Legal Consequences of Weather Modification: An Uncertain Forecast*, 6 MONASH U. L. REV. 122, 127 (1979).
[234] *Id.*
[235] *Southwest Weather Research, Inc. v. Rounsaville*, 320 S.W.2d at 213.

D. Current Projects

Between 1998 and 2004, the State of Texas spent over $12 million on cloud seeding research and operations.[236] Bomar estimated that, in 1999, State-funded rain enhancement program covered nearly one-quarter of the State's acreage.[237] After the Texas Legislature stopped allocating funding, cloud seeding became exclusively sponsored by "underground water conservation districts and other local political subdivisions like county commissions and aquifer authorities."[238] Nevertheless, weather modification is now included in the Texas Water Development Plan, which recommends: "[A]bout 22,000 acre-feet per year of supply from weather modification strategies (. . .) in 2070."[239] Five districts currently hold permits for rain enhancement projects in Texas: the West Texas Weather Modification Association ("WTWMA");[240] the South Texas Weather Modification Association ("STWMA");[241] the Panhandle Groundwater Conservation District ("PGCD");[242] the Trans-Pecos Weather Modification Association ("TPWMA");[243] and the Seeding Operations & Atmospheric Research ("SOAR"), in the Rolling Plains.[244] The WTWMA is the longest ongoing project and is therefore explored in more detail below.

---

[236] *See* TDLR, *supra* note 201.
[237] Bomar et al., *supra* note 95, at 9.
[238] TDLR, *supra* note 201.
[239] TEX. WATER DEV. BD., WATER FOR TEXAS: 2017 STATE WATER PLAN 97 (2017), https://www.twdb.texas.gov/waterplanning/swp/2017/doc/SWP17-Water-for-Texas.pdf?d=5958 [https://perma.cc/73KD-AK99].
[240] W. TEX. WEATHER MODIFICATION ASS'N, http://wtwma.com/ [https://perma.cc/3JFA-ZYYM] (last visited Oct. 14, 2021).
[241] S. TEX. WEATHER MODIFICATION ASS'N, http://southtexasweathermodification.com/ [https://perma.cc/582T-KPGU] (last visited Oct. 14, 2021).
[242] PANHANDLE GROUNDWATER DIST., *Precipitation Enhancement FAQ*, https://www.pgcd.us/precipitation-enhancement [https://perma.cc/6SS6-PMHP] (last visited Oct. 14, 2021).
[243] TRANS-PECOS WEATHER MODIFICATION ASS'N, http://wtwma.com/tpwma.htm [https://perma.cc/JJ9Q-UA94] (last visited Oct. 14, 2021).
[244] CLOUD SEEDING OPERATIONS & ATMOSPHERIC RSCH. (SOAR), *About Us*, http://just-clouds.com/about_us.asp [https://perma.cc/8FPZ-R349] (last visited Oct. 14, 2021).

TABLE 4—SPONSORS AND OPERATORS OF THE DIFFERENT CLOUD SEEDING PROJECTS IN TEXAS[245]

Project	Years	Sponsor	Operator
West Texas Weather Modification Association (WTWMA)	1996–2019	WTWMA	WTWMA
South Texas Weather Modification Association (STWMA)	1998–2019	STWMA	STWMA
Panhandle Groundwater Conservation District (PGCD)	2002–2019	PGWCD	PGWCD
Trans Pecos Weather Modification Association (TPWMA)	2003–2019	TPWMA	TPWMA
Rolling Plains	2002–2019	Seeding Operations & Atmospheric Research (SOAR)	SOAR

1. The West Texas Weather Modification Association Program

As the west-end part of Texas is particularly dry, western municipalities have long engaged in weather modification. Up until the 1990s, the Southwest Cooperative Program conducted randomized cloud seeding from Big Spring to San Angelo.[246] Following this study, the city of San Angelo sponsored a cloud seeding program, from 1985 to 1989, to evaluate silver iodide seeding in the area.[247] In 1995, the West Texas Weather Modification

[245] Table made following a review of National Oceanic and Atmospheric Administration ("NOAA") Weather Modification Project Reports. *See* WEATHER MODIFICATION PROJECT REPS., *supra* note 71; TDLR, *supra* note 201.

[246] *See generally* William L. Woodley & Mark E. Solak, *Results of Operational Seeding over the Watershed of San Angelo, Texas*, 22 J. WEATHER MODIFICATION 30, 40 (1990) (assessing the Southwest Cooperative Program's impact).

[247] *See* WILLIAM L. WOODLEY ET AL., CLOUD SEEDING OPERATIONS AND EVALUATIONS FOR THE SAN ANGELO RAIN ENHANCEMENT PROGRAM DURING THE PERIOD 15 APRIL–15

Association ("WTWMA") was created, and it has now been operational for about 25 years.[248] It is composed of eight counties (Glasscock, Crockett, Irion, Reagan, Schleicher, Sterling, Sutton, and Tom Green counties) covering over 6 million acres.[249] It is funded by the different groundwater conservation districts as well as the city of San Angelo, which hosts the base of operations.[250]

The WTWMA uses aerial cloud seeding to "increase dry land crop revenues, decrease groundwater consumption, save on irrigation cost and to help recharge area aquifers while putting some water in area lakes, rivers and reservoirs."[251] In arid and semi-arid areas of Texas, water users rely almost exclusively on groundwater for irrigation and freshwater consumption.[252] With climate change–driven droughts and increased water demand, precipitation enhancement is increasingly used for groundwater recharge.[253] Reviews of the WTWMA program have shown an increase of 8 to 15% in rainfall, between 2004 and 2013.[254] In a "benefit-cost" analysis of the Texas weather modification programs, conducted in 2014, Johnson shows that the main beneficiaries of weather modification in Texas are dryland crop revenues, grazing land values and irrigated acreage cost savings.[255] The study estimated to $12,757,566 the statewide economic impacts of an additional one inch of rain in counties actively engaged in the West Texas program.[256]

OCTOBER 1989 WITH ADDITIONAL INFORMATION ON THE 1985–1988 SEASONS iv (1989), https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/9483735.pdf [https://perma.cc/WR8Y-FCTV].

[248] TEX. WEATHER MODIFICATION ASS'N, *supra* note 208.

[249] *See* W. TEX. WEATHER MODIFICATION ASS'N, *supra* note 240.

[250] *See* TEX. WEATHER MODIFICATION ASS'N, *supra* note 208.

[251] W. TEX. WEATHER MODIFICATION ASS'N, *supra* note 240.

[252] *See* TEX. WATER DEV. BD., REPORT 356: AQUIFERS OF WEST TEXAS 1 (Robert E. Mace et al. eds., 2001), https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R356/356_AquifersofWestTexas.pdf [https://perma.cc/HQU9-SYYL].

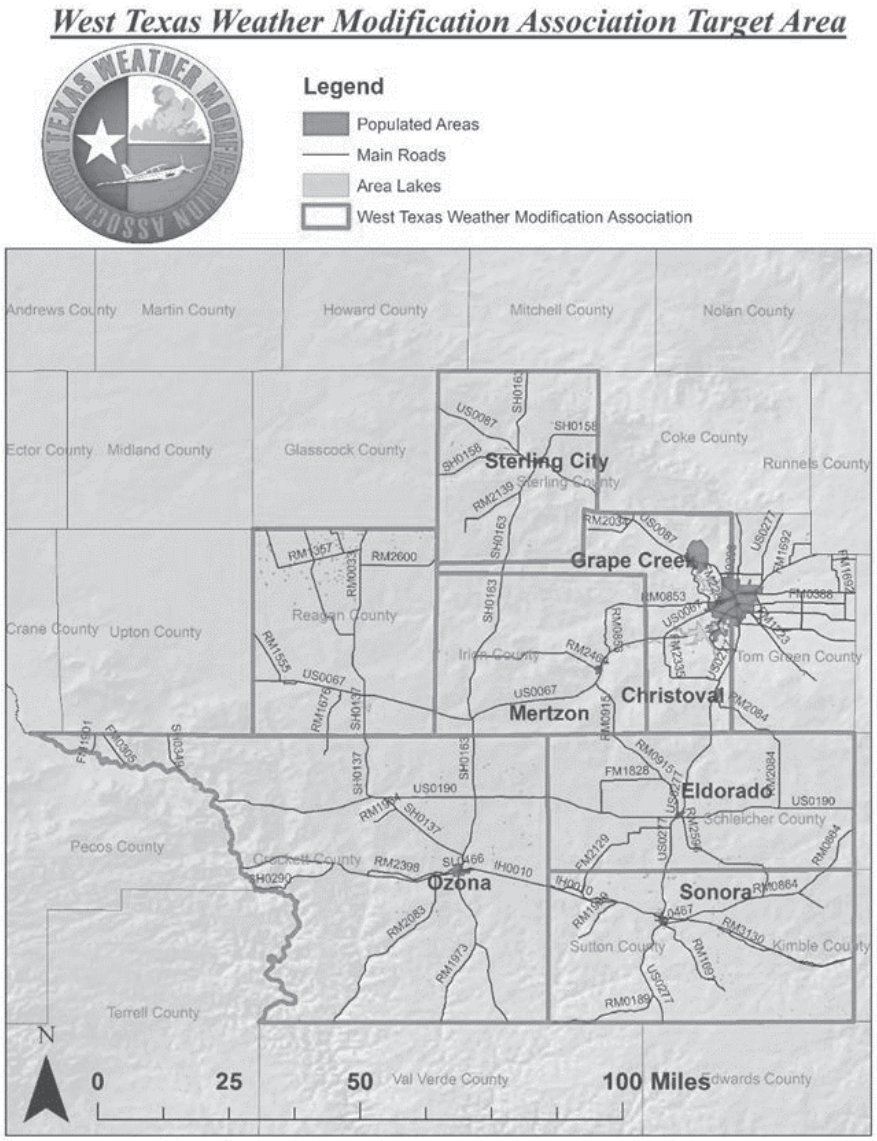
[253] *See generally* Jonathan A. Jennings & Ronald T. Green, *Rain Enhancement of Aquifer Recharge across the West Texas Weather Modification Association Target Area*, 46 J. WEATHER MODIFICATION 45, 52 (2014) (using rain enhancement for groundwater recharge).

[254] *Id.* at 52.

[255] JASON L. JOHNSON, A BENEFIT-COST ANALYSIS OF TEXAS WEATHER MODIFICATION ACTIVITIES RESULTING IN AN ADDITIONAL ONE INCH OF RAINFALL ACROSS A REGION 1, 14 (2014), http://www.texasweathermodification.com/NEW/Benefit%20Cost%20Analysis%20of%20Texas%20Weather%20Modification.pdf [https://perma.cc/ERJ6-HGLZ].

[256] *Id.* at 9.

Figure 4—West Texas Weather Modification Target Area[257]



[257] W. TEX. WEATHER MODIFICATION ASS'N, *Target Areas*, http://wtwma.com/ [https://perma.cc/2986-JYRH] (last visited Oct. 14, 2021). This image was reproduced with the permission of the West Texas Weather Modification Association.

The WTWMA currently holds TDLR permits and a license for both rain enhancement and hail suppression.[258] It is the only association that has applied for the two permits so far.[259] These permits specify several criteria for suspending operations, recognizing that "some cloud systems possess potential to generate large, damaging hail, in addition to rainfall in amounts and rates that can translate into damaging flash floods and other pernicious by-products such as damaging winds. . ."[260] For instance, operations are to be suspended in cases when "Severe Thunderstorm Warning," "Tornado Warning," or "Flash Flood Warning" are issued by the National Weather Service.[261] In recent years, a new suspension criterion has been added to some permits (including the WTWMA's) as follows:

> With any severe thunderstorm warning issued for all counties within the target area, seeding operations may continue for a maximum of twenty minutes, after no more than twenty minutes from the time the severe thunderstorm was issued, seeding operations on the storm with the warning will be suspended and seeding operations may resume after the storm warning expires if conditions warrant.[262]

This clause allows the activities to continue at the beginning of a storm, to avoid missing cloud seeding opportunities.[263] However, this new term could raise liability issues in the event of extreme weather events like floods.[264]

---

[258] *See* TEX. DEP'T LICENSING & REGUL., CURRENT TEX. WEATHER MODIFICATION LICENSES (2019), https://www.tdlr.texas.gov/weather/agendas/StaffReports060619.pdf [https://perma.cc/TEV9-D66C].
[259] *See id.*
[260] *See, e.g.*, TEX. DEP'T LICENSING & REGUL., WEATHER MODIFICATION PERMIT NO. 14-3, at 2 (2014) [hereinafter TDLR WEATHER MODIFICATION PERMIT NO. 14-3], http://www.wichitafallstx.gov/DocumentCenter/View/21865/Weather-Modification-Permit-No-14-3_Issued-030114?bidId= [https://perma.cc/2F6J-J6C9]; TEX. DEP'T LICENSING & REGUL., WEATHER MODIFICATION PERMIT NO. 18-1, at 2–3 (Apr. 4, 2018) [hereinafter TDLR WEATHER MODIFICATION PERMIT NO. 18-1], https://www.tdlr.texas.gov/weather/agendas/WXM%20060718%20Staff%20Reports.pdf [https://perma.cc/NZA5-DRGF].
[261] *Id.* at 2–3.
[262] TEX. DEP'T LICENSING & REGUL. WEATHER MODIFICATION ADVISORY COMM., SUMMARY OF MINUTES (Dec. 8, 2016), https://www.tdlr.texas.gov/search/ [https://perma.cc/CGC9-JRW9] (search in search bar for "Weather Modification Advisory Committee Meeting of December 8, 2016"; then follow the first link).
[263] *See id.*
[264] *See id.*

There is no general EIA process in Texas,[265] and no such assessment was conducted for any of the weather modification programs.[266] The TDLR does not directly evaluate the impacts of the programs, leaving to the associations the competence to conduct evaluation of their cloud seeding activities.[267] Although it has not been enacted by the legislature, the WTWMA follows a self-assessment process. These evaluations have been published in the newsletter of the statewide Texas Weather Modification Association ("TWMA"), between 2007 and 2012, and some years, in the Journal of Weather Modification.[268] The results were posted regularly on the TWMA's website up until 2016,[269] and on the WTWMA's website up until 2017.[270] In 2018, reports on the programs were available in the staff reports of the TDLR Advisory Committee.[271] The evaluations for the following years are not consistently available, but it can be expected that the 2019 amendment requiring reporting on a publicly accessible website will improve the transparency of weather modification results.

V. DISCUSSION

This section addresses some of the governance issues that emerge from the case studies. Clouds and the atmospheric water they contain are common-pool resources and raise complex issues of governing the commons.[272] The ownership of clouds and rainwater has raised a new range of legal issues that existing legal doctrines inadequately address.[273] In recent years, however, a growing school of thought known as "new environmental governance" has been proposing frameworks to solve

---

[265] In 2003, the Texas Commission on Environmental Quality repealed as redundant and unneeded sections 30 TAC §§ 261.1–261.6 on environmental, social, and economic impacts statements and 30 TAC §§ 261.21–261.23 on guidelines for preparation of environmental, social, and economic impacts statements. 28 TEX. REG. 10420 (Nov. 21, 2003).
[266] TEX. DEP'T LICENSING & REGUL., *supra* note 213.
[267] TDLR, *supra* note 201.
[268] *See generally* Todd R. Flanagan et al., *A Review of the Texas Weather Modification Programs in 2007*, 40 J. WEATHER MODIFICATION 85, 85 (2008); Stephanie Beall et al., *Texas Weather Modification Operations in 2008*, 41 J. WEATHER MODIFICATION 127, 127 (2009); Robert E. Rhodes et al., *Texas Weather Modification Operations in 2009*, 42 J. WEATHER MODIFICATION 108, 108 (2010) (assessing environment impact of weather modification in Texas every year).
[269] TEX. WEATHER MODIFICATION ASS'N, *Analysis*, http://texasweathermodification.com/analysis.htm [https://perma.cc/S2RH-52JJ] (last visited Oct. 14, 2021).
[270] W. TEX. WEATHER MODIFICATION ASS'N, *Analysis and Research*, http://wtwma.com/analysis_and_research.htm [https://perma.cc/3U6L-NH67] (last visited Oct. 14, 2021).
[271] TEX. DEP'T LICENSING & REGUL., *supra* note 220.
[272] Chen, *supra* note 110, at 49.
[273] Corbridge & Moses, *supra* note 13, at 225.

complex environmental problems.[274] Because cloud seeding affects common natural resources, it requires polycentric and participatory governance that takes into account ecological impacts and uncertainties. This section uses some of the key elements of new environmental governance to assess weather modification legal arrangements: (1) decision-making framework; (2) EIA and management of uncertainties; (3) public participation; (4) monitoring; and (5) liability. The table below summarizes the differences and similarities between the California and Texas weather modification regimes in respect of each of these issues.

TABLE 5—KEY ISSUES IN U.S. WEATHER MODIFICATION GOVERNANCE[275]

Issue	Tahoe-Truckee	West Texas
Decision-making framework	-NOAA's limited decision-making power (recommendation)	
	-Exempt from a permit under California and Nevada law -DWR's limited decision-making power (notification and report) -Funding from State government (Nevada) and districts -Desert Research Institute self-governance framework	-TDLR reviews permit and license -Advisory Committee on Weather regularly inspect the operation sites -WTWMA (water districts constituted of counties) self-governance framework
EIA and management of uncertainty	-NEPA inapplicable -International standards (e.g., WMO)	
	-CEQA EIA requirements inapplicable but functional equivalent -No formal EIA conducted under the Tahoe Regional Planning Compact	-No EIA legal requirement -No EIA conducted -WTWMA reviews operations following with the assistance of an independent expert

[274] *See generally* Cameron Holley & Ekaterina Sofronova, *New Environmental Governance: Adaptation, Resilience and Law*, *in* RISK, RESILIENCE, INEQUALITY AND ENVIRONMENTAL LAW 129,129–46 (Bridget M. Hutter ed., 2017) (introducing the concept of new environment governance to approach environmental law and regulation).
[275] *See* discussion *infra* Sections V.A–E.

Issue	Tahoe-Truckee	West Texas
Public participation	-NOAA reports are made available to the public "to the fullest extent possible"	
	-No public access to information (but information available on DRI's website) -No public participation -Public engagement in the EIA process but not in the functional equivalent	-Provisions on public access to information (access to report and online publication) -Public participation provisions (public hearings and referendum, mechanism to deny permit application . . .)
Monitoring	-No monitoring mechanism at the federal level	
	-No monitoring mechanism at the state level (under both Californian and Nevadan law) -DRI traces silver iodide dispersion but does not monitor silver levels -No environmental monitoring	-TDLR monitors weather modification programs -Self-assessment of the silver levels prior to 2003 -No environmental monitoring
Liability	-No liability provisions under California law (no proof of financial responsibility and no state immunity) -The State of California may be liable in inverse condemnation for taking and damage -Private operators may be liable under tort law -Under Nevada law, state immunity and proof of financial responsibility requested only for permit applicants	-Proof of financial responsibility required for license and permit application -State immunity -Private operators may be liable but weather modification is not considered ultra-hazardous activities (no strict liability)

A. Decision-Making Framework

In the United States, weather modification decision making generally happens at the State and local levels. Apart from the reporting requirements to NOAA, there is no regulation of weather modification at the federal level. NOAA does not have the competence to approve or disapprove a reported project, however:

> When consideration of a weather modification activity report and related information indicates that a proposed project may significantly depart from the practices or procedures generally employed in similar circumstances to avoid danger to persons, property, or the environment, or indicates that success of Federal research projects may be adversely affected if the proposed project is carried out as described, the Administrator will notify the operator(s) and State officials of such possibility and make recommendations where appropriate.[276]

In addition, NOAA can request information from any person whose activities relate to weather modification "by rule, subpoena, or otherwise."[277] In case when an operator fails to submit the required documents, district courts have jurisdiction to issue an order to produce the documents and failure to obey may be punishable as a contempt to the court.[278] Nonetheless, NOAA's authority is overall limited.

There are only few cases when the federal government can be involved in weather modification activities.[279] These include interstate projects, in absence of interstate compact; projects affecting federal lands or installations (permits may be required from the Forest Service or the Bureau of Land Management);[280] and projects with international implications.[281] In addition, drone technologies are currently regulated under federal law, so that Currier suggests that the federal government may have a role to play in regulating emerging drone-based cloud seeding.[282] However, there have been no new weather modification laws adopted at the federal level since the 1970s.[283] In 2005, a bill was introduced proposing a nationwide weather modification research program.[284] States encouraged

---

[276] 15 C.F.R. § 908.12(d) (2011).
[277] Weather Modification Reporting Act, Pub. L. 92-205, § 4(a), 85 Stat. 735 (1972).
[278] *Id.* § 4(b).
[279] Ralph W. Johnson, *Federal Organization for Control of Weather Modification*, 10 NAT. RES. J. 222, 226 (1970).
[280] *See, e.g.*, PITCHFORD, *supra* note 177, at 2.
[281] *See* Tarek Majzoub et al., *Cloud Busters: Reflections on the Right to Water in Clouds and a Search for International Law Rules*, 20 COLO. J. INT'L ENV'T L. & POL'Y 321, 329, 333 (2008).
[282] Currier, *supra* note 15, at 968.
[283] Weather Modification Research and Development Policy Authorization Act, S. 517, 109th Cong. (2005).
[284] *Id.*

the involvement of the federal government in weather modification activities: the Western States Water Council, for instance, supported the bill and continued funding for the WDMP.[285] However, federal regulations have been deferred pending further research.[286] This goes against precautionary approaches that encourage the development of governance mechanisms in face of scientific uncertainty.

There are no federal regulations governing interstate projects, so state laws have had to regulate on this matter. The Texas law provides that "[t]he executive director [of the TDLR] may represent the State in matters pertaining to plans, procedures, or negotiations for interstate compacts relating to weather modification and control."[287] The TDLR can cooperate with public (federal, counties and municipalities) and represent them in contracting with private agencies.[288] In California, however, there is no provision addressing interstate weather modification projects, leaving the Tahoe-Truckee project unregulated.[289] The Tahoe Regional Planning Compact could be a useful arrangement to regulate interstate issues, but cloud seeding is not regulated under the agreement.[290] In 2018, Colorado-basin states, including Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming entered into the "Colorado River Basin Weather Modification Agreement," an interstate compact proposed to allocate collectively $1.5 million per year for cloud seeding up until 2026.[291] However, the Tahoe-Truckee river basin is not covered under this agreement either.[292] Today, interstate legal issues are still open to discussion as "[n]o national weather policy or law exists and state precedent is limited."[293] The development of a federal framework regulating such projects could prevent potential interstate and transboundary conflicts of interest.

States are the main entity regulating weather modification in the United States. According to Davis, state action in weather modification is appropriate because state regulations can be tailored to the needs of

---

[285] RYAN, *supra* note 61, at 8.
[286] *See, e.g.*, Currier, *supra* note 15, at 962.
[287] TEX. AGRIC. CODE ANN. § 301.056 (West 2003).
[288] *Id.* § 301.057.
[289] CAL. WATER CODE § 235 (West 2021).
[290] *See generally* Tahoe Regional Planning Compact, Pub. L. No. 96-551, 94 Stat. 3233 (1980).
[291] AGREEMENT ESTABLISHING PROGRAMMATIC FUNDING FOR COLORADO RIVER BASIN WEATHER MODIFICATION, 1, 5–6 (2018), https://library.cap-az.com/documents/meetings/2018-03-01/1683-4d-Web-Final-Action-Brief-CRC-Weather-Modification.pdf [https://perma.cc/8PRB-9ERL].
[292] *Id.*
[293] Witt, *supra* note 15, at 122.

each state.[294] The problem, however, is that weather modification regulations have become inconsistent.[295] Different state agencies are responsible for weather modification activities within their jurisdictions: the DWR for California, and the TDLR for Texas.[296] As Farhar and Mewes put it, "[t]he nature of the state agency responsible for decision making has implications for patterns of decision making because agencies vary in the political constituencies to which they are responsive."[297] They argue that an agency's constituency can make it more or less favorable to weather modification.[298] In California, the DWR has shown little interest in regulating cloud seeding and the involvement of the State has been limited to the application of CEQA.[299] Nevertheless, since 2009, weather modification is part of California Water Plan that recommends: "The State should support the continuation of current projects, as well as the development of new projects, and help in seeking research funds for both old and new projects."[300] Yet, California's system that only consists of notification and report is not regulatory per se and the DWR has no true decision-making power in weather modification.

On the other hand, the TDLR has significant decision-making powers, but it is more concerned with licensing requirements than environmental impacts. The license-permit mechanism in Texas allows the State to exert control over individual projects.[301] Violating these provisions can give rise to administrative or other penalties.[302] Baum contends that the main purpose of state weather modification laws is to make weather modification activities "a state or municipal function, not one that individuals can undertake without regulation and permits."[303] Indeed, the

---

[294] Ray Jay Davis, *Weather Modification Law as a Prototype for Legal Control of Inadvertent Weather and Climate Change*, 24 J. WEATHER MODIFICATION 122, 125 (1992).
[295] Currier, *supra* note 15, at 122.
[296] TEX. DEP'T LICENSING & REGUL., *About Weather Modification,* https://www.tdlr.texas.gov/weather/weathermod.htm [https://perma.cc/GA7R-R727] (last visited Oct. 14, 2021); Gretchen Weber, *Seeding Clouds for Hydropower*, KQED SCI. (Sep. 5, 2009), https://ww2.kqed.org/climatewatch/2009/09/05/seeding-clouds-for-hydropower/# [https://perma.cc/M3PF-AZW7].
[297] Barbara C. Farhar & Julia Mewes, *Weather Modification Decision Making: State Law and Public Response*, 14 J. APPLIED METEOROLOGY & CLIMATOLOGY 694, 695 (1975).
[298] *Id.* at 695.
[299] Weber, *supra* note 296.
[300] CAL. DEP'T WATER RES., *supra* note 28, at 11–12.
[301] TEX. AGRIC. CODE ANN. §§ 301.101–103 (West 2003).
[302] TEX. AGRIC. CODE ANN. § 301.201 (West 2003); TEX. OCC. CODE ANN. § 51.301 (West Supp. 2011).
[303] MARSHA L. BAUM, WHEN NATURE STRIKES: WEATHER DISASTERS AND THE LAW 33 (2007).

TDLR can deny a weather modification license or permit if an applicant has been convicted of certain categories of crimes (e.g., deceptive business practices and environmental law violations).[304] In addition, applicants to a weather modification permit must submit a "Plan for Weather Modification Operations" (or Operation Plan) and the permit provides:

> Failure on the part of the Association to comply with the terms, conditions, and provisions of the permit, including the Operations Plan, will subject this permit to reconsideration by the TDLR and such administrative and judicial proceedings as may be necessary to prevent violations and to obtain compliance, including but not limited to, modification or forfeiture and cancellation of all rights granted herein.[305]

The TDLR has broad statutory power to modify or cancel weather modification licenses and permits and is thus actively engaged in the decision-making.

States used to be the main sponsor of weather modification programs, but by withdrawing their financial support, they have left to local entities (e.g., municipalities and water districts) the authority to conduct and regulate weather modification activities. In Texas, weather modification operations are both sponsored and conducted by special water districts, like the WTWMA.[306] In California, municipalities are the main sponsors of weather modification activities (e.g., Kings River Conservation District, Los Angeles County Department of Public Works, Santa Barbara County, etc.) and set their own standards. The DRI also operates the following self-standards: the Cloud Seeding Operations Criteria,[307] and the Cloud Seeding Safety Guidelines.[308] The latest provide for suspension

---

[304] TEX. AGRIC. CODE ANN. §§ 301.252–353 (West 2003); TEX. OCC. CODE § 53.025(a) (1999); TEX. DEP'T LICENSING & REGUL., *Guidelines for License Applicants with Criminal Convictions*, https://www.tdlr.texas.gov/crimconvict.htm [https://perma.cc/WT9K-ZB6X] (last visited Oct. 14, 2021).

[305] *See, e.g.*, TDLR WEATHER MODIFICATION PERMIT NO. 14-3, *supra* note 260, at 4.

[306] TEX. DEP'T LICENSING & REGUL., *Weather Modification Frequently Asked Questions*, https://www.tdlr.texas.gov/weather/weatherfaq.htm [https://perma.cc/2BGP-BSXW] (last visited Oct. 14, 2021).

[307] *Cloud Seeding Operations Criteria*, DRI, https://www.dri.edu/cloud-seeding-program/operations-criteria/ [https://perma.cc/DHE7-8QER] (last visited Oct. 14, 2021).

[308] *Cloud Seeding Safety Guidelines*, DRI, https://www.dri.edu/cloud-seeding-program/safety-guidelines/ [https://perma.cc/GGC7-A8HK] (last visited Oct. 14, 2021).

criteria in case of a warning for extreme avalanches; warm winter storms; floods; and on major holidays. Ryan asserts that "[t]o address potential flooding liability, all ongoing projects have suspension criteria designed to stop seeding any time there is a flood threat."[309] However, such criteria are not clearly stated or readily accessible for other Californian projects.[310] State standards regulating the conducting of weather modification operations, like in Texas, could reduce the risks of inconsistencies from one project to another.

In early discussions on weather modification governance, the involvement of local agencies was considered beneficial to the public interest: "it would be useful to arrange that modification operations be organized primarily by weather-modification districts which are carefully organized and delimited so as to include all those who benefited or lost from modification."[311] Considering that weather modification activities are localized in nature, local governance of cloud seeding appears appropriate.[312] However, the absence of overarching framework creates discrepancies between state laws and local self-governance regimes.[313] Currier, for instance, deplores that weather modification laws are scattered, incomplete and difficult to navigate.[314] Moreover, local decision making is not appropriate to the regulation of interstate and transboundary projects, and the poor coordination between jurisdictions does not adequately regulate both deliberate and potential incidental impacts of cloud seeding beyond municipal jurisdiction.[315] Weather modification requires strong collaboration between governmental institutions at all levels of decision making.[316] Local agencies seem to be an appropriate level of governance for weather modification, but states should ensure coordination between the different programs, like in Texas. The federal government could also play a greater role in the

---

[309] RYAN, *supra* note 61, at 21.
[310] *See e.g.*, CNTY. SANTA BARBARA, SANTA BARBARA CNTY. AND TWITCHELL RESERVOIR CLOUD SEEDING PROGRAM: CEQA FINAL MITIGATED DECLARATION 8 (Oct. 15, 2013), https://www.slocounty.ca.gov/Departments/Public-Works/Forms-Documents/Projects/Cloud-Seeding-for-Lopez-Salinas/Santas-Barbara-County-Cloud-Seeding-MND -2013.pdf [https://perma.cc/CS67-2FD6].
[311] Rita F. Taubenfeld, *Social Norms, the Public Interest, and the Regulation of Weather Modification*, *in* TAUBENFELD, *supra* note 109, at 84.
[312] *Id.*
[313] Currier, *supra* note 15, at 960.
[314] *Id.* at 972.
[315] *Id.* at 950, 960, 964.
[316] *Id.* at 950, n.11.

decision-making: establishing national regulations would ensure that state requirements are consistent and follow international best practices.[317]

B. Environmental Impact Assessment and Management of Uncertainty

Weather modification projects are unevenly subject to EIA requirements, and state laws deal very poorly with scientific uncertainties. In the past, federal programs have been subject to the National Environmental Policy Act ("NEPA") requirements.[318] As part of the Sierra Cooperative Pilot Project, the USBR conducted a NEPA Environmental Assessment and filed a Finding of No Significant Impact,[319] so the project did not require a full Environmental Impact Report.[320] Studies were also conducted to evaluate the socio-environmental impacts of cloud seeding in the basin and the public was encouraged to participate.[321] The Sierra Ecology Project, for instance, was the product of workshop groups evaluating the potential effects of cloud seeding on forest, vegetation and animal habitat in the American River Basin.[322] Similarly, for the High Plains Project, NOAA conducted an assessment of the downwind effects and economic, social and ecological impacts of cloud seeding.[323] For projects involving the federal government, NEPA provisions still apply, including NSF-sponsored projects that require an Environmental Assessment for "[a]ny project that will involve (. . .) weather modification, or other techniques that may alter a local environment."[324] In 2010, the USBR conducted a NEPA Environmental Assessment for the Walker River Basin Cloud Seeding Project.[325] However, few NEPA assessments have been conducted since

---

[317] *Id.* at 950–51, 960.
[318] 40 C.F.R. § 1508.1 (2020).
[319] HARRIS, *supra* note 173, at 16.
[320] *Finding of no significant impact* means a document by a Federal agency briefly presenting the reasons why an action, not otherwise categorically excluded (§ 1501.4 of this chapter), will not have a significant effect on the human environment and for which an environmental impact statement therefore will not be prepared.
40 C.F.R. § 1508.4 (2020).
[321] *See generally* JAMES L. SMITH ET AL., U.S. BUREAU OF RECLAMATION, SIERRA ECOLOGY PILOT PROJECT I-2–3, I-18 (1978).
[322] *Id.*
[323] FLEAGLE ET AL., *supra* note 95, at 10.
[324] 45 C.F.R. § 640.3(b)(4) (2000).
[325] *See generally* CARSON CITY & NEVADA MID-PACIFIC REGION OFF., U.S. BUREAU OF RECLAMATION, ENVIRONMENTAL ASSESSMENT FOR THE WALKER RIVER BASIN CLOUD SEEDING PROJECT (2010).

the withdrawal of federal agencies from weather modification projects in the 1980s.[326]

At the state level, EIA requirements are at the discretion of the state. Only in the State of Montana does the legislation on weather modification explicitly require the conducting of an EIA.[327] In states like California, general environmental laws require that state and local agencies conduct an EIA before approving a project.[328] In 2017, the Sacramento Municipal Utility District filed a CEQA Mitigated Negative Declaration for the El Dorado Cloud Seeding Program Expansion Project, to extend the target area of the Upper American River Snow Augmentation Project from 190 square miles to 444 square miles.[329] Similarly, the Placer County Water Agency recently submitted a CEQA Initial Study/Negative Declaration for the Middle Fork American River project.[330] For private projects, however, governmental agencies decide whether an environmental review is required, so that weather-modification projects are unevenly subject to EIA requirements.[331] Privately funded cloud-seeding projects should be subject to the same requirements as publicly funded projects and appropriate funding allocated to encourage systematic assessment of weather modification impacts.

As explained above, the Tahoe-Truckee project was granted a functional equivalent process to replace the EIA process in the late 1970s, and there has been no assessment of the project's impacts for over forty years.[332] Interestingly, the Tahoe Regional Planning Compact ("TRPC") requires an Environmental Impact Statement for projects conducted in the Lake Tahoe Region,[333] that is "activity undertaken *by any person, including any public agency*, if the activity may substantially affect the land, water, air, space or any other natural resources of the region."[334] The Tahoe Regional Planning Agency ("TRPA") requires an Initial Environmental

---

[326] *Id.*
[327] MONT. CODE ANN. § 85-3-202(1) (1995).
[328] *See, e.g.*, CAL. CODE REGS. tit. 14, §§ 15000–15387 (2009).
[329] SACRAMENTO MUN. UTILITY DIST., EL DORADO CLOUD SEEDING PROGRAM EXPANSION PROJECT, INITIAL STUDY/MITIGATED NEGATIVE DECLARATION 5 (2017), https://www.smud.org/assets/documents/pdf/El-Dorado-Cloud-Seeding-Program.pdf [https://perma.cc/N7HH-V9B5].
[330] PLACER CNTY. WATER AGENCY, MIDDLE FORK AMERICAN RIVER WEATHER MODIFICATION PROJECT, DRAFT INITIAL STUDY/NEGATIVE DECLARATION (2018).
[331] 45 C.F.R. § 640.3.
[332] Roos, *supra* note 129, at 127–28.
[333] Tahoe Regional Planning Compact, *supra* note 192, art. VII.
[334] *Id.* art. II(h) (emphasis added).

Checklist to determine whether an Environmental Assessment is needed.[335] The TRPA can then issue a Finding of No Significant Effect or a Mitigated Finding of No Significant Effect,[336] and alternatively, require a full Environmental Impact Statement.[337] The TRPA can also exempt a project from the requirement (e.g., home renovations), but cloud seeding does not appear to be an activity exempted under the TRPC.[338] It has become common practice to coordinate environmental reviews through joint NEPA and/or CEQA/TRPC environmental assessment for major projects over the Tahoe basin.[339] However, no assessment appears to have been conducted for the Tahoe-Truckee cloud seeding project, or any of the projects conducted under the TRPA's jurisdiction (e.g., Placer and El Dorado counties).[340] Mechanisms under this bistate compact could be developed to ensure that the interests of both the States of California and Nevada are taken into account in cloud seeding projects conducted in the Tahoe region.

As opposed to California, Texas law does not require environmental impact assessment for weather modification projects.[341] In Texas, in order for a permit application to be approved, the TDLR must ascertain that the proposed operation "will not significantly dissipate the clouds and prevent their natural course of developing rain in the area in which the operation is to be conducted to the material detriment of persons or property in that area. . ."[342] However, project evaluations are not undertaken by the state, but by the sponsoring organizations and the criteria used in this process are not defined by law.[343] In absence of legal requirements to assess the impacts of their program, associations follow self-governance frameworks. Each association reports the details of their operations to the statewide Texas Weather Modification Association, created in 1997.[344] Since 2001, associations contracts with Texas Tech University to conduct annual evaluation using the software TITAN (Thunderstorm Identification,

---

[335] Tahoe Regional Planning Agency, Rules of Procedure, § 6.4 (Mar. 11, 2012).
[336] *Id.* §§ 6.6–6.7.
[337] *Id.* § 6.9.
[338] Tahoe Regional Planning Compact, *supra* note 192, art. VII(f); Tahoe Regional Planning Agency, *supra* note 335, § 6.3; Tahoe Regional Planning Agency, Code of Ordinances § 3.2.2 (2013).
[339] Roos, *supra* note 129, at 127–28.
[340] CAL. DEP'T WATER RES., *supra* note 124.
[341] 28 Tex. Reg. 10420 (Nov. 21, 2003).
[342] TEX. AGRIC. CODE ANN. § 301.107 (West 2003); 16 TEX. ADMIN. CODE §§ 79.21(1)(a) (2019).
[343] 28 Tex. Reg. 10420.
[344] TEXAS WEATHER MODIFICATION ASS'N, http://www.texasweathermodification.com/ [https://perma.cc/C75D-RKVA] (last visited Oct. 14, 2021).

Tracking, Analysis, and Nowcasting).[345] The Texas Weather Modification Association made the use of TITAN mandatory in all cloud-seeding projects.[346] This evaluation process allows for regular monitoring and review but does not assess the environmental impacts of the projects.

Current laws deal poorly with weather modification scientific uncertainties. In absence of legal standards, entities engaged in weather modification follow standards set by professional associations, such as statements from the Weather Modification Association,[347] and the American Meteorological Society.[348] The American Society of Civil Engineers has regularly published the *Guidelines for Cloud Seeding to Augment Precipitation*, that provide details on weather-modification science and practice.[349] The North American Weather Modification Council ("NAWMC"), a nonprofit interstate organization created in 2011, also has for objective "to advance the proper use of weather modification technologies through education, promotion and research."[350] It replaced the North American Interstate Weather Modification Council, created in 1975, that long served as a focal point and clearing house for U.S., Canada, and Mexico state agencies.[351] The NAWMC is now composed of representatives from the nine U.S. states engaged in cloud seeding, meeting twice a year.[352]

---

[345] TDLR, *supra* note 201. *See also* TEX. DEP'T LICENSING & REGUL., *Analysis and Research*, http://wtwma.com/analysis_and_research.htm [https://perma.cc/WQ4S-XT4E] (last visited Oct. 14, 2021).

[346] *See, e.g.*, Dale L. Bates & Arquímedes Ruiz-Columbié, *Weather Modification Scientific Management in Texas: The Extensive and Intensive Uses of TITAN*, 34 J. WEATHER MODIFICATION 104, 104 (2002).

[347] *See, e.g.*, WEATHER MODIFICATION ASS'N, *supra* note 50; Bruce Boe et al., *The Weather Modification Association's Response to the National Research Council's Report Titled "Critical Issues in Weather Modification Research,"* 36 J. WEATHER MODIFICATION 1, 3–4, 35 (2004).

[348] *See generally* AM. METEOROLOGICAL SOC'Y, PLANNED WEATHER MODIFICATION THROUGH CLOUD SEEDING, AN INFORMATION STATEMENT OF THE AMERICAN METEOROLOGICAL SOCIETY (2010), https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/statements-of-the-ams-in-force/planned-weather-modification-through-cloud-seeding/ [https://perma.cc/M3E7-6ZCK].

[349] *See generally* AM. SOC'Y CIV. ENGRS, GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION (2016).

[350] N. AM. WEATHER MODIFICATION COUNCIL, http://www.nawmc.org/ [https://perma.cc/K3PE-3MFX] (last visited Oct. 14, 2021).

[351] Ray Jay Davis, *Weather Modification Interstate Legal Issues*, 15 IDAHO L. REV. 555, 568 (1978); C. G. Keyes Jr., *North American Interstate Weather Modification Council: Need, Goals, Purpose and Activities*, 13 J. AM. WATER RES. ASS'N 917, 919 (1977).

[352] RYAN, *supra* note 61, at 8.

The WMO also plays an important role in overseeing weather modification activities. Between 1975 and 1985, the WMO cosponsored the Precipitation Enhancement Project ("PEP"), a collaborative project between the WMO and several Member States, including the United States, conducted to evaluate the potential for precipitation enhancement.[353] The WMO PEP developed guidelines that remain "a test of the scientific credibility of any proposed cloud seeding project."[354] In addition, the WMO created the Expert Team on Weather Modification Research, that regularly publishes statements and scientific guidelines to assist Member States in the design of weather modification programs.[355] These standards have also advised American weather modification programs.

The management of scientific uncertainties appears to be one of the weak points of weather modification legal regimes. Since the beginnings of cloud seeding, uncertainties have prevented governments from regulating on weather modification.[356] Legal scholars have long examined these uncertainties and believed that progress in atmospheric sciences would enable the development of governance mechanisms for weather modification.[357] Yet, Witt argues that the regulatory uncertainties surrounding cloud seeding have, in fact, hampered scientific and technological progress.[358] Weather modification science is confronted to irreducible uncertainties that cannot be used as a reason for postponing regulations any further.[359] Instead, appropriate governance arrangements must be developed so as to address the scientific uncertainties behind weather modification. According to the WMO "any legal system aimed at promoting or

---

[353] WORLD METEOROLOGICAL ORG., THE WMO PRECIPITATION ENHANCEMENT PROJECT—PROGRESS TO DATE AND PRESENT STATUS, 74 (1979).

[354] Michael J. Manton, *Evaluation of the Impacts of Cloud Seeding*, *in* AUSTRALIAN CLOUD SEEDING RSCH. SYMP. 1, 24 (2007).

[355] *See, e.g.*, WMO, *supra* note 9.

[356] Weather modification activities, no adverse effects of which have been proved on the basis of the present state of scientific knowledge, were distinguished from other activities involving pollution and other harmful effects; the view was expressed that the development of new beneficial technology should not be constrained unduly by "punitive" legal sanctions.

WMO & UNEP, REPORT OF THE WMO/UNEP INFORMAL MEETING ON LEGAL ASPECTS OF WEATHER MODIFICATION 731 (1975).

[357] *See generally* James L. Sigel, *International Control of Weather Modification in a Regime of Long-Range Weather Forecasting*, 19 HARV. INT'L L.J. 535 (1978); Heilbronn, *supra* note 233; Julie Ferdon, *Federal Weather Modification Projects: Compensating the Landowner*, 26 ARIZ. L. REV. 681 (1984); M. A. Rabie & M. M. Loubser, *Legal Aspects of Weather Modification*, 23 COMP. & INT'L L.J. S. AFR. 177 (1990); Jones, *supra* note 101.

[358] Witt, *supra* note 15, at 105.

[359] *Id.* at 107.

regulating weather modification must recognize that scientific knowledge is still incomplete."[360] Yet, most weather modification regimes—including EIA procedures—do not account for these uncertainties.[361] Reforms of weather modification legal regimes are thus needed to ensure that governance arrangements integrate and decrease these uncertainties over time.

C. Public Participation

Because the weather can affect all ecosystems, communities and sectors of activity in a given locality, the participation of the public in weather modification planning is of utmost importance. Here, "public participation" is understood broadly, as comprising both access to information, rights to participate in decision-making and rights of appeal (dealt with further in Section E). Cloud seeding projects should be designed in the public interest.[362] Yet, conflicting interests in particular weather conditions have given rise to controversies (e.g., between ranchers and farmers in Texas).[363] As Taubenfeld puts it, "[p]eople's preferences and interests might bitterly conflict on the choice of an ideal weather pattern for society."[364] Therefore, public engagement is necessary for decision makers to evaluate trade-offs and improve decision-making outcomes.[365] The exploitation of atmospheric water resources also has potential impacts on the environment, so that widely recognized principles of environmental law, including meaningful engagement of the public in environmental matters, should fully apply.[366] However, difficulties in assessing the social,

---

[360] WMO, *supra* note 9, at 12.
[361] Witt, *supra* note 15, at 107.
[362] *See generally* FLEAGLE ET AL., *supra* note 95.
[363] *See, e.g.*, Southwest Weather Resources, Inc. v. Jones, 327 S.W.2d 417, 417 (Tex. 1959).
[364] TAUBENFELD, *supra* note 109, at 55.
[365] *Id.*
[366] *See, e.g.*,

> Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

G. A. RES. 47/190, REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (Dec. 22, 1992).

economic and ecological impacts of weather modification makes it all the more complex to strike a balance between the different interests at stake.

Access to information is critical to the smooth functioning of participatory decision making. Sociological surveys conducted in the 1970s showed that information on weather modification was mostly conveyed by informal conversation and media.[367] Today still, in absence of official sources of information on weather modification, the public is mostly informed via media and social media.[368] Yet, lack of transparency in weather modification information feeds conspiracy theories.[369] Today, as misinformation circulates on the internet, parts of the American population firmly believe in "chemtrails" theories, according to which governments run covert programs of chemical spraying that are harmful to human health and the environment.[370] Farhar shows that "opinion leaders at the community level are more potent sources of information than are mass media campaigns."[371] In turn, not only does transparent information ensure a more meaningful participation of the public, but engagement with communities could ensure the dissemination of accurate information.

In the 1970s, controversies, including droughts in the Blue Ridge region and a flood event in Rapid City, South Dakota, following cloud seeding operations contributed to a rise in public opposition.[372] In some states, "natural-weather" organizations started to advocate against weather modification (e.g., Farmers and Ranchers for Natural Weather, later—Citizens for Natural Weather).[373] Over this period, the public increasingly perceived weather modification as antidemocratic, polluting and disrespectful of the natural ecological balance, leading to a general dismissal

---

[367] Barbara C. Farhar, *The Public Decides about Weather Modification*, 9 ENV'T & BEHAVIOR 279, 289 (1977).

[368] *See e.g.*, Rich Pedroncelli, *Cloud Seeding for Rain Is a Growth Area in the U.S.*, NBC NEWS (Dec. 12, 2009, 3:32 PM), https://www.nbcnews.com/id/wbna34383443 [https://perma.cc/D696-Y29G]; Carter Evan, C*ould Cloud Seeding Help with California's Drought?*, CBS NEWS (Mar. 12, 2016, 7:24 PM), https://www.cbsnews.com/news/could-cloud-seeding-help-with-californias-drought/ [https://perma.cc/XV6Z-ZVN5].

[369] *See, e.g.*, TED STEINBERG, ACTS OF GOD: THE UNNATURAL HISTORY OF NATURAL DISASTER IN AMERICA 131–33 (2006).

[370] Carrey Dunne, *My Month with Chemtrails Conspiracy Theorists*, THE GUARDIAN (May 22, 2017, 5:00 AM), http://www.theguardian.com/environment/2017/may/22/california-conspiracy-theorist-farmers-chemtrails [https://perma.cc/2YER-PBZN].

[371] Farhar, *supra* note 367, at 285.

[372] *See, e.g.*, *Pennsylvania Natural Weather Association, Citizens Against Cloud Seeding and the Tri-state Natural Weather Association.* STEINBERG, *supra* note 369, at 131–33.

[373] Otis W. Templer, *Weather Modification: A controversial issue on the Texas High Plains*, 4 J. ARID ENV'TS 71,76 (1981).

of weather modification.[374] Kwa links the demise of weather modification in the 1980s to growing environmental concerns and a shift in the American attitude towards the environment.[375] Farhar explains that opposition to weather modification is largely due to "religio-natural" orientations, that is "a point of view reflecting reservations about human intervention in weather processes either because such activity would upset nature's balance or impinge upon the domain of the Supreme Being."[376] This argument has persisted and contributed to downplaying public lack of support for weather modification.

At the federal level, public participation principles in weather modification law have not been upheld. Under the WMRA, "[a]ll reports, documents, and other information received by the Secretary under the provisions of this Act shall be made available to the public *to the fullest practicable extent*."[377] The Act provides an exception for confidential information, which may be disclosed under certain circumstances including "to the public if necessary to protect their health and safety."[378] Although the WMRA ensures basic public access to information relating to weather modification, it makes no mention of the right to participate in decision-making or to access effective remedies.[379] In the 1970s, sociologists were mandated by the USBR to conduct extensive studies on the societal aspects of weather modification, especially on public attitudes towards weather modification.[380] Farhar explained that "one condition of public acceptance of technology is public involvement in the decision process. . . ."[381] In other words, public participation helps to mitigate public resistance to weather modification. Yet, Matthewman points out that "the social science of weather-modification was created and controlled by the Bureau of Reclamation."[382] It appears that the participation of the

---

[374] STEINBERG, *supra* note 369, at 133.
[375] *See generally* Chunglin Kwa, *The Rise and Fall of Weather Modification: Changes in American attitudes toward technology, nature, and society*, *in* CHANGING THE ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE 135, 135–65 (2001).
[376] Farhar, *supra* note 367, at 289.
[377] Weather Modification Reporting Act, Pub. L. 92-205, § 3(b), 85 Stat. 735 (1972) (emphasis added).
[378] *Id.* § 3(c).
[379] *Id.*
[380] *See generally* Farhar & Mewes, *supra* note 297; Barbara C. Farhar, *What Does Weather Modification Need? A Societal View*, 17 J. APPLIED METEOROLOGY & CLIMATOLOGY 878–88 (1978); Barbara Farhar & Ronald Rinkle, *Community Response to Proposed Snowpack Augmentation in the Sierra Nevada Mountains*, 9 J. WEATHER MODIFICATION 154–92 (1977).
[381] Farhar, *supra* note 367, at 307–08.
[382] Steven David Matthewman, Science in the Social Sphere: Weather-Modification and

public in weather modification has been developed essentially in the interest of the government, with a view to ensuring the social acceptability of weather modification.

At the state level, public participation provisions vary from one jurisdiction to another and only eight states in the United States explicitly provide for public participation in weather modification.[383] In California, the reports submitted to the DWR are not made publicly available.[384] Farhar and Rinkle explain that the Sierra Cooperative Pilot Project was originally designed to take place on both federal and state lands, but that, after small public meetings, the State of California decided to withdraw from the project.[385] Following its withdrawal, the State was meant to maintain a public liaison but failed to do so.[386] The lack of access to information on weather modification in California remains a challenge and Ryan recommends: "[a] public education and outreach component should be considered in any new cloud seeding program."[387] The *California Weather Resources Management Act* does not provide for the participation of the public in decision-making.[388] Under CEQA, the EIA process provides for public notice, meetings and review.[389] However, as outlined earlier, for projects that are not subject to an EIA process (e.g., private projects), there are no legal requirements to consult with local communities.[390] This resulted in tensions and the cancellation of a project proposed by Pacific Gas & Electric in the Pit-McCloud rivers in 2008, following anti-cloud seeding activism in the city of Mt. Shasta.[391] A reform of the Californian weather modification law ensuring greater public participation could prevent future conflicts of interests, instill trust and mitigate resistance.

Texas, on the other hand, sets an example of public engagement in weather modification decision-making. In 1975, controversies between ranchers and farmers over cloud seeding activities pushed a series of

---

Public Response 230 (1999) (unpublished Ph.D. dissertation, University of Auckland) (on file with ResearchSpace@Auckland, University of Auckland).

[383] *See supra* Table 2.

[384] CAL. WATER CODE § 420 (West 1984).

[385] Farhar & Rinkle, *supra* note 380, at 156.

[386] *Id.*

[387] RYAN, *supra* note 61, at 19.

[388] CAL. WATER CODE §§ 402, 410–412 (West 1984).

[389] CAL. PUB. RES. CODE § 21003.1 (West 2009); CAL. CODE REGS. tit. 14, §§ 15073, 15087 (2009).

[390] *Id.*

[391] *See, e.g.*, Elicia Whittlesey, Who Owns the Weather? The Politics of Cloud Seeding in Northern California 31 (2010) (unpublished M.A. thesis, University of Minnesota) (on file with the University Digital Conservancy, University of Minnesota).

amendments to the Texas weather modification law to encourage better consideration of the public's input.[392] A first amendment required public hearings to be held before granting a permit, when at least 25 affected residents requested so, but the Texas Water Development Board retained the discretion to grant or deny a permit.[393] In 1977, another amendment set a referendum mechanism giving the electors the right to vote against the granting of a permit.[394] A further amendment in 1979 made the permit applicant to bear the costs of the election.[395] Notices of intention are required to be published "at least once a week for three consecutive weeks in a newspaper of general circulation in each county in which the operation is to be conducted."[396] In 2018, the TPWMA published a Notice of Intention for its permit application, which led to over fifty residents of the Hudspeth County to request that seeding not be permitted in the county.[397] The TDLR Advisory Committee requested that the county be deleted from the permit.[398] According to Farhar and Mewes, "the use of an advisory committee invites broader public participation."[399] Indeed, the meetings of the Advisory Committee are recorded and available online and, in the context of COVID-19, the TDLR has started to experiment with public hearings in a virtual setting.[400] Although this regulatory system cannot prevent controversies altogether, it allows for concerned populations to voice their opinion. The Texas regime offers a model of public participation, but procedural rights are not always guaranteed under state weather modification laws. Serious reforms are therefore needed to ensure informed public debates on weather modification.

D. Monitoring of Effectiveness and Impacts

Monitoring the effects of cloud seeding is key to evaluating how much precipitation can be attributed to a program. At the international

---

[392] *See* Templer, *supra* note 373, at 74.
[393] *Id.*
[394] *Id.*
[395] *Id.* at 75.
[396] TEX. AGRIC. CODE ANN. § 307.112 (West 2003).
[397] TEX. DEP'T LICENSING & REGUL. ADVISORY COMM. ON WEATHER MODIFICATION, SUMMARY OF MINUTES 3–5 (Feb. 2018), https://www.tdlr.texas.gov/weather/agendas/WXM%20060718%20Staff%20Reports.pdf [https://perma.cc/9CGC-F8YR].
[398] *Id.* at 1–2.
[399] Farhar & Mewes, *supra* note 297, at 695.
[400] TEX. DEP'T LICENSING & REGUL., *supra* note 220.

level, the WMO prescribes the use of statistical and physical analyses to evaluate the validity of cloud seeding hypotheses and recommends the randomization of operations.[401] This means that suitable cloud formations should be seeded on a random basis, so as to compare seeded and unseeded events and evaluate the effectiveness of an operation.[402] As Hunter explained, "[s]ince a portion of the [experimental units] in randomized experiments must be unseeded, they are more costly and are therefore usually attempted only within research projects. There have been relatively few such experiments in the Western United States."[403] In recent years, one randomized experiment—the Wyoming Weather Modification Pilot Project—has attracted the attention of the international scientific community.[404] However, as missed opportunities represent a considerable loss of profit for operators, operational programs are generally non-randomized.

In Texas, like in California, all suitable clouds are seeded and compared to clouds in control areas for statistical analysis.[405] The problem with non-randomized cloud seeding is that it makes it impossible, in the present state of science, to assess accurately the amount of precipitation attributable to a specific operation.[406] There is no monitoring mechanism in place at the federal level and requirements vary at the state level, depending on agencies' competences.[407] In California, there is no legal requirement to monitor the effects of cloud seeding, whereas, in Texas, the TDLR monitors cloud-seeding programs.[408] The Advisory Committee conducts periodic field inspections of the project sites and inspects equipment to verify compliance with the permit and eventually, makes recommendations to the operator.[409] It also reviews regularly the associations' self-evaluations.[410] However, there are no legal requirements to monitor the effects of cloud seeding on the environment.[411]

Because effectiveness evaluations are uncertain, monitoring the environmental impacts of cloud seeding is complex. Cooper and Jolly

---

[401] BRUINTJES, *supra* note 10, at 5–6.
[402] *Id.*
[403] HUNTER, *supra* note 118, at 24.
[404] BRUINTJES, *supra* note 10, at 5.
[405] Bomar et al., *supra* note 95, at 9.
[406] WMO, *supra* note 9, at 5–6.
[407] Farhar & Mewes, *supra* note 297, at 695.
[408] TEX. AGRIC. CODE ANN. § 301.165 (West 2003).
[409] *See, e.g.*, TDLR WEATHER MODIFICATION PERMIT NO. 18-1, *supra* note 260, at 4.
[410] *Id.*
[411] *Id.*

consider two kinds of environmental monitoring: "those designed to detect changes in the concentration of specific substances in the environment, and those designed to measure changes in the abundance of specific animals and plants in natural communities."[412] In the field of weather modification, monitoring mechanisms have focused on the diffusion and concentration of seeding agents, and in particular, silver iodide.[413] For instance, the Texas Legislature entered into contracts with the water districts, in the 1990s, providing for the assessment of silver iodide levels in rainwater from seeded storms.[414] Although not mandated by law, these self-assessments were a requirement for weather modification operators to pursue their project under State funding (G. Bomar 2021, personal communication, 26 Mar.).[415] However, this mechanism has ceased with the termination of State support in 2003.[416] In California, there are no legal requirements to monitor the impacts of weather modification activities, and such mechanisms remain at the discretion of sponsors and operators.[417] The DRI uses trace chemistry techniques to monitor the dispersion of cloud seeding agents but does not monitor silver levels.[418] Environmental governance scholars recognize that traditional monitoring mechanisms do not take into account the complexity of social-ecological systems and often fail to take an ecosystem-based approach.[419] This observation rightly applies to the field of weather modification.

Natural variability makes the monitoring of weather modification activities a daunting task. Yet, the existence of scientific uncertainties should not undermine efforts to monitor the environmental impacts of weather modification. In 1965, the NSF mandated the Ecological Society of America to assess the biological impacts of weather modification.[420] Their report reads:

> Even though complete ecological monitoring of a weather modification program is not feasible, every effort should be

---

[412] COOPER & JOLLY, *supra* note 44, at 92.
[413] *Id.* at 69.
[414] TEX. DEP'T LICENSING & REGUL., *supra* note 224.
[415] TEX. AGRIC. CODE ANN. § 20.003 (West 2001) (repealed 2003).
[416] *Id.*
[417] CAL. WATER CODE § 420 (West 1984).
[418] *Trace Chemistry/Ice Core Laboratory*, DRI (Aug. 19, 2021, 9:42 PM), https://www.dri.edu/labs/trace-chemistry-laboratory/ [https://perma.cc/Z6NF-MDN8].
[419] *See generally* Michelle Boyle et al., *Monitoring in Support of Policy: An Adaptive Ecosystem Approach*, 4 ENCYCLOPEDIA GLOB. ENV'T CHANGE 116–37 (2001).
[420] DANIEL A. LIVINGSTONE, ECOLOGICAL SOCIETY OF AMERICA ECOLOGY STUDY COMMITTEE, BIOLOGICAL ASPECTS OF WEATHER MODIFICATION 42 (1965).

> made to see that systematic observations are carried out. First priority should be given to those species known or suspected of being capable of damaging crops or of causing defoliation of the natural vegetation. The cost of even this minimal surveillance would be high; the cost of not carrying it out might be very much higher. In as much as one cannot predict all of the meteorological consequences of weather modification, it would be folly to allow such a program to be carried out without careful monitoring of the biological consequences.[421]

These recommendations, however, have fallen into oblivion. In recent years, weather modification projects have failed to monitor the ecological impacts of weather modification.[422] In 1981, The Sierra Cooperative Pilot Project recommended monitoring environmental changes and cross-contamination between target areas.[423] However, in California, the lack of coordination between the multitude of projects conducted in the Sierra Nevada does not allow for a consideration of the cumulative impacts.[424] Yet, Cooper and Jolly warn: "Several stresses, each small enough to be relatively insignificant when acting alone, may be more effective in concert than a single stronger stress."[425] Given the recent increase in the number of cloud-seeding projects, the development of monitoring programs that take into account complex ecological impacts is most needed.

Limited incentives to monitor cloud seeding impacts can be partly explained by the shift from governmental to private support of weather modification, which created what Changnon called "the paradox of weather modification."[426] Private companies claimed positive results to advertise their activities, while disregarding the scientific uncertainties that could

---

[421] *Id.*

[422] Anil Acharya, Impacts of Climate Change and Weather Modification on Hydrologic Characteristics of Watersheds in the Western United States 38–43 (May 2011) (Ph.D. dissertation, University of Nevada) (on file with Digital Scholarship@UNLV, University of Nevada).

[423] > However, the greatest problems are in the Truckee Basin in the Lake Tahoe area. Sheet and gully erosion is the historic problem and results in stream sedimentation and degradation and erosion of channels. Federal land agencies manage eroded land and channels in a rehabilitation mode. However, voluntary programs on private lands are less certain.

HARRIS, *supra* note 173, at 55.

[424] *See* Charity Maness, *Cloud Seeding Resumes Over Sierra*, CALVERAS ENTERPRISE (Nov. 4, 2016); CAL. DEP'T WATER RES., *supra* note 28, at 10–11.

[425] COOPER & JOLLY, *supra* note 44, at 109.

[426] Changnon, *supra* note 95, at 33.

undermine the accuracy of their claims.[427] Hauser points out: "they generally did not run projects with intent to prove or disprove efficacy of weather modification techniques."[428] Indeed, monitoring the impacts of weather modification is resource-consuming so that it is not in the operators' economic interest to follow best practices in monitoring weather modification projects.[429] The economic prospects of weather modification have encouraged states and the private sector "to move directly into operational projects."[430] However, this has also prevented the scientific and technological progress needed to better evaluate cloud seeding effectiveness and impacts.[431] Moreover, companies do not systematically report to public agencies on their activities, and it is difficult for public entities with limited expertise, to confirm or infirm their results.[432] Capacity building is therefore required to implement monitoring mechanisms to improve both weather modification science and governance.

In the context of climate change, monitoring the impacts of changes in weather patterns has taken a renewed urgency. Understanding precipitation patterns is critical to designing accurate climate models.[433] Moreover, cloud seeding techniques are being increasingly researched to counteract the effects of climate change (e.g., marine cloud brightening to reflect incoming solar radiation or cirrus cloud thinning to increase outgoing thermal radiation).[434] These new applications will require scientists to improve their understanding of cloud-aerosol interaction as well as the role of precipitation in climate.[435] List proposes "experimental meteorology" to be researched as a discipline that encompasses both weather and climate modification science.[436] Such research would improve the evaluation of weather and climate impacts on hydrological cycles and ecosystems and help to determine whether interventions have the intended positive effects (e.g., protect and restore natural systems).[437]

---

[427] *Id.*
[428] Rachel Hauser, *Using Twentieth-Century U.S. Weather Modification Policy to Gain Insight into Global Climate Remediation Governance Issues*, 5 WEATHER, CLIMATE & SOC'Y 180, 185 (2013).
[429] WMO, *supra* note 9, at 4.
[430] *Id.* at 4.
[431] *Id.*
[432] *See* Witt, *supra* note 15, at 117.
[433] Roland List, *Reinventing Weather Modification*, PROC. 10TH WMO SCI. CONF. ON WEATHER MODIFICATION 83, 85 (2011).
[434] *See generally* NAT'L ACADS. SCIS., ENG'G & MED, *supra* note 18, at 2.
[435] *Id.*
[436] List, *supra* note 433, at 85.
[437] *See id.* at 85–86.

Applying iterative learning processes to monitor and review cloud seeding projects, like scenario planning,[438] could contribute to inform and legitimize weather modification decision-making while advancing atmospheric sciences. To do so, the exploitation of atmospheric water requires flexible governance frameworks that takes into account scientific uncertainties and facilitates transitions.[439] Further inquiry is, therefore, required to adapt weather modification governance frameworks to the climate change context.

E. Liability

Liability for weather modification damage has long been a topic of debate.[440] Determining the remedies available to people allegedly impacted by weather modification requires defining the nature of proprietary rights over clouds and atmospheric water. Scholars attempted to use legal analogies to regulate cloud seeding, but traditional structures of proprietary rights have appeared inadequate to address weather modification issues.[441] The American water rights system has greatly informed weather modification property regime. Generally speaking, Eastern States apply riparian rights over watercourses; and Western States apply the doctrine of prior appropriation (first come, first served). Under these doctrines, landowners must make *reasonable use* of the water (riparian) or use the water for a beneficial purpose (prior appropriation).[442] In both cases, the diversion needs not to compromise the rights of downstream users to access clean water, allowing one author to conclude: "The controlling principle should be the promotion of that use of rain which will produce the greatest general benefit to the community."[443] Given the

---

[438] *See generally* Acharya, *supra* note 422.
[439] Chen, *supra* note 110, at 50.
[440] *See generally Legal Remedies for "Cloud-Seeding" Activities: Nuisance or Trespass?*, *supra* note 14; Ferdon, *supra* note 357; Jones, *supra* note 101.
[441] Some have compared clouds to streams, airspace, groundwater, wildlife, aircraft, radio's ether, atomic energy, animals *ferae naturae* and oil and gas resources. Others have examined the *ad coelum* doctrine ("whoever's is the soil, it is theirs all the way to Heaven and all the way to Hell") but most concluded on the limits of extending land property rights to the clouds beyond "the area of the ordinary use and enjoyment of land." Heilbronn, *supra* note 233, at 135. *See also Who Owns the Clouds?*, *supra* note 13, at 46; Brooks, *supra* note 14, at 116; Binzak et al., *supra* note 13, at 268; Wade, *supra* note 13, at 95; Corbridge & Moses, *supra* note 13, at 216; Frenzen, *supra* note 21, at 511; Charles M. Hassett, *Weather Modification and Control: International Organizational Prospects*, 7 TEX. INT'L L.J. 89, 100 (1971).
[442] *See, e.g.*, *Who Owns the Clouds?*, *supra* note 13, at 50; Binzak et al., *supra* note 13, at 262.
[443] Brooks, *supra* note 14, at 118.

erratic nature of clouds, some scholars considered private ownership of clouds "ridiculous"[444] or "nonsense,"[445] but concurred on a "natural right" to use the land in its natural condition, and thus a right to the reasonable use of atmospheric water.[446] Because cloud water cannot be subject to private appropriation, some states have considered cloud water public property. Five states now recognize sovereign rights in atmospheric water.[447] Others, like California, consider the waters obtained from weather modification activities "as if they were natural precipitation," to facilitate appropriation by landowners.[448] Nevertheless, after more than fifty years of legal research, ownership of weather resources remains a challenge.

Scholars have examined remedies available under a wide array of doctrines and considered tort liability to be the most suitable avenue.[449] Many have considered the application of the trespass doctrine, but trespass would limit remedies to a wrongful interference with the rights to natural precipitation, which would be difficult for a plaintiff to establish.[450] The nuisance doctrine would offer a more complete protection of the landowners' rights.[451] However, several courts have recognized that public interests outweigh any private interest in the weather, thereby limiting individual landowners' remedies.[452] Scholars also examined the negligence theory, but given the high technicality of weather modification, it would be extremely difficult for a judge (or jury) to determine whether operators acted with "reasonable care."[453] Finally, strict liability for ultrahazardous activity has been considered especially appropriate in regards to weather modification's scientific uncertainties.[454] However, apart from Pennsylvania and West Virginia that have adopted this doctrine, this theory has been "uniformly rejected as a roadblock to progress."[455] The

---

[444] *Who Owns the Clouds?*, *supra* note 13, at 48.
[445] Brooks, *supra* note 14, at 114.
[446] *See, e.g.*, *Who Owns the Clouds?*, *supra* note 13, at 50–51; Stark, *supra* note 14, at 703; Heilbronn, *supra* note 233, at 148.
[447] Chen, *supra* note 110, at 82.
[448] Jones, *supra* note 101, at 1192.
[449] *See, e.g.*, Corbridge & Moses, *supra* note 13, at 219; Heilbronn, *supra* note 233, at 123.
[450] *Legal Remedies for "Cloud-Seeding" Activities: Nuisance or Trespass?*, *supra* note 14, at 309; Heilbronn, *supra* note 233, at 127–29.
[451] *Legal Remedies for "Cloud-Seeding" Activities: Nuisance or Trespass?*, *supra* note 14, at 308.
[452] *See, e.g.*, Slutsky v. City of New York, 97 N.Y.S.2d 238, 238 (N.Y. Misc. 2d 1950); Pa. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass., 44 Pa. D. & C.2d 749, 759 (1968).
[453] *See, e.g.*, Heilbronn, *supra* note 233, at 134.
[454] *See, e.g.*, Ball, *supra* note 7, at 228–29; Frenzen, *supra* note 21, at 513–14; Heilbronn, *supra* note 233, at 156–57; Rabie & Loubser, *supra* note 357, at 211–12.
[455] Jamie Harris, *Law and Technological Change: The Case of Weather Modification*, 3

Texas law, for instance, provides: "an operation conducted under the license and permit requirements of this chapter is not an ultra-hazardous activity that makes the participants subject to liability without fault."[456] In 1968, a Pennsylvanian court denied a request for injunction brought under several claims, including trespass, nuisance, negligence, etc., because plaintiffs failed to prove the probability of harm by clear and convincing evidence.[457] Today, remedies available for damage resulting from weather modification activities remain unclear.

In most states, however, the absence of clearly defined rights has not prevented the setting up of liability regimes. State statutes are often one of two categories: "those providing for non-liability of the State or its employees and those calling for proof of financial responsibility as part of the licensing procedure."[458] Immunity from liability for weather modification damage is common (e.g., in federal cloud-seeding projects), but leaves the question of landowners' compensation unsettled.[459] The Texas law both provides for State immunity for operations conducted by private persons or groups,[460] and requires proof of financial responsibility.[461] This proof of financial responsibility has two main functions: first, the guarantee that the operator has the financial means to conduct weather modification operations properly; second, that the operator is able to offer monetary compensation in case of damage.[462] The law further provides that "the fact that a person holds a permit issued by the [TDLR] does not relieve that person from liability for the violation of this chapter or a rule adopted or order or permit issued under this chapter."[463] In turn, the State of Texas is immune from weather modification liability but operators are still liable for violation of the Act.

In California, however, the 1984 law has repealed the section on immunity from liability. Moreover, since 1961, a statute on governmental tort liability requires the State to compensate taking or damage of private

---

YALE REV. L. & SOC. ACTION 27, 40 (1972).
[456] TEX. AGRIC. CODE ANN. § 301.302(a) (West 2003).
[457] *Pa. Nat. Weather Ass'n*, 44 Pa. D. & C.2d at 760.
[458] Corbridge & Moses, *supra* note 13, at 219.
[459] Ferdon, *supra* note 357, at 692.
[460] TEX. AGRIC. CODE ANN. § 301.301 (West 2003).
[461] TEX. AGRIC. CODE ANN. § 307.114 (West 2003). *See also* TDLR WEATHER MODIFICATION PERMIT NO. 18-1, *supra* note 260, at 2 ("The Association is required at all times to maintain adequate insurance coverage, or be able to provide other financial evidence that demonstrates that the program has the ability to respond in damages for liability which might reasonably result from the operation for which the permit has been granted.").
[462] Chen, *supra* note 110, at 72–73.
[463] TEX. AGRIC. CODE ANN. § 301.203 (West 2003).

property.[464] The State of California could thus be subject to liability and compensation for inverse condemnation in case of weather modification damage.[465] To that extent, scholars have suggested that public entities engaging in weather modification be financially responsible or covered under an insurance scheme.[466] However, the California law does not request proof of financial responsibility from entities engaging in weather modification activities, nor provides for any compensation mechanism.[467] In the case of the Tahoe-Truckee project, a plaintiff could also turn to the State of Nevada for remedies.[468] The Nevada legislation recognizes State immunity for weather modification activities, without affecting "contractual, tortious or other legal rights, duties or liabilities between any private persons or groups."[469] Applicants to a permit must furnish proof of financial responsibility "to respond in damages for liability which might reasonably be attached to or result from weather modification and control activities in connection with the *operation* . . . ; but the applicant need not show ability to respond in damages for liability resulting from precipitation caused by weather modification *experiments*."[470] In other words, private permit holders could be liable for the conducting of cloud seeding operations and should be able to compensate potential damage.

To date, the impossibility to prove causation between a particular cloud seeding operation and harmful weather events still bar plaintiffs' access to remedies. Conflict resolution mechanisms set in weather modification have largely failed because of questions of attribution of damage.[471]

---

[464] 1963 CAL. STAT. 3266. *See also* CAL. CONST., art. I § 19(a) ("Private property may be taken or damaged for a public use and only when just compensation, ascertained by a jury unless waived, has first been paid to, or into court for, the owner.").

[465] *See* RONALD STANDLER, WEATHER MODIFICATION LAW IN THE USA 17 (2006), http://www.rbs2.com/weather.pdf [https://perma.cc/C64D-ZQMH]; Michael Brown, *Present and Future Regulation of Cloud Seeding Activities in California*, 43 J. WEATHER MODIFICATION 97, 99–101 (2011).

[466] Sho Sato, *The Role of Local Governmental Units in Weather Modification: California*, *in* CONTROLLING THE WEATHER: A STUDY OF LAW AND REGULATORY PROCEDURES 221, 239 (1970).

[467] *See, e.g.*, CAL. WATER CODE § 401 (West 1984) ("It is hereby declared that atmospheric water within the state which is caused to fall by weather resources management activities shall, for the purpose of water rights determinations, be considered as if it occurred as natural precipitation.").

[468] NEV. REV. STAT. ANN. § 544.130 (West 1961).

[469] *Id.* § 544.230.

[470] *Id.* § 544.190 (emphasis added).

[471] *See, e.g.*, Joshua B. Horton et al., *Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities*, 22 N.Y.U. ENV'T L.J., 225, 261

As Garstang puts it "[d]espite an increasing body of evidence that treatment can modify both the character of the clouds and the precipitation from these clouds, such results constitute evidence but not proof."[472] In most cases, plaintiffs would carry the burden to prove that a cloud seeding operation caused a compensable damage.[473] Farhar and Mewes note "[i]f the statute provides for encouragement of the technology, the informal sense of 'burden of proof' is borne by those resisting the project."[474] However, the 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.[475] As one commentor argued, "when the state of the art is such that a 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."[476] Thus, the public is indeed deprived access to effective remedies in weather modification. The development of innovative solutions to overcome problems of attribution in liability regimes—including for climate change impacts—is thus mandated to resolve potential disputes arising from weather modification projects.

CONCLUSION

This review of the weather modification governance regimes in California and Texas demonstrates a lack of consistency amongst weather modification laws throughout the states. Weather modification decision-making is fragmented and inconsistent. Current regulatory frameworks do not equally ensure the coordination of activities at the local, state and national levels. This is particularly problematic when dealing with interstate projects, like the Tahoe-Truckee project. Public access to information and participation processes are also unsatisfactory. The Texas law provides a good model, but many states do not provide for the participation of local communities in weather modification decision-making. This results in political conflicts—like in the Pit-McCloud rivers, in 2008—mistrust and misinformation. The procedural rights of the public should

---

(2014) ("Early attempts at cross-border regulation of weather modification activities foundered on the apparent impossibility of awarding compensation based on nondeterministic causal statements.").

[472] Garstang et al., *supra* note 100, at 649.

[473] *Id.* at 653.

[474] Farhar & Mewes, *supra* note 297, at 694.

[475] *See generally* Jones, *supra* note 101.

[476] Sato, *supra* note 466, at 239.

apply to weather modification law, like any other environmental and natural resources legal regime. The right to access effective remedies is also left virtually unprotected and there is no guarantee that activities are conducted in the public interest. The absence of clear liability and compensation mechanisms and the impossibility to prove causation and attribute a damage to cloud seeding operations could encourage malpractice and leave parts of communities feeling let down.

The management of uncertainties is also a central issue of weather modification governance. However, environmental impact assessment processes, when they exist, appear inappropriate to deal with the complex and dynamic nature of weather modification. Until now, scientific uncertainties have been used to postpone the development of regulatory mechanisms, but developments in environmental law and governance these past decades reveal that such an argument is no longer admissible. Environmental monitoring mechanisms should be designed to integrate uncertainties and new scientific evidence. This requires capacity building at all levels and joint funding research in atmospheric, social, hydrological, and ecological sciences. Legal reforms will be needed to facilitate collaboration between institutions, the scientific community and other stakeholders, including local communities to combine problem-solving competences.

Several scholars have argued that weather modification regulations could apply to climate intervention.[477] However, current legal regimes appear inadequate to address cloud seeding issues and it is not desirable to apply weather modification frameworks to climate intervention as is. The laws and regulations that govern weather modification activities have become outdated and structural reforms are needed to better integrate scientific uncertainties and public considerations in weather modification decision-making. Nonetheless, the analogy between weather modification and climate intervention governance creates an opportunity to review weather modification laws so as to improve the legal regimes governing atmospheric resources. New environmental governance approaches, such as adaptive governance, offer one avenue to improve current weather modification frameworks. In any event, pursuing cloud seeding to counter and adapt to the adverse impacts of climate change requires urgent revision of current regulatory regimes.

---

[477] *See generally* Albert C. Lin, *US Law*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 154–223 (Michael B. Gerrard & Tracy Hester eds., 2018); JESSE L. REYNOLDS, THE GOVERNANCE OF SOLAR GEOENGINEERING: MANAGING CLIMATE CHANGE IN THE ANTHROPOCENE 138–49 (2019); Tracy D. Hester, *Remaking the World to Save it: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOLOGY L.Q. 851–902 (2011).