SEEDING CLOUDS OF UNCERTAINTY

Alan W. Witt*

ABSTRACT: Weather modification through cloud seeding is a process that mimics nature by dispersing materials—seeds—into clouds that cause precipitation. Cloud seeding is reemerging as a promising technology for dealing with increasingly volatile weather conditions, including drought and flood damage. Recent developments in related technologies and scientific understanding are making cloud seeding an increasingly cost-effective method for controlling precipitation, especially in the western United States. Societal and technical uncertainty, however, prevent governments from enacting adequate law and regulation that could encourage cloud seeding development and protect stakeholders. Instead, the resultant regulatory uncertainty severely encumbers cloud seeding practice by, among other things, failing to allocate associated rights and liabilities. Societal, technological, and regulatory uncertainty, therefore, combine to hinder beneficial cloud seeding practices. By enacting clear legal and regulatory guidance for cloud seeding, governments can dispel these clouds of uncertainty and take advantage of the benefits afforded by this practice.

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In 2014, three modified Cessna 340 aircraft in California airspace glided over the types of clouds pilots usually want to avoid.[1] With arrays of cloud seeding flares mounted behind their wings, the pilots sought their target temperature. If released between five and twenty-two degrees Fahrenheit, water vapor would form on the flares' discharged silver iodide particles causing the clouds to unload their precipitous payload.[2] Sacramento Municipal Utility District used these three Cessna to wring water from clouds over El Dorado County. Their mission helped to induce precipitation that would power eight hydroelectric powerhouses and supply water to eleven reservoirs on the upper American River as well as provide additional runoff for Folsom Lake.[3]

In 2015, about six hundred miles northeast of El Dorado County, Idaho Power decided to expand cloud seeding experiments from the Payette area to the Big Wood, Boise, and Upper Snake River basins to increase snowpack and

*J.D. Candidate & Sustainability Law Student Research Fellow, Sandra Day O'Connor College of Law at Arizona State University; B.A., 2014, English, Brigham Young University–Idaho. The author would like to acknowledge Professor Rhett Larson, faculty advisor, and David Turnbull, J.D., 2016, Sandra Day O'Connor College of Law for their assistance during the writing and research of this comment.

1. Tom DuHain, *Cloud Seeding Under Way over El Dorado County*, KCRA (Feb. 3, 2014, 5:54 AM), http://www.kcra.com/news/local-news/news-sacramento/cloud-seeding-underway-over-el-dorado-county/24232696.

2. *Id.*

3. *Id.*

reservoir levels.[4] With weather models predicting hot spells impacting crops and animals, all water rights subordinated to upstream beneficial uses, and reservoirs depleted by subpar snowpack, Idaho Power hoped to meet the increasing demand for its decreasing water supply by seeding the clouds.[5] Meteorologists using weather models to predict the coming hot spells had seen a significant increase in precipitation where cloud seeding had been used. For example, in the Payette area, precipitation had increased by an average of fifteen percent.[6] Using the United States Department of Agriculture (USDA) Natural Resources Conservation Service's streamflow model, a mere ten percent increase in precipitation would result in an additional "200,000 acre-feet of water in the Boise area, 100,000 acre-feet in the Big Wood and almost 200,000 acre-feet in the Upper Snake" than would otherwise be present without cloud seeding.[7] An acre-foot of water is approximately 325,851 gallons, which is enough to supply a family of four for a year.[8] In response to the news of Idaho Power's plans, one commentator noted that, when suit is inevitably brought for cloud seeding depriving others of water, that he knew of no laws regulating such waters overhead.[9]

Cloud seeding has been around since the mid-twentieth century;[10] however, as this commentator suggests, existing legal and regulatory gaps fail to govern cloud seeding,[11] a resurging technique that can combat weather associated problems like droughts and floods.[12] Cloud seeding is a process that mimics nature by dispersing materials—seeds—into clouds to cause rain, usually by either airborne or ground-based systems.[13] Several states are beginning to experiment with cloud seeding programs, methods, and compatible technologies.[14] Cloud seeding in the United States is most commonly used by utilities

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4. Cindy Snyder, *Cloud Seeding Pays Off*, MAGIC VALLEY (June 29, 2015), http://magicvalley.com/news/local/cloud-seeding-pays-off/article_dbb25276-a23f-57ca-8886-d8e75d3b5f78.html.

5. *Id.*

6. *Id.*

7. *Id.*

8. *About Us—Fact Sheet*, BUREAU RECLAMATION, http://www.usbr.gov/main/about/fact.html (last updated Aug. 23, 2016).

9. Dick F, Comment to *Cloud Seeding Pays Off*, MAGIC VALLEY (June 29, 2015, 9:10 AM), http://magicvalley.com/news/local/cloud-seeding-pays-off/article_dbb25276-a23f-57ca-8886-d8e75d3b5f78.html.

10. *See* discussion *infra* Section II.A.1.

11. *See* discussion *infra* Section II.C.

12. *See* discussion *infra* Section III.C.1–2.

13. For a description of the natural ice-forming nuclei process involving soil particles, see *Cloud Seeding Frequently Asked Questions*, N. AM. WEATHER CONSULTANTS, http://www.nawcinc.com/wmfaq.html (last visited Sept. 7, 2016).

14. *See* discussion *infra* Section II.B.1. In an effort to combat recent droughts, for example, California counties are beginning to revive cloud seeding practices. *See* Carter Evans, *Could Cloud Seeding Help with California's Drought?*, CBS NEWS (Mar. 12, 2016, 7:24 PM), http://www.cbsnews.com/news/could-cloud-seeding-help-with-californias-drought/; Melissa Pamer & Steve Kuzj, *As Drought Continues Despite El Nino, L.A. County Turns to Cloud-Seeding in Hope of More Rain*, KTLA (Mar. 11, 2016, 5:35 PM), http://ktla.com/2016/03/11/as-drought-continues-despite-el-nino-l-a-county-turns-to-cloud-seeding-in-hope-of-more-rain/.

for providing a less expensive alternative to importing out-of-state water resources or for increasing water flow to power hydroelectric dams.[15]

The overall demand for water in the nation continues to increase and supplies dwindle as resources are over appropriated, populations expand, climate changes increase drought, and economic demands grow.[16] The question of how to solve water shortages has led to several augmentation technologies, one of which is weather modification by cloud seeding.[17] While it may not be the entire answer for the nation's escalating water problems, cloud seeding can be a cost-effective part of the solution.[18]

Cloud seeding is underused and underdeveloped in the United States because of societal, technological, and regulatory uncertainty. Atmospheric water, which could supply water in times of drought or replenish over-apportioned resources, goes largely untapped. The current strategy of waiting for societal and technological uncertainty to ebb before resolving regulatory uncertainty is a failing one. Instead, regulatory certainty can pave the way for a better understanding by providing law designed to address specific societal and technological concerns.

With demand for water in the United States increasing, cloud seeding is one augmentation technology that, if regulated effectively, would help replenish scarce water resources. Government law and regulation addressing these uncertainties will clear the way for cloud seeding development and practice.

Part I introduces the basic scientific process, methods, and potential uses for cloud seeding. Part II identifies the societal, technological, and regulatory uncertainties hindering the reemergence of cloud seeding technology and practice. Part III explores how only a few of these uncertainties have been addressed and why regulation addressing remaining uncertainties is necessary. Part IV proposes laws and regulations for safeguarding stakeholders as well as accommodating and encouraging cloud seeding practice and development.

I. RAINMAKING: WHAT IS CLOUD SEEDING?

Cloud seeding offers many potential benefits and can be implemented in a number of ways. These benefits can be used to resolve present and future weather related problems on both a local and global scale. Developments in methodology and technology continue to increase the potential for cloud seeding to provide these benefits.

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15. *See* Samantha Young, *Governments Turn to Cloud Seeding to Fight Drought*, U.S. NEWS & WORLD REP. (Dec. 11, 2009, 12:29 PM), http://www.usnews.com/science/articles/2009/12/11/governments-turn-to-cloud-seeding-to-fight-drought.

16. *See* discussion *infra* Section III.C.1.

17. Apart from weather modification by cloud seeding, other augmentation strategies may include storage, transportation, or desalination. *See generally* COLO. RIVER WATER CONSULTANTS, STUDY OF LONG-TERM AUGMENTATION OPTIONS FOR THE WATER SUPPLY OF THE COLORADO RIVER SYSTEM (2008), http://www.usbr.gov/lc/region/programs/crbstudy/longtermaugmentationrpt.pdf.

18. Lauren Sommer, *In Dry Year, California Looks to Cloud Seeding*, KQED SCI. (Jan. 6, 2014), http://ww2.kqed.org/quest/2014/01/06/in-dry-year-california-looks-to-cloud-seeding/.

A. The Untapped Potential of Cloud Seeding

Clouds are a largely untapped resource for distributing water. Water suspended in the atmosphere indiscriminately glides over parched and flooded lands until, when conditions are right, it either evaporates into greenhouse gas or falls as precipitation to the ground.[19] Cloud seeding is an attempt to induce precipitation that can be used to produce rain or snow, suppress hail, or weaken hurricanes.[20] Such uses can be implemented to fight wars or drought, avert natural disaster, fill water basins, provide water for farmers, disperse fog, or clear away air pollution, among other uses.[21] Cloud seeding may also become increasingly relevant for mitigating climate change impacts; for example,[22] the Clausius Clapeyron curve for water vapor shows that for every 1°C rise in temperature the atmosphere's ability to hold water increases by seven percent.[23] If the Earth's temperature continues to rise, society may find itself needing more and more water from the sky, increasing the need to reclaim that water through cloud seeding.[24]

B. Cloud Seeding Methods

There are three primary methods for seeding clouds: hygroscopic, dynamic, and static.[25] Hygroscopic (warm cloud) seeding disperses seeds into the lower part of clouds.[26] Dynamic seeding, a complex process achieved in stages, attempts to lift vertical air currents to invigorate water through the clouds, resulting in more rain.[27] Static (cold cloud) seeding spreads ice-nucleating agents

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19. *See* William R. Cotton, *Weather and Climate Engineering*, *in* STRUNGMANN FORUM REPORTS: CLOUDS IN THE PERTURBED CLIMATE SYSTEM, 339, 339–340 (Jost Heintzenberg & Robert J. Charlson eds., 2009).

20. Ronald B. Standler, Weather Modification Law in the USA 2 (rev. Oct. 22, 2006), http://www.rbs2.com/weather.pdf (unpublished essay); Jacob Silverman & Robert Lamb, *Can China Control the Weather?*, HOWSTUFFWORKS, http://science.howstuffworks.com/nature/climate-weather/meteorologists/cloud-seeding1.htm (last visited Sept. 7, 2016); *see, e.g.*, ROBERT E. BECK & AMY K. KELLEY, 1 WATERS AND WATER RIGHTS § 3.04(a) (Amy K. Kelley ed., LexisNexis/Matthew Bender 2016); Tracy D. Hester, *Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOLOGY L.Q. 851, 860 n.31 (2011); Joe Gelt, *Weather Modification: A Water Resource Strategy to Be Researched, Tested Before Tried*, ARROYO (Water Res. Research Ctr., Univ. of Ariz. Coll. of Agric. & Life Scis. Tucson, Ariz.), Spring 1992, at 3; David C. Morrison, *Snow Jobs*, 19 NAT'L J. 651, 651 (1987) (discussing Operation Popeye, a cloud seeding military operation in Vietnam).

21. *See* sources cited *supra* note 20.

22. *See* Martin Rees, *The World Is Getting Warmer—But Here's What We Can Do Now to Prepare*, HUFFINGTON POST (Feb. 8, 2016, 5:30 PM), http://www.huffingtonpost.com/martin-rees/world-warm-prepare_b_9186650.html.

23. Intergovernmental Panel on Climate Change, *FAQ 3.2 How Is Precipitation Changing?*, IPCC (2007), http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-3-2.html; *see also* Kathryn Hansen, *Water Vapor Confirmed as Major Player in Climate Change*, NASA (2008), http://www.nasa.gov/topics/earth/features/vapor_warming.html.

24. *Cloud Seeding Frequently Asked Questions*, *supra* note 13.

25. *See* Silverman & Lamb, *supra* note 20 (providing a simple explanation of how each method works).

26. *Id.*

27. *Id.*

into clouds already containing moisture that condenses around the nuclei and falls as precipitation.[28] Static cloud seeding, in the right conditions, will cause water to start freezing, releasing latent heat which can push the cloud upward.[29] This makes the cloud larger and more resilient, resulting in more precipitation.[30] Both methods described in the introduction's narratives are examples of static seeding, which mimics what already occurs in nature; soil particles often act as ice-forming nuclei in clouds. Dust from sand storms in Asia, Africa, and the Middle East have been known to make the seven to ten day journey over the Pacific to the United States where the dust seeds the clouds and induces precipitation.[31]

Cloud seeding is usually accomplished via aircraft delivery or ground-based generation.[32] While aircraft delivery is more effective (averaging ten to twenty percent additional yield) than ground-based generation (averaging ten percent additional yield), it is also more expensive.[33] New dispersing technologies and nucleating agents are being developed to increase and better control yield, which may affect these averages.[34] For example, drones could be used to bridge the gap between the cost benefit of ground-based systems and the effective reach of airborne systems.[35]

II. CLOUDS OF UNCERTAINTY

> Risk greases the wheels of a free-market economy; uncertainty grinds them to a halt.
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> —Nate Silver[36]

Cloud seeding is reemerging as a promising technology for augmenting diminished and over-appropriated water resources; however, it is hindered by uncertainty.[37] Like many new technologies, the reemergence of cloud seeding

28. *Id.*

29. *See Cloud Seeding Frequently Asked Questions*, *supra* note 13.

30. Silverman & Lamb, *supra* note 20.

31. Sommer, *supra* note 18.

32. *Cloud Seeding Frequently Asked Questions*, *supra* note 13.

33. BECK & KELLEY, *supra* note 20, § 3.04(c).

34. *See, e.g.*, *id.* ("Post 2000 efforts that have injected clouds with salt-laden smoke apparently show promise for producing more rain"); Desert Research Inst., *Unmanned Cloud-Seeding Aircraft Takes Flight in Nevada*, PHYS.ORG (May 4, 2016), http://phys.org/news/2016-05-unmanned-cloud-seeding-aircraft-flight-nevada.html ("For the first time in aviation history, a fixed-wing unmanned aircraft has successfully tested a cloud-seeding payload . . . .").

35. *See* Katy Galimberti, *Drones Offer New Horizon, Solutions for Weather Modification*, ACCUWEATHER.COM (June 10, 2014, 4:28 AM), http://www.accuweather.com/en/weather-news/drones-weather-modification/28257378.

36. NATE SILVER, THE SIGNAL AND THE NOISE: WHY SO MANY PREDICTIONS FAIL–BUT SOME DON'T 29 (2012).

37. Gelt, *supra* note 20, at 3. Gelt discusses the need for additional weather modification research given its promising potential for augmenting water supplies as stressed by Arizona's Groundwater Management Act's Second Management Plan. *Id.*

faces societal, technological, and regulatory uncertainty.[38] The key goal of a viable cloud seeding strategy, therefore, is overcoming these uncertainties.[39]

A. Societal Uncertainty

Societal uncertainty surrounding cloud seeding is a symptom of its poor history and potential ethical impact. Tainted by a history of public overestimation and private exploitation, many perceive cloud seeding as a science fiction. Additionally, cloud seeding may be thought of as interfering with the "natural order" and can be at odds with the ecological ethics held by some. These concerns make society unsure of seeding and hinder much needed support.[40]

1. *Between Aliens and Voodoo: A Public Image Problem*

Society has good reason for questioning cloud seeding credibility. Its public image problem is the result of a too rapid shift from innovation to practice in the mid-1900s.[41] The initial burst of unrestrained enthusiasm coupled with "inadequate knowledge of cloud physics parameters and insufficient development of engineering techniques led to disappointing results."[42] These results promulgated a history of exploitation, overestimation.

Society was exploited during these early decades as people paid peddling cloud seeders, often con artists, to make it rain. Desperate for water, these residents and towns dumped savings into "rainmakers," many of whom merely shot pyrotechnics into the sky.[43]

While supposed cloud seeders exploited society, overoptimistic predictions abounded during the 1950s and 1960s.[44] For example, in the 1950s, the President's Commission on Water Resources declared that cloud seeding could soon double rainfall in the country.[45] Compounding the problem, names given to initial cloud seeding projects, like "Project Skyfire" (to reduce forest fires) in the 1950s and "Project Stormfury" (to manipulate hurricane clouds) in the 1960s, conveyed science fiction-like expectations for technology still in its infant

38. *E.g.*, Jeremy Hall et al., *Developing and Diffusing New Technologies Strategies for Legitimization*, 56 CAL. MGMT. REV. 98, 99 n.3 (2014) ("Hall and Martin suggest that an innovation must overcome four areas of uncertainty: technological, commercial, organizational, and societal.").

39. *Id.*

40. *Id.* (stressing the importance of considering the "relevant ethical, religious, cultural, or social concerns of those affected by the technology" in emerging technology development).

41. *See* Gelt, *supra* note 20, at 4 ("During the early years of weather modification work in the 1950s and 1960s, the shift from research to actual application was too rapid. This premature action was not consistent with the careful evolution of a body of knowledge and the maturing of recognized scientific principles. This created weather modification credibility problems.").

42. BECK & KELLEY, *supra* note 20.

43. *See* Sandra Zellmer, *The Anti-Speculation Doctrine and Its Implications for Collaborative Management*, 8 NEV. L.J. 994, 1017 (2008) [hereinafter Zellmer, *The Anti-Speculation Doctrine*]; Sandra Zellmer, *Boom and Bust on the Great Plains: Déjà Vu All Over Again*, 41 CREIGHTON L. REV. 385, 392–93 (2008) [hereinafter Zellmer, *Boom and Bust*]; Standler, *supra* note 20, at 4.

44. Gelt, *supra* note 20, at 2 ("[E]arly advocates of weather modification often promised more than could be delivered.").

45. John Leshy, *Notes on a Progressive National Water Policy*, 3 HARV. L. & POL'Y REV. 133, 134 n.7 (2009).

stages.[46] As a result, society slotted cloud seeding into a fantastic category somewhere between aliens[47] and voodoo.[48]

2. *Environmental, Ecological, and Cultural Concerns*

> And therefore lift up thy love to that cloud: rather, if I shall say thee sooth, let God draw thy love up to that cloud and strive thou through help of His grace to forget all other thing.[49]
>
> —Anonymous

The image of aircraft blazing through the atmosphere and cannons deployed on the peaks of mountains blasting silver iodide into the environment can be disconcerting and evokes environmental, ethical, and cultural concerns. These concerns contribute to societal uncertainty.

Some worry that the silver iodide primarily used for cloud seeding contaminates the environment or that cloud manipulation negatively impacts natural ecosystems.[50] Others believe that technology will cause more problems than it solves, and that the "natural order" is better.[51] Proponents of this view argue that interfering with natural processes is an eco-hubris that will not fix society's problems.[52]

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46. *See* Gelt, *supra* note 20, at 2.

47. *See, e.g.*, Colin B. Picker, *A View from 40,000 Feet: International Law and the Invisible Hand of Technology*, 23 CARDOZO L. REV. 149, 194–95 (2001) ("[S]cholars also considered the need for a weather modification treaty to deal with the expected technology associated with cloud seeding and a set of principles to deal with the first human contact with extraterrestrials. However, as these technologies and many others came to naught, so too did the scholars' proposed international legal regimes.").

48. *See, e.g.*, Sommer, *supra* note 18 ("Cloud seeding has been used for six decades in California. In the early days, it was closer to 'magical thinking,' an idea Tilley says has stuck around. 'We get voodoo,' he says. 'We get Dr. Frankenstein. We get all sorts of things. But we've been able to refine the technology.'" (quoting Dr. Jeff Tilley, Desert Research Institute)).

49. ANONYMOUS, A BOOK OF CONTEMPLATION THE WHICH IS CALLED THE CLOUD OF UNKNOWING, IN THE WHICH A SOUL IS ONED WITH GOD 50 (My Mind Books 2d ed. 2012) (c. 1350 A.D.).

50. *Id.* ("The silver iodide eventually ends up in the local environment, where some worry it's a contaminant, though Tilley says tests show it's only a trace amount." (citing Dr. Jeff Tilley, Desert Research Institute)); *see also* Gelt, *supra* note 20, at 6 (giving examples of cloud seeding impacts that can affect plant and animal populations).

51. For a discussion on how the public zeitgeist transformed from the idea that technology, like cloud seeding, was good and could solve all of humanity's problems in the early 1950s to the idea that technology caused too many problems and that the natural order was better, as well as how there is no evidence of cloud seeding negatively impacting the environment, see Ronald B. Standler, History and Problems in Weather Modification (Jan. 21, 2003), http://www.rbs2.com/w2.htm (unpublished essay).

52. *E.g.*, News Release, ETC Group, United Nations Science Body Calls for Halt on Climate-Hacking Experiments Geoengineering Moratorium Proposal Will Go To UN Biodiversity Convention (May 18, 2010), http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/pdf_file/ETCNR_Nairobi180510.pdf ("If we learn one lesson from this disaster, let it be that we cannot control the effects of our technology, nor is our technology capable of fixing the Earth-disruptions that we unleash. It's time for some collective humility in the face of awesome natural forces, not more eco-hubris." (quoting Canadian author Naomi Klein)).

Cultural sensitivities and divergent values regarding clouds compound the issue. Culturally, clouds have inspired awe and are often associated with heaven and deity; the Greek god Zeus was known as "god of rain and the cloud-gatherer."[53] A fourteenth-century monk is credited with the passage quoted at the beginning of this section written to describe that a person is nearer to God if up in clouds.[54]

Interfering with the clouds can imply a type of sacrilege to those who consider them the exclusive domain of Gods or nature.[55] People may imagine a world where clouds are bought and sold to depletion, and the holiness is stripped away through commodification.[56]

B. Technological Uncertainty

Another factor hindering cloud seeding practice is technological uncertainty. Technological uncertainty, in this context, is concerned with scientific, technical, and engineering uncertainty.[57] Since the 1950s, researchers have been exploring cloud seeding applications and effects while scholars have continued to demand more proof, control, and predictability regarding weather modification technology.[58] These technological uncertainties have been resolved in part, but studies have yet to satiate the opposition who believe that the jury is still out and the research inconclusive.[59] These uncertainties have staggered weather modification law and include the effectiveness, control, and predictability of seeding technologies on atmospheric processes.

1. *Effectiveness*

Whether cloud seeding is a realistic option for controlling precipitation depends largely on how well it works. Studies show that seeding is effective and induces five to twenty-five percent additional precipitation, depending on operational parameters.[60] In 2003, the National Research Council questioned seeding

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53. GAVIN PRETOR-PINNEY, THE CLOUDSPOTTER'S GUIDE 35 (2006).

54. *Id.* at 41.

55. 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 ENVTL. L. & POL'Y 321, 333 (2009).

56. *See, e.g.*, *id*. ("Ethical and environmental issues aside, the active market in cloud ownership is a clear sign of an economic problem in the making.").

57. *See, e.g.*, Hall et al, *supra* note 38, at 99 ("concerned with overcoming scientific, technical, and engineering hurdles (i.e., does the technology work?)").

58. *See* Majzoub et al., *supra* note 55, at 323 ("[W]eather modification activities . . . have remained controversial and will continue to be so until more experiments are conducted and a more complete understanding of weather modification results is possible"); *see also* Gelt, *supra* note 20, at 7 ("In 1985 the American Meteorological Society (AMS) adopted a policy statement addressing planned . . . weather modification. . . . conclud[ing] that the science of weather modification [was] mostly still in a research and experimentation stage, with more work to be done to establish a sound scientific basis.").

59. *See* Gelt, *supra* note 20, at 2.

60. *See* Don A. Griffith et al., *Target/Control Analyses for Santa Barbara County's Operational Winter Cloud Seeding Program*, 47 J. WEATHER MODIFICATION 10 *passim* (2015); John C. Ruple & Robert B. Keiter, *Water for Commercial Oil Shale Development in Utah: Allocating Scarce Resources and the Search for New Sources of Supply*, 30 J. LAND RESOURCES &

effectiveness, adding that the problem was a failure to accurately predict the results and understand atmospheric processes.[61] In response, Wyoming sought to find verifiable results with a fourteen-million dollar experiment extending from 2008 to 2014.[62] Using the paralleling Sierra Madre and Medicine Bow mountain ranges, storms were alternatively seeded over one while the other would act as a control.[63] The National Center for Atmospheric Research (NCAR) designed and evaluated the experiment.[64] When the study included measurements of snowmelt-driven stream flow, results indicated a five to fifteen percent increase in precipitation. These results were reported during the Colorado River Water Users Association conference on December 18, 2014.[65] This and other studies suggest that cloud seeding could be a cost-effective tool for securing additional water resources.[66]

2. *Predictability and Control*

Beyond effectiveness, technological uncertainty impacts the law, specifically liability issues like causation. Because atmospheric processes affecting predictability and control are not fully understood, it is difficult to determine whether harmful precipitation or deprivation was the result of a seeding operation.[67]

Difficulty in predicting and controlling the impacts of cloud seeding make allocating liability difficult. What is the plaintiff's burden for causation amidst this uncertainty? What standards apply to operators who are limited in their control and ability to predict operational impacts? The combination of unpredictable technology and jurisprudence can make cloud seeding a risky endeavor.

C. Legal and Regulatory Uncertainty

While all three branches of government have dabbled in weather modification law, the existing structure represents an ex post patchwork of "sparse and

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ENVTL. L. 95, 127 (2010); Sommer, *supra* note 18. For a study elaborating on the operational parameters affecting outcomes, including the type and amount of seeding agent as well as the type and stage of cloud formation, see Baojun Chen & Yan Yin, *Can We Modify Stratospheric Water Vapor by Deliberate Cloud Seeding?*, 119 J. GEOPHYSICAL RES.: ATMOSPHERES 1406 *passim* (2014).

61. Allen Best, *Biggest Cloud-Seeding Experiment yet Only Sparks More Debate*, LIVE SCIENCE (Dec. 26, 2014, 1:30 PM), http://www.livescience.com/49263-cloud-seeding-experiment-debate.html (citing COMM. ON THE STATUS AND FUTURE DIRECTIONS IN U.S. WEATHER MODIFICATION RESEARCH AND OPERATIONS, NAT'L RESEARCH COUNCIL, CRITICAL ISSUES IN WEATHER MODIFICATION RESEARCH 68 (2013).

62. *Id.*

63. *Id.*

64. *Id.*

65. *Id.*

66. *Id.*; *see also* discussion *infra* Section III.C.3.

67. *See* Galimberti, *supra* note 35 ("It's hard to prove if it works or not because we don't know what would happen if we hadn't seeded." (quoting Jesse Ferrell, AccuWeather.com meteorologist)).

contradictory" law.[68] These regulatory uncertainties are perhaps the most burdensome on cloud seeding in that they not only create their own domain of uncertainty, but also enable societal and technological uncertainty.

1. *International Weather Modification Law*

While international weather modification law is limited, it does provide, in part, for national rights to cloud water,[69] and prohibits the militarization of weather modification technology that could be used to cause floods or draught.[70] Another significant international law directly addressing weather modification is its prohibition against militarization.[71]

From 1967 to 1972, the U.S. military used weather modification as a tactical weapon for its war effort in Vietnam.[72] During the war, North Vietnamese infiltrators used the Ho Chi Minh Trail as a supply route.[73] In an attempt to deny access to the route, the U.S. military initiated Operation Popeye hoping to extend the monsoon season and make the trail impassable by seeding clouds over the trail with over two-thousand flights.[74] Officials have since described the operation as unpredictable and ultimately irrelevant.[75] Despite doubts about the effectiveness of Operation Popeye, this and other military efforts eventually led to the International Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 (ENMOD).[76]

The United States is a signatory to ENMOD which entered into force in 1978.[77] The treaty prohibited the "hostile use of environmental modification techniques having widespread, long-lasting, or severe effects."[78] Environmental modification techniques include, among other things, "deliberate manipulation of . . . [the] atmosphere."[79] In other words, the treaty effectively banned the use of cloud seeding as a weapon for war between nations.

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68. George W. Bomar, *Weather Modification and the Law*, SW. HYDROLOGY, Mar./Apr. 2007, at 22, 22 [hereinafter Bomar, *Weather Modification & Law*] (quoting an unnamed law professor with expertise "in weather modification practices").

69. *See* Majzoub et al., *supra* note 55, at 328.

70. *See* Jennifer Ann Neuhauser, *U.S. Military Responsibility for Environmental Cleanup in Contingency Environments*, 45 ENVTL. L. 129, 153 (2015).

71. *See* Neuhauser, *supra* note 70.

72. Morrison, *supra* note 20.

73. *Id.*

74. *Id.*

75. *Id.*

76. *See* Neuhauser, *supra* note 70 ("Though not applicable in current post-conflict areas, the United States is also a signatory to the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 (ENMOD). ENMOD arose in the wake of the use of mechanical and chemical defoliants—such as Agent Orange—and cloud seeding techniques in Vietnam, and is designed to prohibit the 'hostile use of environmental modification techniques having widespread, long-lasting, or severe effects.'") (quoting Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques, May 18, 1977, 31 U.S.T. 336, 1108 U.N.T.S. 153, at art. I (1977)) [hereinafter ENMOD].

77. ENMOD, *supra* note 76, 31 U.S.T. at 333, 1108 U.N.T.S. at 151.

78. G.A. Res. 31/72, ¶ 1–2 (Dec. 10, 1976).

79. *Id.*

2. *Federal Weather Modification Law*

No national weather modification policy and no substantive federal weather modification law governs rights, liability, or disputes between states. Also, federal funding for cloud seeding dwindled to zero in 2005 when the Bureau of Reclamation announced that no additional funding would be forthcoming for weather modification.[80] Despite lack of federal funding, utilities and some government agencies within the United States spend about fifteen million dollars a year on cloud seeding.[81] This is far lower than what other countries spend.[82] China, for example spends nearly seven times as much, one hundred million dollars per year on seeding.[83] Although the federal government's involvement has been limited when it comes to weather modification regulation, it has established reporting requirements.[84] These requirements address the exploitation factor of societal uncertainty discussed earlier by requiring operators to report their activities or face a fine.[85] However, such reporting is primarily for disclosure, and short of a failure to report, the government does not act.[86]

In 1971, these reporting requirements for potential cloud seeders were enacted by Congress in the Weather Modification Reporting Act (WMRA).[87] The Act first requires that individuals and organizations attempting weather modification report operations to the Secretary of Commerce (Secretary), providing up to a $10,000 fine for noncompliance.[88] These reports are required throughout the operation and provide notice and information regarding plans and operational errors that must be retained by cloud seeders and submitted to the Secretary.[89] Second, the Secretary must maintain records of weather modification activities.[90] Lastly, the Secretary may publish summaries of weather modification activities; however, no such summary has been published since 1978.[91]

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80. *See* Ray Jay Davis, *Law and Urban-Induced Weather Change*, 25 U. TOL. L. REV. 379, 399 (1994); Best, *supra* note 61.

81. Young, *supra* note 15.

82. *Id.*

83. *Id.*

84. BECK & KELLEY, *supra* note 20, § 3.04(f); *see* Zellmer, *Boom and Bust*, *supra* note 43, at 393 n.59 ("Federal law has little to say on the subject, other than imposing reporting requirements.").

85. George W. Bomar, *Legal Aspects of Weather Modification Operations*, *in* 81 GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 43, 43 (Am. Soc'y Civil Eng'rs 2d ed. 2006) [hereinafter Bomar, *Legal Aspects*].

86. *Id.* at 53.

87. BECK & KELLEY, *supra* note 20, § 3.04(f) ("Congress enacted the Weather Modification Reporting Act in 1958, repealed it in 1968, but then enacted a new Weather Modification Reporting Act in 1971."). The act is codified in 15 U.S.C. §§ 330–330(e) (2014).

88. BECK & KELLEY, *supra* note 20, § 3.04(f).

89. *Id.*

90. *Id.*

91. *Id.*

The National Oceanic and Atmospheric Administration (NOAA), on behalf of the Secretary, accomplishes most of these responsibilities, including maintaining records and describing reporting requirements.[92] By implementing reporting requirements, the government deters potential operators from exploiting the public by requiring operators to either report faux operations or risk a $10,000 fine.[93]

In 1976, the 94th Congress passed the National Weather Modification Policy Act.[94] This Act was passed "to authorize and direct the Secretary of Commerce to develop a national policy on weather modification."[95] Despite this authorization, as of March 2015, no such policy has made its way into law, even though proposals to implement a national policy were made in 2005.[96] Other federal laws, such as the Clean Air Act, Clean Water Act, and Forest Service regulations may also collaterally impact weather modification operations, but to date their applications are largely unsettled.[97] For landowners claiming a right to airspace, neither the *ad coelum* doctrine (vesting landowners ownership over everything above and below their land)[98] nor the modification theories (affording airspace for use by aircraft) deal with the rights to atmospheric water.[99]

Few federal cases have tackled weather modification and most have focused on patents for the technology. The few cases which could have clarified rights and liability allocation, were dismissed before such issues could be addressed.[100] No federal case law deals with interstate weather modification disputes even though seeding operations in one state may impact another by increasing or decreasing precipitation or water flow across jurisdictional borders. An Idaho attorney general has even threatened to sue Washington in the

92. National Weather Modification Policy Act of 1976, 15 U.S.C. §§ 330–330(e) (2012); *see* Davis, *supra* note 80, at 391 ("Cloud seeding activities must be reported by operators both to the state regulators and to the National Oceanic and Atmospheric Administration.").

93. *See* BECK & KELLEY, *supra* note 20, § 3.04(f); Bomar, *Weather Modification & Law*, *supra* note 68, at 22.

94. 15 U.S.C. §§ 330–330(e) (2012).

95. National Weather Modification Policy Act of 1976, Pub. L. 94-490, § 330 note, 90 Stat. 2359 (1976); *See* BECK & KELLEY, *supra* note 20, § 3.04(f) ("The Subcommittee on Climate Change of the Environmental Resources Committee of the Domestic Council assessed the federal role in weather modification in a 1975 report. Congress passed the National Weather Modification Policy Act of 1976, requiring the Secretary of Commerce to do a one year study of the state of weather modification and to present recommendations.").

96. The Weather Modification Research and Technology Transfer Authorization Act of 2005 states its purpose in section two to "develop and implement a comprehensive and coordinated national weather modification policy and a national cooperative Federal and State program of weather modification research and development." H.R. 2995, 109th Cong. § 2 (2005).

97. For a more in depth discussion of how weather modification projects may be affected by federal law including the Clean Air Act, Clean Water Act, Endangered Species Act, National Environmental Policy Act, etc., see generally Hester, *supra* note 20.

98. *Ad Coelum Doctrine*, BLACK'S LAW DICTIONARY (10th ed. 2014) ("The common-law rule that a landowner holds everything above and below the land . . . .").

99. BECK & KELLEY, *supra* note 20, § 3.04(d)(1).

100. *See, e.g.*, Lunsford v. United States, 570 F.2d 221, 226–27 (8th Cir. 1977).

Supreme Court if it were to seed clouds and reduce Idaho's precipitation.[101] As seeded clouds begin to cross state lines, a difficult situation will arise when states that do not allow seeding are affected by those that do.[102]

Federal law relating to weather modification, therefore, is full of legal and regulatory gaps despite an act directing development. Lacking guidance for interstate disputes, rights, or liability, potential stakeholders are deterred from cloud seeding. Additionally, technological uncertainty is fueled by the lack of federal funding mechanisms for research and development. Lastly, any policy that could interpret societal benefits, promote national interest, encourage scientific understanding, assess needs, or otherwise provide support for weather modification still does not exist.[103] The federal government has thus left substantive weather modification regulation to state authorities.[104]

3. *State Weather Modification Law*

In general, few states have yet to take full advantage of the weather modification law-making authority afforded to them.[105] With the exception of the federal reporting requirement contained within the WMRA, state governments retain the ability to adapt and regulate weather modification to meet the needs and goals of their respective territories; however, what now exists is an inept body of unclear and incomplete law, both legislative and judicial.

About half of the United States, mostly in the west, has some form of law touching on the subject of weather modification.[106] State weather modification statutes, however, most often "merely express policy in the broadest sense," leaving the fine-tuning to administrative entities, local government, and the courts, which have taken entirely different approaches to rights and liabilities.[107] What laws do exist are usually implemented in the form of licensing and permitting by regulatory agencies.[108]

State weather modification laws may cover one or more of five categories.[109] First, laws can provide public funding. Illinois, for example, has special service areas for weather modification and can tax farmland to acquire money to support cloud seeding projects.[110] Also, the NOAA's Cooperative Atmospheric Modification Program has had five state participants receive aid for

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101. DOUGLAS L. GRANT & BRET C. BIRDSONG, 3-45 WATERS AND WATER RIGHTS § 45.01 n.18.1. (Amy K. Kelley ed., LexisNexis/Matthew Bender 2016).

102. Majzoub et al., *supra* note 55, at 343.

103. *See* Gelt, *supra* note 20, at 2.

104. Hester, *supra* note 20, at 873–74.

105. *See infra* Appendix (providing examples of a few states which have taken advantage of the weather modification authority afforded them).

106. *See* Bomar, *Weather Modification & Law*, *supra* note 68, at 22.

107. Bomar, *Legal Aspects*, *supra* note 85, at 43; *see infra* Appendix; *see also* BECK & KELLEY, *supra* note 20, § 3.04e (analyzing approaches, regulations, and districting used by various state weather modification regimes); Bomar, *Legal Aspects*, *supra* note 85, at 47 tbl.3-1.

108. *See* Bomar, *Legal Aspects*, *supra* note 85, at 43–44.

109. *Id.* at 47 tbl.3-1.

110. *See* Davis, *supra* note 80, at 397.

weather modification studies.[111] Second, laws can regulate projects by ensuring practitioners are competent and have the resources to compensate anyone harmed by operations. Most states with weather modification statutes require that day-to-day decision making be made by those having academic degrees in related fields like meteorology.[112] Third, laws usually impose notice requirements via Notices of Intention (NOI) to inform the public of when, where, and how operations will be conducted and often allow a forum for expressing views and soliciting feedback.[113] Fourth, most states require operators to report seeding activity. Lastly, a few states do have law referring to legal rights and liabilities.[114] These state laws, which address public funding, project regulation, and cloud seeding reporting,[115] are designed, like the WMRA, to "protect citizens from incompetent, or dishonest, purveyors of weather modification technology."[116] Cloud seeding operators may be required to obtain an operational license and permit, comply with environmental law stipulations, and enter into a contract with sponsors.[117]

Legal rights and liabilities have likely been the greatest cause of cloud seeding uncertainty. In many jurisdictions, it is unclear who has a right to the clouds and who, if anyone, may be liable for deprivation or harm caused by seeding.[118] Of the twenty-eight states with weather modification statutes, only eight address legal rights or liabilities.[119] These statutes often take different approaches to rights and liabilities. Liability approaches, for example, have included relatively broad liability provisions such as absconding the state from liability for approving operations, allowing operators to be liable regardless of whether regulations were followed, or explaining that relevant law does not affect liabilities.[120]

a. Statutory Rights and Liabilities

Weather modification technology, despite being more than fifty years old, is still governed by a relatively new and incomplete area of law. Incomplete law makes litigation slow and expensive, and judges, rather than deciding the applicable facts or law of a case, are left to wrestle with novel unprecedented legal issues.[121] Very few statutes have addressed rights and liabilities associated with cloud seeding. Those laws that exist are often inadequate and contradictory.

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111. *See* Gelt, *supra* note 20, at 6.
112. Bomar, *Weather Modification & Law*, *supra* note 68, at 22.
113. *Id.*
114. *See* BECK & KELLEY, *supra* note 20, § 3.04(e).
115. Bomar, *Legal Aspects*, *supra* note 85, at 47 tbl.3-1.
116. *Id.* at 43; *see also id.* at 47 tbl.3-1.
117. *Id.*; *see* BECK & KELLEY, *supra* note 20, § 3.04(d)(2).
118. *See* Bomar, *Legal Aspects*, *supra* note 85, at 47 tbl.3-1 (listing eight states which address liability or rights, including California, Colorado, New York, North Dakota, Pennsylvania, Texas, Utah, and West Virginia).
119. *Id.*
120. *See* BECK & KELLEY, *supra* note 20, § 3.04(e).
121. Bomar, *Weather Modification & Law*, *supra* note 68, at 22.

Competing interests for rights to atmospheric precipitation include public, property owner, and operator interests. Statutes addressing rights and liabilities related to cloud seeding are few. Only three states (Colorado, Utah, and North Dakota) have statutorily addressed rights to augmented water by cloud seeding.[122] While some statutes do outline state authority and management of atmospheric water, they avoid addressing private ownership.[123] Absent guidance, courts are left to rule instinctively on weather modification issues.

Four state statutes have directly addressed liability for cloud seeding.[124] Texas does not regard cloud seeding as an ultrahazardous activity that makes operators subject to liability without fault.[125] Liability for seeding in Utah is possible only for negligence.[126] Both Pennsylvania and West Virginia have a no fault theory wherein defendants are only liable if the conduct has harmed the plaintiff.[127]

The most comprehensive weather modification statutes, such as those used by Colorado, North Dakota, Pennsylvania, Texas, and Utah, include provisions for (1) regulation, (2) notice, (3) reporting, (4) legal rights and liabilities, and (5) other miscellaneous laws.[128] Each of these states also allow for private party operations.

b. Common Law Rights and Liability

Only three cases have substantially addressed rights and liabilities related to cloud seeding, each from a different state and all during the initial cloud seeding boom of the mid-1900s.[129] The actions brought in all three cases were temporary injunctions, so their precedential value is limited.[130] Each case allocates atmospheric water rights and liabilities differently.[131]

In 1950, the New York County Supreme Court rejected property owners' rights to atmospheric water in *Slutsky v. New York*.[132] The plaintiffs in *Slutsky* were country club owners who filed a motion for temporary injunction to restrain the City of New York from cloud seeding.[133] The City of New York planned on conducting cloud seeding experiments to mitigate the effects of a

122. Bomar, *Legal Aspects*, *supra* note 85, at 55 tbl. 3-2.

123. BECK & KELLEY, *supra* note 20, § 3.04(d)(1).

124. Bomar, *Legal Aspects*, *supra* note 85, at 55 tbl. 3-2.

125. TEX. AGRIC. CODE ANN. § 301.302(a) (West 2015); Bomar, *Legal Aspects*, *supra* note 85, at 55 tbl. 3-2.

126. Bomar, *Legal Aspects*, *supra* note 85, at 55 tbl. 3-2.

127. *Id.*

128. *See infra* Appendix.

129. Bomar, *Legal Aspects*, *supra* note 85, at 58.

130. *Id.*

131. *Id.* at 47 tbl.3-1; Standler, *supra* note 20, at 18 ("*Slutsky* in New York absolutely rejected a landowner's rights in water from Clouds; *Southwest Weather Research* in Texas accepted a landowner's rights in water from clouds and found that the landowner might be harmed by future cloud seeding; while *Pennsylvania Natural Weather Assoc.* accepted a landowner's rights in water from the cloud with some conditions, but found that the plaintiffs had not proved they would be harmed by future cloud seeding.").

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

133. *Id.*

serious drought.[134] The country club owners claimed that such experiments would swell local streams, causing damage to riparian land owners (owners of land that abuts a body of water), and the rainfall would threaten business by producing an undesirable climate for clientele.[135] The New York County Supreme Court reasoned that it would "not protect a possible private injury at the expense of a positive public advantage."[136] *Slutsky*, therefore, rejected the idea that property owners have a right to prevent atmospheric precipitation when weighed against the public interest.[137]

In 1959, the Supreme Court of Texas upheld a Texas Court of Civil Appeals ruling that a property owner has atmospheric water rights to "such rainfall as may come from clouds over his own property that Nature, in her caprice, may provide."[138] The appellate court modified and affirmed a district court injunction ordering defendants to refrain from cloud seeding.[139] Plaintiffs were ranchmen who claimed that weather modification operators hired by the defendants, farmers, to suppress hail destroyed potential rain clouds over the ranchers' property and deprived them of precipitation.[140] The evidence presented at the trial court consisted of conflicting expert testimony and witnesses testifying that they actually observed the repeated destruction of clouds which would have provided rain.[141] While the appellate court refused to decide the right of property owners to clouds not over their land, it did hold that landowners are entitled to the natural precipitation which would have fallen and found that there was enough evidence showing that the clouds over plaintiffs' property had been destroyed by defendants' weather modification operations.[142] The appellate court issued an injunction to restrain defendants from activity as it applied to the plaintiffs' lands.[143]

In 1968, the Common Pleas Court of Fulton County, Pennsylvania, ruled that "the moisture in the clouds . . . [is] common property belonging to everyone who will benefit from what occurs naturally in those clouds."[144] In *Blue Ridge*, the defendants, orchard owners, in an effort to suppress hailstorms, contracted with an association, also a named defendant, to conduct cloud seeding operations. Plaintiffs argued that the operations caused a drought and brought an action for injunctive relief.[145] Like *Slutsky*, the court considered the public interest and declared that all landowners have a property right to moisture in clouds and

134. *Id.*
135. *Id.*
136. *Id.* at 240.
137. Standler, *supra* note 20, at 6.
138. Sw. Weather Research, Inc. v. Duncan, 319 S.W.2d 940, 945 (Tex. Civ. App. 1958); *see* Sw. Weather Research, Inc. v. Jones, 327 S.W.2d 417, 421–22 (Tex. 1959).
139. Duncan, 319 S.W.2d at 945.
140. *Id.* at 941.
141. *Id.* at 942–43.
142. *Id.* at 945.
143. *Id.*
144. Pa. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 759 (Pa. Ct. Com. Pl. 1968).
145. *Id.* at 749, 752.

the right to receive it naturally, but that such a right is subject to weather modification activities carried out by governmental authorities in the public interest.[146] In Pennsylvania, therefore, cloud seeding is proper if it is government authorized. Although plaintiffs have a remedy at law, it is their burden to show certainly, not just possibly, that operations have resulted or will result in immediate and irreparable damage.

The implications of these cases on rights to atmospheric water and liability for harm are not trivial.[147] No damages were awarded in any case. In the two cases involving the public interest and operations implemented by the government, the courts ruled in favor of the cloud-seeding defendants—the government. The burden rested on the plaintiffs to prove damages in all three cases; however, courts disagreed on the weight of that burden. In Texas, conflicting expert testimony and witnesses' claims satisfied the plaintiff's burden. In the Pennsylvania case, however, the court required unequivocal proof that seeding caused or would cause harm. Litigation is already slow and expensive, and the lack of case law governing cloud seeding disputes compounds the problem for plaintiffs. Plaintiffs' beneficial economic interests may abate as circumstances change and judges wrestle with "novel legal issues that transcend the particular case."[148]

4. *Extending Existing Water Rights Systems to Atmospheric Water Rights Allocation: Riparian and Prior Appropriation*

Reemerging cloud seeding practice, fueled by an increasing national demand for water and more feasible emerging technologies, give rise to the question of cloud ownership. Put off for decades as ridiculous or premature, the question can no longer be avoided with the reemergence and "growth of weather modification."[149] Theories for property rights to clouds accompanied the initial emergence of seeding in the mid-1900s. Drawing from analogies and "common elements of property rights in . . . other fields," these theories are worth exploring.[150] To adequately address the question of atmospheric water rights, laws for both the natural resource itself, water in the atmosphere, and the location of the resource in airspace, must be considered.

In general, a state owns and holds all land-water (surface and groundwater) in trust for its citizenry, which may gain a usufructory water right (right to use) by occupancy (abutting land in riparian jurisdictions, and first in time users in prior appropriation jurisdictions).[151] However, these allocation systems exclude, among other things, water in the process of evaporation, transpiration, or pre-

146. *Id.* at 763.

147. Majzoub et al., *supra* note 55, at 328–29.

148. *See* Bomar, *Weather Modification & Law*, *supra* note 68, at 22.

149. John Edward Cribbet, *Concepts in Transition: The Search for a New Definition of Property*, 1986 U. ILL. L. REV. 1, 20–21.

150. *See* Note, *Rainmaking Part One: Who Owns the Clouds*, 1 STAN. L. REV. 43, 46 (1948).

151. *See id.* at 47.

cipitation because, until recently, water in these states was beyond physical control.[152] Advances in cloud seeding, however, have brought atmospheric water within a person's physical control, which can be used to harm or benefit others. Atmospheric water plays at least as vital a role as land-water in benefiting the public and, therefore, ought to be held in trust by states for the public's benefit. The difficulty of allocating "cloud" rights comes with assigning a usufructory right by occupancy.

In both riparian and prior appropriation jurisdictions, the land-water right is granted and defined based on both the use (e.g., irrigation, domestic, and industrial) and manner of occupancy (overlying land, abutting land, first in time, and instream). Rights are often maintained by continued use subject to the public interest. The real world qualities of atmospheric water make extending either of these regimes to atmospheric waters problematic,[153] which is why "[g]enerally, precipitation that results from cloud seeding is treated as a public resource, indistinguishable from natural precipitation and available for appropriation through existing state regulatory programs."[154]

5. *Implications of Legal and Regulatory Uncertainty*

International, federal, and state law fail to adequately address issues related to reemerging and useful cloud seeding augmentation technologies. As discussed, these gaps include the governance of international and interstate disputes, resolving societal and scientific uncertainty, guidance for courts, remedies for harms, and other stakeholder safeguards. Without a more robust legal framework addressing these issues, practitioners will continue to be discouraged and any court addressing cloud seeding actions will be burdened, forced to tackle unregulated issues post facto. Environmental justice issues are also implicated because those impacted by seeding may not have the resources to pay for expensive litigation under law that provides no sure remedy.

In interstate disputes, for example, Texas and Pennsylvania precedent may be a basis for arguing for territorial jurisdiction to clouds over their land. Bordering states, like New York, may reject the notion of property owners' rights to clouds. In a federal court with original jurisdiction, how would such disputes be resolved? No national weather policy or law exists and state precedent is limited. Could operators be liable? And, if so, would the burden be on the plaintiff to establish "with certainty" that cloud seeding operations destroyed or will destroy clouds over the plaintiff's land as in the Pennsylvania case?[155]

Beyond interstate disputes, *intrastate* actions are equally perplexing. Texas, Pennsylvania, and New York may have some fifty-year-old precedent to reference, but what about the other forty-seven states? States not affected by drought

152. *See id.*

153. *See generally id.* at 46–63 (offering a more in depth discussion of the conflicting characteristics of Riparian and Prior Appropriation systems).

154. Ruple & Keiter, *supra* note 60, at 127.

155. Pa. Nat. Weather Ass'n, 44 Pa. D. & C.2d at 759.

may want to suppress hail, avert storms, reapportion water supplies, or otherwise control weather in the public interest. These legal and regulatory gaps fail to protect property rights or provide guidance for operators and courts.

III. SEEDING THE CLOUDS OF SOCIETAL, TECHNOLOGICAL, AND LEGAL UNCERTAINTY

With the recent resurgence in cloud seeding and the current state of diminishing and over appropriated water resources, ex ante federal and state law could incentivize operations and help restore and stabilize the nation's water problems. Additionally, with an increasingly unpredictable and volatile climate, it is important that governments implement every practical precaution for maintaining water supplies that are decreased daily by droughts, water contamination incidents, global warming, and other causes.[156] While cloud seeding may not be a silver bullet, it is a big gun in a limited augmentation arsenal.

A. Resolving Societal Uncertainty

Law has partly addressed societal uncertainty but can do much more to clear the way for cloud seeding. Laws that encourage a better scientific understanding of cloud seeding and promote its use would help to dispel society's overestimation and exploitation concerns.

1. *Law Legitimizing Cloud Seeding*

Federal and state weather modification law has resolved much of society's exploitation concern by establishing permitting and licensing schemes. Peddlers can no longer sell you fireworks and run off with your money. At least they cannot do so without reporting it to the Secretary of Commerce first or being penalized with a hefty fine. These laws protect the public from exploitation by ensuring a minimum level of occupational and operational competency.

Estimating the effects of cloud seeding operations has become more accurate in the past six decades and people are far less likely to promise the fantastic without research beforehand. More accurate estimates will become available as laws clear the way for a better scientific understanding of the process and fund innovation through research and development programs designed to control seeding operations. The question is not so much whether cloud seeding works, but *how* it works and how *effective* is it.[157] Laws requiring an analysis of anticipated outcomes to be submitted prior to operations and additional research would help identify and track more predictable outcomes. By promoting seeding efforts, governments can legitimize cloud seeding as a credible augmentation strategy.

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156. *See* Matt Cartwright & Michael Shank, *America's Water Supply Is Going Down the Drain*, U.S. NEWS (Jul. 2, 2014, 8:00 AM), http://www.usnews.com/opinion/articles/2014/07/02/americas-cheap-and-quality-water-supply-could-be-in-peril; *see* discussion *infra* Section III.C.2.

157. *See* Sommer, *supra* note 18.

2. *Laws Requiring Reporting of Possible Adverse Environmental Effects and Identifying Societal Benefits*

The environmental effects of silver iodide on seeded area environments have been studied since the 1960s.[158] The primary environmental concern of cloud seeding is whether the silver iodide released into clouds can achieve toxic levels harmful to life, especially lower organisms, in aquatic environments.[159] Although some studies conducted in laboratory aquariums have shown that silver can be toxic to lower, less evolved, organisms over an extended period of time, these artificial tests fail to "include the specifics of the chemical form of . . . silver [iodide], the quantities involved, and the chemical, even physical, nature of the environment."[160] Studies of seeded areas have shown that operations do not harm the natural environment.[161] Sierra Nevada, for example, has studied the effects of seeding for over three decades in over one hundred operational areas, many "extremely susceptible" to silver and detected no silver from seeding.[162] Three decades of study and "tens of thousands of samples" have revealed that the precipitation from cloud seeding operations contain less than .01 micrograms of silver per liter of water.[163] Compare this with the U.S. Public Health Service's established limit of "50 micrograms of silver per liter of water in public water supply."[164] This research led the Weather Modification Association to declare that "silver iodide is environmentally safe as it is currently being used in the conduct of cloud seeding programs."[165] To date, there is no evidence that cloud seeding has or will substantially affect natural ecosystems.[166] Although no adverse environmental or ecosystem evidence has surfaced to date, proactive law requiring the reporting of potential adverse environmental impacts could only be beneficial to ensuring environmentally responsible practices.

3. *Coping with an Already Weather Modified World*

Interfering with the natural process may cause more problems than it solves; however, humanity already lives in a weather modified world.[167] The

158. *See* WEATHER MODIFICATION ASSOCATION (WMA), POSITION STATEMENT ON THE ENVIRONMENTAL IMPACT OF USING SILVER IODIDE AS A CLOUD SEEDING AGENT (2009), http://www.weathermodification.org/images/AGI_toxicity.pdf.

159. *Id.*

160. *Id.*

161. *Id.*

162. *Id.*

163. *Id.*

164. *Id.*

165. *Id.*

166. *Id.*

167. *See generally* Gelt, *supra* note 20, at 7 ("The foremost example of inadvertent weather modification is of course the greenhouse effect, an occurrence some claim will become increasingly disruptive to global processes. The extent and, indeed, even the existence of the greenhouse phenomenon is much debated."); Sommer, *supra* note 18 ("Air pollution, from California sources and . . . Asia, could be adding too many tiny cloud seeds. . . . 'Potentially it's us affecting our own water supply . . . .'" (quoting Kimberly Prather, Distinguished Chair in Atmospheric Chemistry at Scripps

American Meteorological Society has linked human activities with unintended weather modification in both local and regional weather.[168] Cloud seeding is one way to take control of the weather, and even restore the "natural order." For example, air pollution has been known to decrease downwind precipitation by overseeding clouds with seeds so small that water in clouds cannot reach the critical mass needed to fall.[169] Air pollution has been linked to an estimated fifteen to twenty-five percent reduction of precipitation in California and at least thirty percent in Colorado's Rocky Mountains.[170] Laws allocating funding for cloud seeding research would help scientists understand how these processes work and how better to avoid or control existing unintentional weather modification.[171] Additionally, operations implemented outside of air-polluted areas could offset losses. The prospect of cloud modification also raises societal concerns about the indiscriminate nature of cloud use—an issue that can be effectively regulated by limiting provisions.[172]

B. Resolving Technological Uncertainty

Laws can address technological uncertainty by encouraging practice and implementing research and development programs; however, both practice and research cost money. High resolution modeling is one example of an emerging technology that could be funded by the government.

Government funding is needed to further scientific research that would help scientists understand atmospheric processes and how they interact with seeding technology.[173] It is clear that cloud seeding works, that it can be more effectively designed, and that society would greatly benefit if weather related damages could be reduced.[174] Laws encouraging seeding applications would allow the technology to develop through practice as seeders become more willing to invest

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Institution of Oceanography and the Department of Chemistry and Biochemistry at University of California, San Diego).

168. Davis, *supra* note 80, at 381.

169. Ruple & Keiter, *supra* note 60, at 128. *See generally* Sommer, *supra* note 18.

170. Ruple & Keiter, *supra* note 60, at 128.

171. *Id.* Ruple and Keiter drew on reports from the Intergovernmental Panel on Climate Change and the National Research Council. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT 49 (2007) (There is also high confidence that many semi-arid areas (e.g. . . . western United States . . .) will suffer a decrease in water resources due to climate change.); COMM. ON THE SCIENTIFIC BASES OF COLORADO RIVER BASIN WATER MANAGEMENT, NAT'L RESEARCH COUNCIL, COLORADO RIVER BASIN WATER MANAGEMENT: EVALUATING AND ADJUSTING TO HYDROCLIMATIC VARIABILITY 109 (2007) ("[T]he preponderance of scientific evidence suggests that warmer future temperatures will reduce future Colorado River stream flow and water supplies.").

172. Majzoub et al., *supra* note 55 (highlighting arguments against cloud trading, including interfering with the natural order, environmental concern, and indiscirimnate use).

173. *See* Standler, *supra* note 20, at 33; Robert Glennon & Michael J. Pearce, Symposium, *Water Law and Policy Conference: Transferring Mainstem Colorado River Water Rights: The Arizona Experience*, 49 ARIZ. L. REV. 235, 255 (2007).

174. *See* Standler, *supra* note 20, at 33.

in research and operations.[175] As the technology develops, state laws can respond by refining policy.[176]

Recent developments in cloud-monitoring technologies, such as the use of high resolution models, could be further developed to provide information needed for informed decision making.[177] Modelling is giving scientists and operators a better understanding of atmospheric processes, enabling them to better predict the effects of cloud seeding operations.[178] These models could address predictability and control issues as they become more accurate and are used more often.

Technological innovation is making seeding even cheaper. Nevada, for example, is spearheading a drone program that would significantly decrease the costs of seeding by aircraft.[179] Aircraft seeders are more effective and can cover a greater area than the usually cheaper ground-based seeders. Using drones to seed would make operations less expensive and more effective.[180] Recent efforts have also been made to produce alternatives to silver iodide such as using salt-laden smoke, which may generate more rain.[181]

Atmospheric tracers are another emerging technology that could be funded by the government. Materials like chaff or sulfur hexafluoride (SF_6) are already used to track plumes in the atmosphere.[182] Tracers like these, if funded and developed, could ease the plaintiff's burden of proving specific causation. They could also be used to better understand and predict interactions between operations and the environments they affect.

C. A Nation Primed to Resolve Legal and Regulatory Uncertainty

Conditions within the United States have set the stage for cloud seeding and the need for weather modification law to guide its implementation is steadily growing. These conditions include increasingly frequent cloud seeding operations, a growing demand for more water, and technological developments making cloud seeding more cost effective.

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175. Gelt, *supra* note 20, at 2 (outlining the optimistic views of cloud seeding advocates who believe that the "potential will be realized with more research and the eventual application of cloud seeding activities").

176. Bomar, *Weather Modification & Law*, *supra* note 68, at 23.

177. *See* Majzoub et al., *supra* note 55, at 343; David J. Gochis, Research Assistant, Univ. of Ariz., Emergent Precipitation Enhancement Techniques and the Rights to Developed Water, Globalization and Water Resource Management: The Changing Value of Water, AWRA/IWLRI-University of Dundee International Specialty Conference (Aug. 6–8, 2001), http://www.awra.org/proceedings/dundee01/Documents/GochisD.pdf.

178. Gochis, *supra* note 177.

179. *See* Galimberti, *supra* note 35.

180. *Id.*

181. BECK & KELLEY, *supra* note 20, § 3.04(c).

182. *See* Gochis, *supra* note 177, at 2.

1. *Resurgence Will Lead to Disputes*

Cloud seeding operations have jumped by about a third from 1999 to 2009 as the United States has faced population growth and climate change threats.[183] Even without funding from the government, private and public operations reported to NOAA have increased steadily.[184] As the frequency of cloud seeding operations increases, it will become increasingly necessary to clarify law: "[w]here there is money to be made by controlling nature, it is a safe bet that there will be conflicts over property and ownership."[185] By enacting clear law and policy, legislatures can accommodate this reemerging practice and avoid future costly litigation.

2. *The United States Needs Water*

In 2015, according to the United States' drought monitor, at least forty-six states had areas experiencing drought with eight experiencing extreme drought conditions and two experiencing exceptional drought conditions (the worst possible condition).[186] Most traditional sources of water have been over allocated, meaning there is not enough water from the source to satisfy everyone's water right.[187] Climate change will likely exacerbate these issues by contributing to drier climates and decreasing water for apportionment.[188] Demands for water are continuing to rise with population and industry growth, despite conservation and recycling efforts.[189] When traditional options for meeting an increasing water demand, like building dams, diverting rivers, or drilling wells, do not work, states can either import water or find a way to augment their supply with technology.[190] States are discouraged from relying on cloud seeding because of the "complicated and nuanced legal and scientific issues" it presents.[191] With demographic changes, development, population growth, and climate change, the United States will need about fifty percent more water, food, and energy in the next twenty-five years; water security is the real issue.[192] Now is the time to explore how cloud seeding can be used to supply water.

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183. Young, *supra* note 15.

184. *Id.*

185. THEODORE STEINBERG, SLIDE MOUNTAIN, OR THE FOLLY OF OWNING NATURE 84 (1995).

186. Steve Brachmann, *Western U.S. Drought Sparks Innovation in Irrigation Management, Desalination*, IPWATCHDOG (Sept. 27, 2015), http://www.ipwatchdog.com/2015/09/27/western-u-s-drought-sparks-innovation-in-irrigation-management-desalination/id=61546/.

187. Kevin Taylor, *Drought Hits Harder in Already Parched Indian Country*, AL JAZEERA AMERICA (Mar. 19 2014, 5:00 AM), http://america.aljazeera.com/articles/2014/3/19/drought-is-nothingnewinindiancountry.html.

188. Majzoub et al., *supra* note 55, at 322; *see* Bruce Kennedy, *Is the U.S. Running Out of Well Water?*, CBS NEWS (Mar. 19, 2014, 8:19 AM), http://www.cbsnews.com/news/is-the-us-running-out-of-well-water/; Cartwright & Shank, *supra* note 156.

189. *See* Cartwright & Shank, *supra* note 156; Kennedy, *supra* note 188.

190. Glennon & Pearce, *supra* note 173, at 255.

191. *See id.*

192. Rhett B. Larson, *Innovation and International Commons: The Case of Desalination Under International Law*, 2012 UTAH L. REV. 759, 760 (2012); Ian Sample, *World Faces "Perfect*

3. *Economic Feasibility and Innovation*

Cloud seeding is already cost-effective and operations are becoming more economically feasible with technological innovation, often a cheaper alternative than building dams or using desalination plants.[193] Other countries seem to have caught on and are spending much more on cloud seeding than the United States.[194] In the United States, utilities are among the most common users of cloud seeding.[195] Utilities use cloud seeding to power hydroelectric dams, which has been said to increase limited water supplies by at least ten percent.[196] Farmers in Texas and the Midwest use cloud seeding to make hail smaller and reduce crop damage.[197]

Cloud seeding operations are increasing as the technology becomes cheaper and more effective. For example, a 1974 U.S. Weather Bureau study described the potential for seeding the Upper Colorado Basin and predicted that the additional water from runoff would cost about two to five dollars per acre-foot.[198] NCAR estimated a cost of $35 to $107 per acre-foot in the North Platte River Basin with a ten percent increase in precipitation in sixty percent of the basin. Even with the increase, these costs were considered cheap where "[a]t the headwaters of the Colorado River . . . water [was] valued at up to $40,000 per acre-foot."[199] In 2014, John C. Ruple and Robert B. Keiter asserted that if preliminary cost estimates for several operations were correct, "the amount of water potentially made available and its relatively low cost make cloud seeding a very attractive technology."[200] As innovation continues to improve the economic feasibility of cloud seeding, it will become a more appealing option for states and private parties combatting dwindling water supplies.[201]

While the idea that law lags behind technological advancement is not new,[202] lawmakers have more than six decades of weather modification research and legal theory at their disposal. As the demand for water continues to increase,

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Storm" of Problems by 2030, Chief Scientist to Warn, GUARDIAN (Mar. 18, 2009 1:19 PM), https://www.theguardian.com/science/2009/mar/18/perfect-storm-john-beddington-energy-food-climate; *see* Patricia Wouters et al., *Water Security, Hydrosolidarity, and International Law: A River Runs Through It* . . ., 19 Y.B. INT'L ENVTL. L. 97, 98 (2008) (discussing the "perfect storm" for a global energy and food crisis as being caused by economic development, climate change, and increasing populations).

193. *See* Young, *supra* note 15.

194. *See id.* ("But spending in the United States is far lower than in many other countries. China spends an estimated $100 million a year on cloud-seeding efforts that include using anti-aircraft guns and rocket launchers to blast the sky with silver iodide").

195. *See* Young, *supra* note 15.

196. *Id.*

197. *Id.*

198. Gelt, *supra* note 20, at 4.

199. Best, *supra* note 61.

200. Ruple & Keiter, *supra* note 60, at 127; *see also* Best, *supra* note 61 (discussing estimated market savings per acre-feet of water for the Colorado River).

201. *See* discussion *supra* Section III.B.

202. *See* Symposium, *Thinking About Biomedical Advances: The Role of Ethics & Law*, 31 CAP. U.L. REV. 1, 6 (2003).

the demand for weather modification will also continue to increase.[203] By focusing research and development to refine the technology, stakeholders can enjoy the benefit of seeding at affordable costs.[204] For these reasons, the U.S. government should use regulation to dispel these clouds of uncertainty and incorporate cloud seeding as a part of its water resource management strategy.[205] With the resurgence in operations, recent drought conditions, and cost-effectiveness of seeding, now is the time to fill in legal and regulatory gaps that burden innovation and jurisprudence.[206]

IV. JUST ADD LAW: PROPOSED REGULATION FOR CLOUD SEEDING

Clear law and policy will impact cloud seeding by providing legal security for cloud seeders and those affected by seeding operations. Under a robust legal framework, seeders and their investors could develop and rely on programs that both further state interests and reliably secure private rights. Likewise, those affected by seeding could rely on the protection afforded by clear law. Whether cloud seeding is a viable part of the solution for the nation's water problems will only be determined once laws are defined. As the technology develops, laws can and should respond by refining policy because governments have traditionally regulated the allocation of water.[207]

If seeding is viable, weather modification benefits (combating climate change, mitigating severe weather, and supplying water) will outweigh the price (transaction costs) of enacting law. If it is not viable, the benefits of settling the issue (alleviating current and future investment costs) will outweigh the price of enacting law. The following are ways in which law can help clarify the uncertainties that have entrapped cloud seeding in a six-decade limbo.

A. Hypothetical: What if Cloud Seeding Is Not Viable?

Opponents may beckon advocates to wake up to the realities of cloud seeding and acknowledge that it does not work.[208] However, even if cloud seeding were not a viable augmentation strategy, resolving legal and regulatory uncertainty for weather modification is still in the public's best interest. Assuming that cloud seeding does not work, it is necessary to resolve related weather modification law for four reasons.

First, cloud seeding efficacy will remain inconclusive until there has been further activity, research, and development implemented through programs and funding mechanisms provided by the government. Second, with quicker efficacy determinations, stakeholders currently investing in weather modification

203. *See* discussion *supra* Section III.B.1.
204. *Id.*
205. *Id.*
206. *Cloud Seeding Frequently Asked Questions*, *supra* note 13.
207. *See* Bomar, *Weather Modification & Law*, *supra* note 68, at 23.
208. *See* discussion *supra* Section II.B.; *see, e.g.,* Zev Levin et al., *Reassessment of Rain Enhancement Experiments and Operations in Israel Including Synoptic Considerations,* 97 ATMOSPHERIC RES. 513, 513 (2010).

can cease ineffective cloud seeding operations and invest in more reliable augmentation or conservation operations. Third, as the science behind why seeding "does not" work is understood and research and development are funded, alternative methods would likely come to light as well as methods for how best to address unintentional pollution-induced cloud seeding. Finally, the question concerning the practicality of weather modification is not so much about *if* as it is about *when*; clouds provide a most precious resource on the planet—water. The water supply will continue to diminish with increased use and a warmer climate.[209] Weather will continue to have catastrophic effects on society as patterns grow more volatile and populations grow. It may be later than sooner, but having laws in place that provide guidance for undeniably foreseeable issues, such as rights and liability allocation for weather modification, will expedite the process of adapting to an already weather modified world. The costs of enacting regulation may be burdensome, but the alternative may be even more so in the long run. For example, if cloud seeding is a dead end, stakeholders will continue to make misguided investments in flawed technology. Or, if cloud seeding holds promise, potential stakeholders will continue to hesitate and underuse the valuable technology. Either way, law can clear the way for greater certainty in the decision-making process.

B. Level of Governance

The existing hierarchy for weather modification governance should remain; states should continue to have authority over substantive weather modification within their jurisdiction while the federal government has the power to make general policy and require reporting. While states would retain their authority, the federal government could integrate additional programs for the public good, such as reapportioning water sources to combat drought where it is severe.

Given the uncertainty surrounding weather modification, some argue that the international community should control and regulate seeding for public, rather than private, interests and be penalized under a tort liability scheme.[210] It is argued that a top-down rather than bottom-up approach would "provide drafters, policymakers and technical experts, as well as state governments, with a 'tool kit' of the issues related to the regulatory framework for cloud safety."[211] However, such an approach introduces fragility to the cloud seeding endeavor. In the laboratory of states, a state may attempt novel laws or experiments where the impact of failure is mostly contained, multiplying opportunities for success and allowing proven ideas to be adopted more widely. Placing the sole discretion and authority for weather modification in a single or few bodies multiplies the impact of failure by affecting the entire weather modification program, limiting perspectives and opportunities for success, and increasing its susceptibility to abuse. For these reasons it may be wiser for the federal government to retain an

209. *See* discussion *supra* Section III.C.2.

210. For arguments supporting international oversight, see Majzoub et al., *supra* note 55, at 335 & 345.

211. *Id.* at 345.

oversight role while leaving primary weather modification governance to the states.

C. Federal Law

The NOAA and Secretary of Commerce should consider exercising their authority to develop a national weather modification policy as directed by the 94th Congress. The 2015 Bill S 517 RS (SB 517), introduced in two versions but never voted on, provides a glimpse of how policy can address uncertainty.

As mentioned, a greater scientific understanding of weather modification is key to eliminating uncertainty and, in turn, reticent seeding practices. SB 517 proposed a weather modification subcommittee for coordinating a national research program.[212] Composed of representatives from the NOAA, National Science Foundation, and National Aeronautics and Space Administration, this committee was to plan and coordinate federal activities meant to establish goals for "effectively advanc[ing] scientific understanding."[213] A policy emphasizing scientific understanding helps to dispel uncertainty as technology and atmospheric processes are better understood.

The committee was directed to achieve its goals by identifying "specific activities . . . [such as] funding competitive research grants . . . training . . . and participation in international research efforts."[214] Funding competitive research grants would incentivize potential operators to innovate the most economically and technologically feasible bids for funding. This would likely lead to the development of more predictable, controllable, and affordable seeding technology, thereby addressing major obstacles to adopting cloud seeding. A better understanding of cloud seeding and more economically and technologically efficient operations mean expedited cloud seeding viability.

SB 517 encouraged the subcommittee to coordinate an interdisciplinary approach and partner with foreign, federal, state, and academic agencies and institutions to fund, research, improve, and predict the effects of weather modification technology.[215] Mandating training and participation in international efforts will afford opportunities to learn from other countries, many of which are more experienced in cloud seeding than the United States. International cooperation progresses the technology and helps to legitimize cloud seeding as a hard science. Such training would address divergent values by promoting social learning. As in most international conventions, countries lacking domestic capacity could receive financial assistance and capacity-building aid from the United States in exchange for seeding studies and research.

SB 517 would have provided for cooperation amongst U.S. public and private agencies by providing funding and collective research efforts.[216] The subcommittee would have submitted regular reports and recommendations to the President and Congress on activities including research, progress, expenditures,

212. S. 517, 109th Congress § 4(d)(1) (2005).
213. *Id.*
214. *Id.*
215. *Id.*
216. *Id.*

recommendations, technology, and potential adverse consequences. Interestingly, the subcommittee would have also been required to contribute its weather modification research toward efforts outlined in the Global Change Research Act of 1990, illuminating once again cloud seeding's potential for combating climate change.[217] A policy requiring the reporting of potential adverse consequences protects the public and the environment from exploitation by stressing precaution in seeding endeavors. Requiring reports that predict the effects of an operation encourages accurate estimations rather than hopeful and potentially harmful guesswork.

The policy should identify societal benefits and the nation's interest in cloud seeding. Societal benefits include cloud seeding's ability to provide clean, safe water for public use in irrigation, hydroelectricity generation, and natural resource revitalization.[218] Additional benefits may include mitigating drought, suppressing hail and storms, and otherwise coping with the effects of climate change.

Absent federal law governing interstate disputes,[219] states should design compacts among themselves depending on their shared interests and concerns.[220] Because of the difficulty in extending prior appropriation and riparian allocation schemes to atmospheric water, the usual water tensions that bring states to blows would not likely be an issue. States could implement de novo agreements on how to best implement weather modification practices tailored to their individual needs rather than use often antiquated water rights schemes.

For example, a prior appropriation state attempting to extend its system of allocating water to the clouds could pass law allocating cloud rights at specific times and places to appropriators whose land is accustomed to receiving precipitation. During the winter, a state could restrict seeding one hundred miles upwind of a watershed unless within ten to thirty minutes of upwind currents. Such a restriction would preserve snow needed to fill rivers that flow to appropriators. Utilities could contract with rights holders to front the cost of seeding operations in exchange for permissions to build hydroelectric powerhouses or dams on the river. A state could also tax a rural area in exchange for seeding, as Illinois has done.[221] A neighboring state might work out a compact committing to refrain from seeding clouds within the "established" one-hundred-mile upwind restriction encroaching on its jurisdiction. A commitment to refrain could be exchanged for shared benefits such as water banking, credits, money, or food in proportion to the estimated ten to fifteen percent increase of precipitation falling from clouds flowing from its restriction zone. Unlike many other natural resources, the unpredictable and mobile nature of clouds means that clouds may cross state boundaries going one direction on a particular day but cross the same border in a different direction on another day. This mobility provides incentive

217. *Id.*

218. *See* Gelt, *supra* note 20, at 3.

219. *See* discussion *supra* Section II.C.1.

220. Interstate compacts may require congressional consent if such a compact tends to increase political power in states "which may encroach upon or interfere with the just supremacy of the United States." Virginia v. Tennessee, 13 S. Ct. 728, 734 (1893).

221. *See* Davis, *supra* note 80, at 397.

for states to be cautious in shorthanding neighbors because a state can sometimes be both upwind and downwind at different times and places over the course of seeding operations. As contracts evolve and the science becomes better understood, this soft law approach would eventually harden into law that could be adopted by federal courts later in resolving weather modification related disputes amongst states.

Where compacts fail or do not exist, equitable apportionment, a federal law doctrine applied in interstate water rights disputes, can be used to govern cloud seeding conflicts between states. The U.S. Supreme Court applies equitable apportionment by looking at relevant factors, such as local state law, in an effort to balance equities and avoid giving either state an unfair advantage.[222] Relevant factors include physical and climatic conditions, consumptive uses, character and rate of return flows, extent of established uses, availability of storage (different geographies such as valleys where it is hard to store a lot of water), practical effect of wasteful uses on downstream users, comparative damage and benefits, and the possibility of conservation (whether a state could do more for conservation purposes).[223] For example, storage conditions have influenced courts in making equitable apportionment determinations.[224] Better conditions for storage may tip the scales in one state's favor by entitling it to greater water allocation. Applied in cloud seeding disputes, similar factors could be considered in determining a state's right to seed clouds that may affect another state. For example, the benefits reaped by a state with favorable conditions for seeding may outweigh the likely damage caused to another state. As an alternative to interstate compacts and in lieu of governing law, equitable apportionment could likely be tailored to govern interstate cloud seeding disputes.

D. State Law

A comprehensive state weather modification statute should provide for all five of the previously discussed categories: (1) public funding, (2) project regulation, (3) notice, (4) reporting, and (5) legal rights and liabilities. Additionally, weather modification statutes should outline public policy and designate a board to oversee the implementation and promotion of weather modification practice and associated law.

First, states like Colorado, North Dakota, and Pennsylvania as well as the federal government's equitable apportionment laws can serve as examples for what comprehensive weather modification laws addressing policy, public funding, and general regulation could look like. Second, the similarities adopted by most states in their weather modification statutes can serve as a model for what

222. *See generally* Arkansas v. Oklahoma, 503 U.S. 91 (1992) (holding that the impacts of use on other states are a consideration for determining equitable apportionment); Colorado v. New Mexico, 467 U.S. 310 (1984) (ruling that rights should be determined based on benefits, harms, and efficiencies of the competing uses).

223. JOSEPH W. DELLAPENNA, 3-49 WATERS AND WATER RIGHTS § 49.05, art. 16(b)(1) (Amy K. Kelley, ed., 3rd ed. LexisNexis/Matthew Bender 2016).

224. Nebraska v. Wyoming, 325 U.S. 589, 618 (1945).

is working in regard to rights allocation. Lastly, a combination of a default liability rule and Utah's weather modification liability provisions can be used to clearly allocate liability in a way that navigates the uncertainty associated with cloud seeding technologies.

1. *Policy Addressing Societal Uncertainty*

Colorado, North Dakota, and Pennsylvania weather modification statutes demonstrate how law can outline societal benefits and promote cloud seeding.[225] A state integrating similar provisions can set a clear foundation for its weather modification program.

Colorado's weather modification policy recognizes that cloud seeding is "properly a commercial activity which the law should encourage to be carried out, whenever practicable, by private enterprise."[226] The potential for misuse is a common concern of allowing private parties to engage in cloud seeding operations.[227] However, a state can act as a gatekeeper by enforcing permitting and licensing regulation and can protect affected parties with clear rights and liability law. A policy allowing private practice encourages competition and innovation.

North Dakota's declaration of policy and purpose for weather modification stresses that, in the public interest, cloud seeding ought to be regulated and controlled in a way that safeguards the public by requiring accurate information accountability.[228] State Legislatures should consider officially recognizing the economic benefits of seeding and affirm, as North Dakota did, that seeding can improve "the public health, safety, and welfare . . . [improve] water quality and quantity, reduce losses from weather hazards, and provide economic benefits for the people of the state."[229] Pennsylvania's statute is similar and adds that encouraging cloud seeding experimentation will "develop, conserve, and protect the natural water resources of the State and to safeguard life and property."[230]

2. *Public Funding: A Tool for Overcoming Scientific Uncertainty*

As was done in North Dakota, a weather modification fund ought to be established to fund boards and programs designed to promote cloud seeding research and activities. Following Texas' model, the board should be allowed to accept and solicit appropriations, gifts, grants, and other donations. States should consider taxing "special service" areas that would benefit from seeding efforts to support local government projects.[231] A public funding mechanism like this one could fund operations at private or public expense.

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225. COLO. REV. STAT. ANN. § 36-20-102 (West 2015).

226. *Id.*

227. *See* Andrew Jackson Heimert, Book Note, *Uncommon Property*, 105 YALE L.J. 2297, 2301 (1996).

228. N.D. CENT. CODE ANN. § 61-04.1-02 (West 2015).

229. *Id.*

230. 3 PA. STAT. AND CONS. STAT. ANN. § 1101 (West 2015).

231. *See* Davis, *supra* note 80, at 397.

3. *Regulating Projects: A Tool for Overcoming Societal and Technological Uncertainty*

A permitting and licensing scheme that (1) requires proof of financial responsibility for damages and an operational plan, (2) outlines benefits and goals, and (3) projects risk and effects of operations can protect society from exploitation and encourage more predictable and controllable operations. Like Colorado and Pennsylvania's statutes, states should consider adopting laws that address environmental concerns by establishing and prohibiting dangerous concentrations of substances used during seeding and requiring a report of expected environmental impacts.

Rather than prohibit operations altogether or restrict them based on estimated interstate effects, states should require compacts for seeding activities that may affect other states. By providing clear guidance, states can take advantage of the many water bodies that commonly intercept state lines and work out agreements that are mutually beneficial for both parties. Texas, for example, provides that a designee may "represent the state in matters pertaining to plans, procedures, or negotiations for interstate compacts relating to weather modification control."[232]

Depending on state characteristics, like geography and seasonal weather patterns, the legislature ought to consider providing exemptions to the regular permitting and licensing requirements. Texas, for example, exempts, among other things, operations for emergencies "against fire, frost, sleet, or fog."[233] Emergencies like this, in the public's interest, may weigh heavier when balanced against the individual water right of affected parties.

Notice and reporting requirements address community concerns by providing estimated precipitation and requiring accountability for seeding activity. A common notice requirement requires publication every week for three weeks prior to operations and allows for a public hearing. A requirement like this would provide communities with opportunities to voice concerns associated with societal uncertainty: exploitation, overestimation, and viability. Regular reporting compiled in biennial reports assure accountability for operations while simultaneously providing ground for further development.

4. *Legal Rights and Liability Allocation: A Tool for Overcoming Societal, Scientific, and Legal Uncertainty*

Robust law that clearly allocates rights and liabilities to atmospheric moisture is crucial to sovereign water security. Atmospheric water that falls to the earth as precipitation plays an indispensable role in the water cycle as the primary source of freshwater on the planet.[234] Law, therefore, should recognize that

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232. TEX. AGRIC. CODE ANN. § 301.056 (West 2015).

233. *Id.* § 301.102(a)(3).

234. U.S. Geological Survey, *The Water Cycle: Freshwater Storage*, USGS, http://water.usgs.gov/edu/watercyclefreshstorage.html (last modified Sept. 23, 2015, 7:43 AM).

this connection, and its emerging use and sale by weather modification techniques like cloud seeding, has implications for affected parties and communities.[235]

a. Rights Proposal: State Owns Atmospheric Waters and Precipitation

Because of the difficulties involved in extending riparian and prior appropriation regimes to include atmospheric waters, states ought to treat all precipitation as a "natural resource" and retain ownership of atmospheric waters until precipitation becomes a part of the state's land-water system (where water can be allocated under the already existing regime). Most states with weather modification statutes allocating rights to atmospheric precipitation do so in this way.[236] A right to water induced from cloud seeding could only be captured after becoming a part of the land-water system and occupied by private parties under the applicable regime of the state. States can thus focus on the real issue of rights allocation as it relates to cloud seeding liability: the concerns of affected parties that may be deprived of or damaged by water from cloud seeding. These concerns can be addressed once rights to atmospheric water are clearly assigned.

If adopted, a rule like this, which treats all precipitation as natural until it hits the ground, absconds precipitation as a potentially owned right that can be deprived. Any claim to precipitation, therefore, would be defeated by the state's existing ownership. This rule is better suited for rights allocation than a natural rights, or pre-possessory, rule for three reasons.

First, the proposed rule accounts for scientific uncertainty and caters to common property law by requiring a measure of occupancy before rights can be definitively assigned. While the *ad coelum* doctrine, as explained earlier, cannot extend to the realities of atmospheric waters, such an inability does not imply a now existing pre-possessory interest granting all downwind landowners the right to rainfall from inbound clouds. To grant a pre-possessory, or natural, right in clouds is to grant none given the current lack of understanding in atmospheric processes. There is almost always another downwind landowner expecting rain from a cloud, and the complexity of predicting when, where, and why it will rain makes pre-possession an impractical solution to allocating rights. In lieu of an alternative, such an ex ante law allocating atmospheric water rights to the state ought to be implemented to provide some operational and jurisprudent guidance and assurance.

This is not to say that such a law could not later evolve. Adopting this law and giving states, not landowners, ownership of atmospheric water can pave the way for innovation and the emergence of more predictable and effective technologies. As these technologies emerge, the law can adapt, for example, by placing ceilings on targeted yields as more efficient and controllable technologies emerge, or boundaries protecting pre-possessory rights as better predicting technologies emerge. In the meantime, however, landowners should not have a pre-possessory natural right to rain interfered with by cloud seeding. In this way the

235. Zellmer, *The Anti-Speculation Doctrine*, *supra* note 43, at 1029.
236. *See infra* Appendix.

cycle of law, practice, and innovation can resume its natural course rather than waiting on innovation hindered by uncertainty.

The second reason that this rule is better suited for allocation than a natural rights rule is that the ecological justifications for allowing the "natural" bestowal of rain is less applicable to the modern world than it was when argued in the 1950s. The anthropomorphic impact on the planet has made it more likely that human interference, not "nature," has deemed to bestow precipitation on one's land.[237] Like proximate cause, there does not currently exist a clear line where, once crossed, a party becomes responsible for their effects on the atmosphere, intentional or unintentional. Air pollution from New York overseeding clouds and thereby contributing to a lack of precipitation downwind in New Jersey is not likely to be actionable or proven, but it happens.[238] Conversely, if there were actionable pre-possessory rights to natural rainfall, the floodgates would unduly burden courts because, arguably, everyone is in some way impacted by unintentional weather modification and could sue for deprivation. For these reasons, given current scientific understanding, landowners should not have a pre-possessory exclusive right to natural rain that may have fallen on their property and may have been deprived by cloud seeding.

Lastly, the proposed rule is more practical than a natural rights rule. If landowners had natural rights to precipitation, under the applicable property rule approach, entitlements would likely be protected. For cloud seeders to interfere with pre-possessed rain, therefore, the cloud seeder would have to determine where the rain will fall and then enter into voluntary transactions to purchase rights from deprived landowners.[239] This approach would be most harmful to cloud operators who would have to rely on voluntary bargaining and be burdened by high transaction costs and holdout problems.[240] However, whether such harm is acceptable is beyond the scope of this argument because cloud seeders cannot yet determine where rain will fall. Alternatively, if states own atmospheric water up until it hits the ground, operators may lose out on precipitation that literally windfalls to other properties. Such a rights allocation, however, incentivizes operators to invest in research and development programs that can increase the accuracy and predictability of cloud seeding technology. State ownership of atmospheric water until it hits the ground should not mean that private parties cannot attempt to seed clouds for the benefit of private parties because such endeavors would likely be regulated in the states' interest for promoting related polices.

Allocating rights this way solves issues with claims for precipitation deprivation, however this is only half of the answer. To address claims for damage

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237. *See* discussion *supra* Section III.A.3.

238. *See* discussion *supra* Section III.A.3.

239. *See generally* Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089 (1972) (describing the property rule and associated transactional costs).

240. *Id.* at 1095.

caused by cloud seeding, like flooding or hail, laws addressing liability must be implemented.

b. Liability Proposal: A Default Liability Rule with a Rebuttable Presumption

Integrating a default liability provision with a rebuttable presumption into weather modification statutes will help dispel societal and technological uncertainties. This would complement an already existing permitting scheme.[241] In determining the standards for default liability, governments would have autonomy to determine the acceptable level of risk. Once set, such a provision would both protect stakeholders and further cloud seeding efforts in the public's interest.

Providing this guidance will encourage cloud seeding efforts and dispel uncertainty by breaking down information barriers and protecting parties. Clear liability allocation enables operators to accurately assess liability risks and more confidently conduct operations. Also, the uncertainty regarding predictability and control makes it difficult for plaintiffs to show causation. With default standards, this uncertainty is replaced with the certainty that statutorily qualified parties will often have a reliable remedy at law. Additionally, a rebuttable presumption incentivizes operators to sooner understand technological and scientific weather modification practices to avoid or counter claims for damage.

An adequate liability law for cloud seeding should (1) clearly set the legal obligations and responsibilities of operators and (2) provide enforceable civil safeguards by ensuring that any financial or pecuniary obligations for damage can be met. The standard for responsibility should be set up in a way that reduces potential damages appropriately by protecting private property and landowner, public water, and operator interests.

Once legal obligations and responsibilities for operators are set, there are several ways that states can ensure that any financial or pecuniary obligations for damage can be met. States can require proof of financial responsibility, such as a bond, corporate guarantee, or financial insurance certificate, be submitted as part of a cloud seeders application.[242] This can provide public assurances for protection against potentially dangerous operations.[243]

Operator obligations and responsibilities are best defined under a liability, rather than property, rule and ought to be restricted to damages.[244] A liability rule would further a public policy goal to promote cloud seeding operations while recognizing existing landowner rights.[245] Operators ought to be held liable

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241. *See* discussion *supra* Section IV.D.3.

242. See UTAH CODE ANN. § 73-15-6 (West 2012) for an example of a state statute requiring proof of financial responsibility.

243. *Id.*

244. Additionally, while an equitable apportionment doctrine may be expanded to help resolve interstate disputes dealing with atmospheric water entitlements where deprivation is concerned, it does not help courts in addressing potential damages. *See* discussion *supra* Section IV.D.3.

245. For an example of how liability rules have been used in the past to further public policy, see Fiske v. Framingham, 29. Mass. 68, 71 (1831) (discussing the purpose of mill statutes, which

for damage rather than deprivation of precipitation given the high cost of litigation, complexity of proving deprivation, and the rights related justifications discussed earlier.[246]

Allocating liability for cloud seeding is difficult because of the uncertainties involved in proving cause ex post. Two obstacles arise when deciding how best to allocate liability for damages allegedly caused by cloud seeding.[247] First is proving that cloud seeding caused the rain.[248] Second is proving that the *induced* rain caused specific injury.[249] If the rights allocation law proposed in the previous section applies, and no one is entitled to "natural" rainfall until it hits the ground, then liability is limited to damages. Even though damages are easier to assess than deprivation, there are still issues in overcoming these two liability obstacles. Obstacles made grimmer by the likelihood that potential plaintiffs do not have access to the same expertise, technologies, or funds as cloud seeders. While the uncertainties surrounding cloud seeding may make proving cause and allocating liability difficult, it can be done.

Until cloud seeding technology develops in such a way that proving causation is feasible and affordable, a default liability approach is the best option for assigning responsibility to cloud seeders for damage caused by precipitation, like flooding or hail. This is the best option because default liability can mollify the two causation obstacles, lower transaction costs, and place the burden of proof on cloud seeders who are the least cost avoider and the party with the greatest relative institutional competence.

A default liability rule would create a rebuttable presumption that holds a defendant cloud seeder liable for damage caused when the defendant has breached a provision establishing prima facie general causation. General causation would exist if a specific cloud seeding operation was capable of producing the damage caused, as determined by special committees set up by the state's weather modification statutes.[250] This provision would prescribe under what circumstances cloud seeders would be presumed liable for damage. The presumption could be rebutted by operators who could show they did not specifically cause the damage.

Decision makers should also consider implementing into their permitting scheme, laws allowing operators to contract out of the default rule and into an alternative contract liability allocation regime. This would incentivize operators to develop a better understanding of cloud seeding so that they could limit their liability by convincing the permitting agency that their methods are safer than the default provision. As cloud seeding becomes better understood, the default liability rule would need to be updated. An option to contract out would provide

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protected owners from being enjoined from flooding neighbors land, but may nonetheless have to pay damages).

246. For additional reasoning why cloud seeders should not be currently liable for deprivation, see discussion *supra* Section IV.D.4.a.

247. Note, *supra* note 150, at 60.

248. *See* discussion *supra* Section II.B.2.

249. *See* discussion *supra* Section II.B.2.

250. Pennsylvania's weather modification board fulfills similar responsibilities. *See infra* Appendix.

a way for the law to more flexibly accommodate technological development as operators temporarily opt out pending updates. This allocation would complement existing permitting schemes which ought to require and adapt to the submitted operational plan, public hearings, scientifically and technically feasible risk assessments, and potential interstate impacts.

The specialized committee set up by the statute can help in assessing and developing the general causation provision assigning default liability. The committee ought to be composed of experts familiar with the science of cloud seeding and can stand alone or have its responsibilities absorbed by an already existing agency, like a Division of Water Resources.[251] This way, states can rely on experts in assessing the risks of harm based on up-to-date information maintained by the committee and establish their own universal standard where the risk of damage outweighs the potential benefits of seeding activities, a balancing act otherwise left largely to operators.[252]

The general causation provision set up by the committee would hold operators liable for conducting seeding operations capable of producing the damage. For example, operations conducted within fifteen to thirty minutes or one hundred miles upwind of damage caused by precipitation if accomplished within a certain time period would be, by default, liable unless defendants could show that they did not specifically cause the damage.[253] Decision makers could look to the analytical strategies used by others for determining general causation. The International Center for Toxicology and Medicine has a five-step approach for analyzing general causation. The approach (1) reviews available relevant literature, (2) actively seeks new developments in the field, (3) analyzes the strengths and weaknesses of research, (4) assesses opposing literature, and (5) summarizes the information.[254] General causation can also be approached more like proximate cause which looks to the foreseeability and risk associated with a harm.[255]

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251. *See* UTAH CODE ANN. § 73-15-6 (West 2012).

252. In some ways, liability uncertainty shields operators who know that plaintiffs are unlikely to bring or prevail in a cause of action. This likely makes the public feel vulnerable and uncertain about cloud seeding. Without clear law, operators are often forced to act based on their own risk-benefit analysis, a determination arguably more suited for governments who are responsible for considering when operations are publicly, not just capitally "worth" it. *See* DeSiree Fawn, *Man vs Nature: Cloud Seeding in Idaho*, 11KMVT.COM (Feb. 11, 2016), http://www.kmvt.com/content/news/Man-vs-Nature-Cloud-seeding-in-Idaho-368553431.html.

253. *See* Young, *supra* note 15 ("The invisible silver iodide vapor is carried by the wind into the clouds, and it can begin to snow within 15 to 30 minutes."); *Cloud Seeding Frequently Asked Questions*, *supra* note 13 ("Analyses of precipitation data from areas downwind of several cloud seeding projects have indicated small percentage precipitation increases extending as far as 100 miles downwind of the intended areas of effect on projects that had indications of increases in the intended target area.").

254. *See General and Specific Causation Analyses*, INT'L CTR. FOR TOXICOLOGY & MED., http://ictm.com/Litigation-Support/Causation-Analyses.aspx (last visited Mar. 9, 2016) (summarizing general and specific causation in the context of the medical field).

255. *See* W. PAGE KEETON ET AL., PROSSER AND KEETON ON THE LAW OF TORTS § 41, at 264 (5th ed. 1984) (discussing the limits of proximate cause, "[a]s a practical matter, legal responsibility

Although default liability means that in some instances operators may be held initially liable for damages they did not cause in fact, operators can still rebut the presumption by showing that they did not specifically cause the damage. Specific causation is a more fact-specific determination.[256] The general causation presumption makes litigation more available to plaintiffs who can rely on a default liability provision rather than their financial ability to fund expensive litigation and expert witnesses in an attempt to prove specific causation in an uncertain scientific field. By placing the burden on cloud seeders to rebut the presumption, that operations meeting the general causation provision did not specifically cause the damage, those best suited for developing related technologies and understanding are incentivized to do so to avoid and defend against claims for damage.

Despite absconding themselves from default liability, cloud seeders should not be immune from suit where plaintiffs still allege harm. In such cases, an appropriate jury instruction may look similar to the instruction described by the second edition of American Jurisprudence for cloud seeding.[257] This instruction establishes a negligence standard based on whether others, "skilled in the science of cloud seeding, [who] either would have known or should have known" could have anticipated that the operation was dangerous and could proximately cause the alleged damages.[258] Plaintiffs with the means could also attempt to prove specific causation. Precedent from these cases would inform future statutory revisions outlining default liability criteria. By enacting liability laws like these, states can set clear standards assigning responsibilities for damages caused by cloud seeding.

Weather modification laws and regulations allocating rights and liabilities help to resolve societal, technological, and legal uncertainty. Uncertainty hinders cloud seeding development when governments fail to establish laws to guide and protect stakeholders. For reticent governments, there is good reason to consider constructing an experimental or sun-setting legal regime that could be modified in response to developments for several years until settling on permanent rules based on data gathered during the experimental period. If state governments exercise their police powers to regulate weather modification in these ways, the public interest can be both protected from and benefited by cloud seeding.

Cloud seeding has the potential to mitigate the harms, like drought or flood, caused by increasingly volatile weather patterns. Societal, technological, and legal uncertainty, however, hinder this reemerging practice in many states. By

must be limited to those causes which are so closely connected with the result and of such significance that the law is justified in imposing liability. Some boundary must be set to liability for the consequences of any act, upon the basis of some social idea of justice or policy").

256. *Id.*

257. 7D AM. JUR. PL. & PR. FORMS *Crops* § 79 (2013).

258. *Id.*

failing to establish a robust legal and regulatory framework in its weather modification laws, federal and state governments discourage responsible cloud seeding operations and inadequately address stakeholder concerns. Without the stability afforded by law, many potential seeders are deterred from entering a market where the risks of liability are too great. When cloud seeders operate despite uncertain laws, affected parties are often left inadequately protected. Without changes in how governments regulate cloud seeding, therefore, many geographical areas will likely continue to forgo valuable cloud seeding benefits.

Law and regulation tailored to address cloud seeding uncertainties can promote effective seeding practices that both benefit and protect the public. As the laboratory of states takes advantage of cloud seeding, more competent laws and technology can evolve to help supply water and mitigate damage. When interests conflict or damage occurs as a result, parties can more readily rely on law to provide guidance and remedies for harm. By dispelling uncertainty, the United States can accommodate developing cloud seeding practices and take advantage of its many potential uses.

APPENDIX. PROMINENT STATE WEATHER MODIFICATION LAWS[259]

State	Public Funding	Regulation	Notice	Reporting	Rights (R) & Liability (L)	Miscellaneos Additions
CO	N/A	- Permitting scheme - Proof of financial responsibility - Operational plan - Public hearing - Project must benefit - Scientifically and technically feasible - Risk assessment	Published within one week	Director discretion	**R:** CO property with prior right to permit and seed; water can be appropriated. **L:** Failure to obtain or violate permit is negligence per se.	N/A
	Colo. Rev. Stat. Ann. § 36-20 (West 2015)					
ND	Yes	- License and permit - Operational plan - Proof of financial responsibility - Risk assessment - Public hearing if objections	Published notice in newspaper	Biennial report	**R**: Treated as natural precipitation. **L**: Failure to obtain license guilty of class B misdemeanor.	- State Atmospheric Resource Board - Encourages R&D program - Creates operating districts - Bids
	N.D. Cent. Code Ann. § 61-04 (West 2015)					
PA	N/A	- License - General operational plan - $50,000 minimum insurance for potential damage - Prohibits dangerous concentrations of seeding agent	Published every week for 3 weeks prior to operation	Report for every operation	**R:** Water treated as natural resource. **L:** Operators liable for damage as determined by board.	- Establishes Weather Modification Board
	3 Pa. Stat. Ann. § 1101 to 1114 (West 2015)					

259. *See* Bomar, *Legal Aspects*, *supra* note 85, at 47 tbl.3-1. Bomar's table contains less information but lists more states; however, it was useful as a basis when designing this appendix.

State	Public Funding	Regulation	Notice	Reporting	Rights (R) & Liability (L)	Miscellaneous Additions
TX	Yes	- License and permits - Exempted operations - Interstate compacts - Risk assessment - Public hearing if requested by 25 persons - Proof of financial responsibility	Published every week for 3 weeks prior to operation	Report for every operation	**L:** State immune from liability; Not an ultra-hazardous activating that makes operators subject to liability without fault.	- Establishes weather modification and control program - Encourages research and development
	Tex. Agric. Code Ann. § 301 to 302 (West 2015)					
UT	N/A	- Registration - Proof of financial responsibility - Allows interstate impacts in adjoining states if in compliance with target area state.	Notice of intent prior to operation	As established by Division of Water Resources	**R:** Water treated as natural water supply as if no cloud seeding. **L:** Operators liable for damages and must prove financial responsibility. Not liable for trespass or nuisance.	- Research and development - Permanent record of all projects, research, etc.
		Utah Code Ann. § 73-15-3 to -8 (West 2015)				