I. Introduction

"I'm going in a plane; any cloud that crosses me, I'll zap it so that it rains."¹ Venezuelan President Hugo Chavez made this statement in a ceremony announcing plans to cloud seed to generate rain and stave off El Niño-caused drought in November 2009.² Chavez enlisted the help of ally Cuba, through both scientists and specialized equipment, in the effort to compensate for depleted reservoirs that have caused water shortages and power blackouts (most of the country's electricity comes from hydroelectric dams).³ The Guri Dam "supplies 73 percent of the country’s electricity by feeding the massive Guri hydroelectric plant . . . along with two other smaller plants."⁴ With twenty-eight million Venezuelans suffering the risk of losing water and power, Chavez has "imposed rationing that include[s] penalty fees for energy overuse, shorter workdays for many public employees and reduced hours for shopping malls."⁵ Desperate to conserve the depleted water supply, Chavez even asked citizens to take three-minute showers and banned watering lawns, flowerbeds, and filling pools.⁶

Chavez's recent request that Cuba aid Venezuela in his effort to cloud seed represents more than an effort to respond to drought—it signals the increasingly political nature of weather modification. Venezuela and Cuba extended their friendship through this part-

² Id.; Ian James, Tying to Make Rain, Hugo Chavez 'Bombarding' Clouds in Venezuela with Cuba's Help, ASSOCIATED PRESS, Nov. 28, 2009, http://www.startribune.com/templates/Print_This_Story?sid=77995887.
³ James, supra note 2.
⁴ Fabiola Sanchez, Drought Could Drain Venezuela’s Electricity, STAR-LEDGER, Jan. 10, 2010.
⁵ Id.
nership (Chavez already offers subsidized oil to the island nation). He says that Cuba has provided equipment for the new endeavor. In his ceremony announcing the project alliance, Chavez spoke with “family members of five Cubans convicted of spying in the United States.” Therein Chavez also seized an opportunity to take a jab at the United States. Furthermore, his efforts to cloud seed were not purely a move toward helping his citizens, but also have been viewed as a response to his own failures to prevent or ameliorate the drought. The government has been criticized for poor planning after it was forced to impose strict water rationing in the capital Caracas and power rationing in other parts of the country. Indeed the country’s water and power shortages have brought blame on the leadership, and Chavez’s turn to weather modification may be viewed as an attempt to cover up mistakes rather than solely a response to a weather crisis. Chavez has even removed his electricity minister in a move to respond to, and perhaps shift blame surrounding, the current crisis.

Cloud seeding and weather modification are not new. Presently at least twenty-seven countries cloud seed. What has changed is freshwater’s global availability. The world is on the cusp of a water crisis. With an emerging global shortage, there is extreme pressure on our freshwater resources. Due to exploding populations, undeniable climate change, and pollution rendering much existing freshwater unusable, the demand for freshwater has never been greater, and where there is scarcity, there is competition and the potential for conflict. In the past, these conflicts over water have been resolved primarily through treaties and settlements between neighboring states or communities. But as the situation grows direr, negotiations may turn hostile and efforts to distribute water will cry to be managed on a larger scale than between a limited number of parties. The potential for using a scarce resource as a political tool grows as well.

Water is a transient, shared resource. Clouds do not know jurisdictional boundaries. “[W]ater not only ignores political boundaries; it evades institutional classification and eludes legal generalizations.” Cloud seeding may be the means by which one country can capture water resources that another cross-boarder neighbor has a reasonable expectation of having available via rainfall. Does a country own the clouds above it as they pass? And if so, does that ownership create a right to affect those clouds so that a neighboring country will receive changed weather from those efforts? Who owns water vapor? Do old rules of owning the air above/within territorial boarders endure, even if it means the environmental collapse of a neighbor? What duties are owed to neighbors, to fragile ecosystems? These are questions that beg for answers as the world creeps closer to a global water crisis.

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10. See id.
11. Id.
This article will first examine the world freshwater shortage and how weather modification may help remedy the crisis. Then it will turn to how nations and the law have addressed conflicts over water. This examination will also delve into a brief explanation of the science and history of cloud seeding, as well as examples of its uses and results. Then this article will examine the sources of law regarding ownership of clouds and water vapor, as well as the limitations on that ownership. And finally, this article will propose that the impending water crisis calls for development and international coordination regarding cloud seeding efforts and research.

II. The Freshwater Shortage

Water is not leaving Earth—so how can there be a shortage? Firstly, a very small amount of the earth’s water is accessible freshwater. “[N]inety-seven percent of all water is salt water.”15 And most of the remaining three percent is “locked in polar ice caps, glaciers, and deep underground aquifers.”16 Freshwater isn’t distributed evenly across the planet. “[E]ven small increases can be important for sub-tropical regions in which rain is scarce.”17 And as populations grow and move, individuals settle in arid lands with already strained water resources—as is the case in the United States where “[s]even of the ten fastest-growing states in the country between 2000 and 2003 are in the [more dry and arid] West.”18 In addition to the uneven distribution of freshwater putting certain areas at greater risk, “[r]obust climate modeling indicates that subsidence and dryness over the eastern Mediterranean will increase.”19 Estimates are that river flow in the Catalonia region of Spain “will decline thirty percent by 2050.”20 Climate change is believed to intensify an already worsening situation as “[t]here is considerable consensus that global climate change’s adverse impacts are likely to be most severe in arid and semi-arid areas because historically variable rainfall patterns may be altered; increased precipitation during the wrong time of year may actually exacerbate efforts to provide reliable water supplies.”21

Measures, sometimes desperate, to conserve water or save it for future use carry consequences as well—in India “38 million people have been displaced due to the construction of large dams.”22 The status of the world’s water supply is getting worse.

The implications of a shortage of freshwater stretch beyond human and crop thirst. Hydroelectric turbines provide significant percentages of power in many countries, in-

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16. Id.

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cluding Venezuela and the United States. Without flowing freshwater to power those plants, nations risk losing electricity as well. Furthermore, a lack of freshwater also risks a sanitation crisis, which could lead to the spread of disease and death. Drought conditions also cause political stress on previously settled agreements over joint use of water, as has been the case between the United States and Mexico. The U.S. Central Intelligence Agency noted in 2005 that “prolonged drought, population growth, and outmoded practices and infrastructure in the [U.S.-Mexico] border region have strained water-sharing arrangements with the U.S.”

III. Weather Modification: The Science and History of Cloud Seeding

A. The Science of Cloud Seeding

In a response to the increasingly strained global water supply, technical solutions such as cloud seeding “continue to dominate discussions about drought response.” Cloud seeding is a technique used to increase or release the rain in clouds before it would naturally fall on its own. “Rain starts as tiny droplets of water suspended in clouds. Then the droplets clump together into bigger drops (or freeze together into bigger crystals). Once the drops or crystals are big and heavy enough, they fall out of the sky. Cloud seeding aims to jump-start this process.” But keep in mind that “[n]ot all clouds produce rainfall or are nascent rain clouds or rain-laden clouds. Therefore the growth mechanism of raindrops is important in determining how much rainfall reaches the Earth’s surface.” Indeed, a range of droplet sizes within the cloud is necessary to generate rain, and the aim of cloud seeding is to control both the type and quantity of these droplets in existing clouds to release, or in some cases stop, the rain.

In one of the earliest, if not the first, attempt at manipulating the clouds, General Electric in the 1940s had scientists inject dry ice into a cloud. They found that “[they] could freeze tiny droplets of water, which would in turn make it easier for other droplets to glom on and freeze as well. Later experiments showed that silver iodide—

25. Tarlock & Van de Wetering, supra note 18, at 47.
26. Id.
30. Engber, supra note 27.

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which has a crystal structure similar to that of ice—could also help.”

Currently, there are two primary methods of cloud seeding: glaciogenic seeding and hygroscopic seeding. “Glaciogenic seeding disperses ice producing materials into a cloud containing water drops at a temperature below 0°C, stimulating precipitation. Hygroscopic seeding disperses large or 'giant' hygroscopic particles (e.g. salt powders) into a cloud.” The most common chemical used to cloud seed is silver iodide, which is injected into clouds, either by dropping it from planes or launching it from the ground. Silver iodide has a “lattice structure at the molecular level [that] is very, very close [to that of ice],” and scientists “think that's why ice wants to bond to it.” Once silver iodide is launched into clouds, snow can begin within fifteen to thirty minutes. Liquid nitrogen and dry ice may also be used as catalysts to bring the rain. In the winter, precipitation needs an extra boost because there are fewer ice crystals, and “[i]f droplets fall in liquid form they generally evaporate.” The winter orographic clouds may in fact be more amenable to cloud seeding though because they can “produce precipitation even in the absence of large-scale meteorological disturbances.”

But cloud seeding operates only within existing clouds, so some scientists question the effectiveness of cloud seeding during drought because there aren’t clouds to seed. This has been one obstacle to current cloud seeding operations in the Philippines, where officials report that struggling to find clouds to seed has been a major hurdle. “The best time to do cloud seeding is when you have normal levels, or higher-than-normal levels, of precipitation. Then you could save the extra water in a reservoir for when you are in a drought. It certainly won’t bring you out of one.” Executive Director of the American Meteorological Society Keith Seitter has noted that “[t]here is no technology that can create rain when there was no potential for it to begin with. Cloud seeding appears to be able to get a little bit more than you would have got otherwise.” Therefore, planning ahead of time is key to any potentially successful cloud seeding operation, although the

effectiveness of a cloud seeding operation will continue to be negligible because scientists
cannot know exactly what rainfall would or would not have occurred but for their
efforts.46

Even though cloud seeding is an expensive operation, "proponents say [it] is far cheaper
than building a new dam or running ocean water through a desalination plant."47 This
argument holds less weight though, considering the lack of hard data showing that cloud
seeding does effectively increase rainfall.48 In fact, a study conducted in Valladolid, Spain
from 1979-1981 by the World Meteorological Organization ended in a determination that
"the potential for significant rain enhancement in the region during the winter months
was insufficient to warrant a full-scale seeding operation."49

B. THE CONTROVERSIAL EFFICACY OF CLOUD SEEDING

Despite having been used for over sixty years, cloud seeding’s effectiveness is ques-
tioned.50 The primary complaint is simply the lack of substantive evidence of the true
ability of cloud seeding to increase rainfall.51 "Reports by the National Research Coun-
cil . . . and the World Meteorological Organization . . . stress that for cloud seeding to be
accepted as a viable procedure for enhancing rainfall strong physical and statistical evi-
dence of its effectiveness are required."52 Hu Zhijin, an expert from the Institute of Artifi-
cial Rain under the China Meteorological Administration, stated that "the main problem
is that because rainfall is so variable from day to day and from place to place, it’s incredibly
difficult to tell if you’ve achieved anything or not."53 This challenge caused confusion
with a study surrounding a cloud seeding effort in Israel that initially was hailed as suc-
cessful but under reexamination years later was questioned and, as it turned out, may have
even decreased rainfall in larger storms.54

The Cyprus Institute, a non-profit science and technology research and educational
institution that has partnerships with various groups including the Massachusetts Institute
of Technology in the United States, examined the state of rain enhancement in a 2009
report.55 "While cloud seeding affects microphysical processes in clouds, there is little evidence that it affects rain on the ground."56 Cyprus also re-ex-
amined data from formerly considered "successful attempts" and said those reports "fail[ ]
to confirm that rainfall has increased."57

46. See id.
47. Young, supra note 37.
48. See generally Levin, supra note 17.
49. Id.
50. Chavez Plans Cloud Seeding With Cuban Help to Ease Drought, supra note 6.
51. Levin, supra note 17.
52. See id.
102176.htm.
54. Levin, supra note 17, at 5.
56. Levin, supra note 17, at 2.
57. Id.
Successful cloud seeding is not merely a claim of governments, as a recent independent study showed statistically significant results in Tasmania. Researchers from Monash University examined cloud seeding programs and rainfall from 1960-2005 in Tasmania and found a "consistent increase of at least 5% in monthly rainfall over the catchment area," according to Associate Professor Steven Siems. This positive news came with a caution that the unique conditions of Tasmania's clouds, namely that the clouds are cleaner and contain higher amounts of supercooled liquid, may indicate that such success is limited to that climate and does not extend to other cloud seeding operations around the world. Some in the field still find the effectiveness of cloud seeding not only unproven but even "absurd" as a response to drought, including Charles Doswell III of the Cooperative Institute for Mesoscale Meteorological Studies and formerly a meteorologist for the National Severe Storm Labs in Norman, Oklahoma, United States.

Beyond its debatable success, cloud seeding has also taken criticism as being dangerous. "In China weather altering was blamed for a snow blizzard that killed at least 40 people and caused more than $500 million in damages." Environmentalists are also concerned about the possible consequences of injecting sodium iodide into clouds and manipulating the weather. These concerns are further stirred by the fact that "silver iodide is a salt that does not dissolve in water." But potentially harmful environmental effects have not been confirmed, and a study published, following years of research by the Weather Modification Association in the United States, states that no "environmentally harmful effects" from silver iodide were shown.

More bizarre consequences and risks have also occurred as a result of cloud seeding. Wang Diange, a Chinese resident of Inner Mongolia, was killed in a loud explosion in his home. Days later as his body was being cremated, a silver-iodide-filled shell exploded in the cremation chamber. Officials determined that the shell was launched by the government to "break up hail in order to protect the local tobacco crop," and had struck his home and lodged into his body. The severity of the man's injuries from the original explosion likely allowed for the shell to remain in his body unnoticed. In 2008, the family of Diange received 80,000 yuan from the weather bureau in response to the deadly accident.
Possible risks to health posed by cloud seeding have not been confirmed by studies.\textsuperscript{72} While "silver iodide can cause temporary incapacitation or possible residual injury (e.g., chloroform) to humans and mammals with intense or continued but not chronic exposure . . . there have been several detailed ecological studies that showed negligible environmental and health impacts."\textsuperscript{73} Basically, the amount of the chemical inserted into the clouds is relatively small—particularly compared to other forms of increased exposure such as through emissions or silver tooth fillings.\textsuperscript{74}

IV. Countries That Cloud Seed: Case Studies

Since the mid-1940s, countries have used cloud seeding to attempt to control the rain.\textsuperscript{75} As would be expected, these programs have met with varying success and mixed responses. Nonetheless, currently countries around the world, including Australia, China, France, Greece, India, Russia, Saudi Arabia, and Turkey, are conducting cloud seeding research or operations.\textsuperscript{76}

A. Australia

Australia was one of the first countries to cloud seed, beginning in the 1940s, and still explores the practice today.\textsuperscript{77} And like other nations, the effectiveness has been contentious.\textsuperscript{78} As an example, journals report that the Hydro-Electricity Commission of Tasmania "has run very successful cloud seeding projects in mountainous parts of the state" since the 1980s, whereas the Melbourne Water experiment "generated no statistical increase in rainfall over catchments."\textsuperscript{79} These cloud seeding operations have caused community scuffle and disagreement though, with some citizens lobbying politicians to get involved and control who is permitted to cloud seed, where, and when.\textsuperscript{80} In 2007, the Tasmanian Greens, an Australian political party, urged Hydro Tasmania, the group running cloud seeding operations, to wait for completed studies into cloud seeding before adjusting the operations schedules.\textsuperscript{81} The Greens party was concerned about the possible environmental impact of cloud seeding and also stated that any such projects should be done per community agreement.\textsuperscript{82}

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\textsuperscript{72} Cloud Seeding, \textsc{Absolute Astronomy}, http://www.absoluteastronomy.com/topics/Cloud_seeding (last visited Feb. 27, 2010).
\textsuperscript{73} Id.
\textsuperscript{74} Id.
\textsuperscript{75} Engber, \textit{supra} note 27.
\textsuperscript{76} Young, \textit{supra} note 37; \textit{see also} Press Release, Australia Bureau of Meteorology, Scientists Gather in Melbourne to Discuss Cloud Seeding (May 4, 2007), \textit{available at} http://www.bom.gov.au/announcements/ media_releases/ho/20070504.shtml.
\textsuperscript{77} Brian Ryan, \textit{Can Cloud Seeding Bring Drought Relief?}, 24-1 \textsc{Australasian Science}, Jan. 1, 2003, at 42-43.
\textsuperscript{78} \textit{See} id.
\textsuperscript{79} Id.
\textsuperscript{80} Michelle Paine, \textit{Cloud Seeding Widens Hydro Bid to Bust Drought for Farms}, \textsc{Mercury} (Hobart, Australia), Sept. 4, 2007, at 3.
\textsuperscript{81} Id.
\textsuperscript{82} Id.
B. China

In early November 2009, Beijing experienced its earliest snowfall since 1987.83 Local officials from the city’s weather modification office “fired 186 doses of silver iodide into the air . . . to prompt precipitation, causing an extra 16m cubic meters of snow to fall on the city.”84 Deputy Director of the weather modification office, Zhang Qiang, said the hope was that as this snow melted it would hydrate parched crops.85 China, no rookie in the cloud seeding game, “has the most extensive weather modification program in the world, with more than 35,000 people working in cloud seeding programs across the country.”86 In 2004, the Chinese government reported it eased drought by employing “[a]ircraft, rockets, artillery shells, meteorological balloons and mountain-top-based devices . . . to scatter silver iodide particles into gathering clouds to induce precipitation in the form of rain or snow over the city.”87 Cloud seeding programs, such as this 2004 initiative, have brought complaints by neighboring towns that areas with cloud seeding are “stealing” rain, a concern which the Chinese government combated with regulations “promot[ing] co-operation between provinces and regions.”88 In 2004, meteorologists in Zhoukou claimed that cloud seeding operations in neighbor Pingdingshan “stole” rain when Pingdingshan got ten centimeters of rain while Zhoukou only received two and a half.89

China has also sought to control the rain by stopping it—as in the case of the 2008 Olympics.90 Before the Olympics, China was already spending $100 million annually on cloud seeding.91 But in preparation for the games, officials set up cloud seeding stations where “peasants don military fatigues and helmets and squat behind anti-aircraft guns and rocket launchers blasting the sky with silver iodide, hoping to shock rain from the clouds.”92 Officials planned to have these stations ready and, if rain threatened either the opening or closing ceremonies, they would “seed threatening clouds [using rocket launchers] outside the city . . . and cause them to release their rain before it reaches the capital.”93

China’s Olympic cloud seeding effort also included cloud seeding to remedy the heavily polluted air.94 The International Olympic Committee threatened to postpone events if the air quality did not improve.95 These dual goals of cleaning the air and creating rain may actually be self-defeating, though, as there is some indication rain may decrease pol-

84. Id.
85. Id.
86. Barker, supra note 23.
87. Cloud Seeding Eases Drought, supra note 53.
88. Id.
89. Ravilious, supra note 29.
90. Wade, supra note 38.
91. Id.
92. Id.
93. Id.
94. Id.
95. Id.

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olution—so by preventing rain from hitting the capital, China would be maintaining high levels of pollution.96

This was not the first time weather control was attempted as a method to improve the Olympic games. The 1960 winter games in Squaw Valley, California bore the risk of being snowless.97 Irving Krick, a weather forecaster from California, “was named the official ‘weather engineer’ for the Winter Olympics,” and promised to make the snow come.98 True to his word, in January 1960, Krick blasted silver iodide from twenty ground-based cloud seeding generators when snow clouds began to appear.99 And “[b]y Jan. 10, more than 3.5 feet of snow buried the valley floor, with more than 7 feet on the upper mountain.”100 Of course, the snow could have arrived of its own, natural accord, and it would be impossible to determine whether his efforts contributed to increased snowfall at all—but that did not stop Krick from taking credit.101 Despite these prior arguable successes in Olympic games preparation, not all countries have turned to weather modification. Canada chose instead to prepare for the 2010 Winter Games by installing weather stations to monitor conditions and bringing in snow from other areas of the country.102

C. INDIA

India first investigated cloud seeding technology in 1951.103 And currently in India, “[a] team of forty scientists from the [Indian Institute of Tropical Meteorology, Pune, have] begun an experiment of seeding rain clouds across India to trigger an increased rainfall from as early as 2010.”104 In response to a weak monsoon, the government-initiated program seeks to cause rainfall by “injecting small amounts of specific substances (like aerosols), naturally found in clouds, causing them to open up.”105 The scientists hope that this method will allow smaller droplets, not large enough in size to normally fall yet, to exit the cloud.106

In 2009, India’s Institute of Tropical Meteorology also conducted cloud seeding experiment to prepare for possible drought.107 Aside from the need for water in supply, the absence of the cooling effect of water also caused a heat wave that killed over a hundred people as of June 2009.108 Of course the effects extend beyond thirst and heat, “India’s agriculture, stock markets and the fortunes of its political parties traditionally depend on

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96. Wade, supra note 38.
98. Id.
99. Id.
100. Id.
101. Id.
103. Page, supra note 13.
105. Id.
106. Id.
108. Id.; Page, supra note 13.
good monsoon rains."\footnote{109} Scientists in India, though, went beyond traditional techniques seeking to release the existing rain from clouds, and also investigated the possibility of bringing more or larger raindrops, researching "\textit{why some clouds yield more... [and then] replicate the same reaction using chemicals.}"\footnote{110} In 2007, another cloud seeding operation in India claimed to have produced an eight percent rise in rainfall after ninety days.\footnote{111}

D. \textbf{PHILIPPINES}

Like Venezuela, the Philippines is currently grappling with the El Niño-produced drought.\footnote{112} By mid-February 2010, over $61 million worth of damage to the nation’s crops had been reported, with almost 400,000 acres of farmland affected by the drought.\footnote{113} In fact, Carlito Claudio, an official with the National Grid Corporation, said "he expected two to three-hour blackouts every day, possibly until the national elections in May."\footnote{114} The Philippine Air Force is conducting a seeding operation, which was announced as initiated at the request of farmers and local officials.\footnote{115} Between the start of operations in early February and February 21, the Office of the Provincial Agriculturist had conducted fifty-five flight missions to cloud seed.\footnote{116} The country plans to conduct the procedures through the usual process of "showering sodium chloride (iodized salt) into cumulous clouds to produce rain."\footnote{117} The primary concern in drought is agriculture.\footnote{118} The president of the National Federation of Sugarcane Planters, Enrique Rojas, noted to reporters that "\textit{dry conditions will adversely affect agricultural productivity in Negros Occidental, particularly its sugar industry, which produces 60\% of the country’s sugar supply.}"\footnote{119} Officials also hope these operations will increase the water in dams and rivers, as well.\footnote{120} But, threats to successful operations exist, including "\textit{high temperature, strong wind velocity and absence of seedable cloud formations.}"ootnote{121}

E. \textbf{RUSSIA}

Some individuals, on the other hand, are concerned with stopping the precipitation—not creating it. In Moscow, Russia, major snowfalls burden the city. And in an effort to reduce the cost of clearing (estimating a USD $13 million savings), "the city is weighing a
plan to seed the clouds with liquid nitrogen or dry ice to keep heavy snow from falling inside its limits.”\textsuperscript{122} Russian scientists say that dropping cement powder into the clouds will eliminate them—a concept that was accidentally discovered forty years ago when scientists “dropped powdered blue paint into the clouds to tag them for observation . . . [and] the powder melted the clouds away.”\textsuperscript{123} Former President Vladimir Putin also ordered cloud seeding operations in an attempt to drain rain from clouds before the precipitation could arrive over St. Petersburg’s 300th anniversary celebrations.\textsuperscript{124} That method is not free from risk though: in 2008 “a clump of cement tumbled to earth instead of dissipating in the cloud . . . [and] crashed through the roof of a house.”\textsuperscript{125} “This goal of suspending the snow has also caused trouble with neighboring areas “which would receive the brunt of the displaced snowfall.”\textsuperscript{126}

As was only recently, and controversially, revealed by former soldiers, Russia also used cloud seeding over twenty years ago in an attempt to prevent the spread of radioactive matter.\textsuperscript{127} Following the Chernobyl nuclear accident, Russian military pilots were dispatched to drop “artillery shells filled with silver iodide to make rain clouds that would ‘wash out’ radioactive particles towards densely populated cities.”\textsuperscript{128} The government has denied any cloud seeding operations, but pilots who claim to have flown the missions came forward with their story, which is supported by witnesses in Belarus who say “aircraft . . . circling in the sky ejecting coloured material behind them.”\textsuperscript{129} A British scientist who examined the fallout around Chernobyl, and was later expelled from Russia for his statements, said “the population in Belarus was exposed to radiation doses 20 to 30 times higher than normal as a result of the rainfall, causing intense radiation poisoning in children.”\textsuperscript{130}

F. United States

Individuals in the United States first began cloud seeding in earnest in the 1940s.\textsuperscript{131} “In the 1950s General Electric Co. scientists and the U.S. military unsuccessfully tried to steer a hurricane by seeding clouds with dry ice and silver iodine to generate rain.”\textsuperscript{132} “The U.S. government was at one time very optimistic about weather manipulation; by

\textsuperscript{122} Megan K. Stack, \textit{A New Foe for Russia's Snow Scientists Work On a Process to Control the Flakes}, \textit{Houston Chronicle}, Dec. 13, 2009, at A34.

\textsuperscript{123} Id.


\textsuperscript{125} Stack, \textit{supra note} 122.

\textsuperscript{126} Id.


\textsuperscript{128} Id.

\textsuperscript{129} Id.

\textsuperscript{130} Id.


the late 1970s, annual funding for cloud-seeding projects hit $20 million.”133 The most prominent U.S. cloud seeding operation was “Project Storm Fury,” which ran from the 1960s to the 1980s with effectively “inconclusive” results.134 One of the goals of the research project was to lessen the severity of hurricanes through cloud seeding, but again the results were not encouraging and scientists found that “hurricanes contain little of the supercooled water necessary for cloud seeding to work.”135 Although it should be noted that these periods refer to official cloud seeding operations, but the United States actually issued a patent as early as 1891 to an individual for his process of “making rain by use of ‘liquified carbonic acid gas.’”136 And “[i]n 1916, the city of San Diego hired Charles M. Hatfield” to make rain by mixing chemicals.137 The city saw 2.5 inches of rain in twenty-four hours, which “washed out a dam, causing loss of life and great property damage.”138

Today, “[g]overnment agencies and utilities throughout the United States spend an estimated $15 million USD a year on cloud seeding, and the number of projects has jumped by nearly a third in the last decade.”139 The numbers regarding participation in cloud seeding are on the rise: sixty-three projects in nine states were reported in 2008, fifteen more than in 1998, according to the National Oceanic and Atmospheric Association.140 But in the United States, just as in China, many “programs are run by local governments with little coordination from the nation’s capital.”141 And, in fact, some states even ban weather modification on the theory that rain falling prematurely is rain stolen from the location where it would otherwise naturally fall.142 As an example, in February 2010, the Wyoming state legislature considered the Omnibus Water Bill, which passed the House Agriculture Committee and would add “another $2.8 million towards definitively finding whether cloud seeding works.”143 The state legislature has previously devoted $8.8 million “towards the Wyoming Weather Modification Five-Year Pilot Project.”144 But state legislators expressed serious doubt about the value investing in a cloud seeding program.

133. Engber, supra note 27.
136. Who Owns the Clouds?, 1 STAN. L. REV. 43, 63 (1948) (stating “Gathman’s process used compressed gases contained in a projectile and fired into the air. The container was exploded, allowing the gas to expand rapidly and thus cool. ‘Liquified carbonic acid gas’ was preferred. Since this is only carbon dioxide, many minute particles of dry ice must have been formed when it cooled rapidly. Gathman went one step further than present rainmakers: he created his own clouds by the rapidly cooling gases”).
137. Id. at 43-44.
138. Id. at 44.
139. Young, supra note 37.
140. Id.
141. Wade, supra note 38.
144. Legislature Briefs, supra note 143.
State Rep. Dan Zwonitzer, R-Cheyenne, said "[i]f it doesn't work, you wasted $13.4 million."145

G. PRIVATE WEATHER MODIFICATION PROJECTS

Governments are not the only groups cloud seeding—private companies are investing in programs and an industry of weather alteration services exists. Weather Modification, Inc. is an American company based out of Fargo, North Dakota.146 Founded in 1961, the company primarily provides cloud seeding for-hire across the world.147 The company's website says it has run programs in areas including Alberta, Argentina, North Dakota, Texas, Oklahoma, Mexico, Jordan, and Greece, and says "[o]ur valued clients include private and public insurance companies, water resource management organizations, and federal and state research organizations."148

Also in the United States, the Idaho Power Co., in November 2009, invested up to $1 million USD "to seed the clouds above Idaho's mountains, in hopes of increasing the snowpack that will drive the hydroelectric turbines to produce the cheapest power the company can get."149 The company expects to more than double the snowpack for its hydro dams annually.150 Within Idaho, "counties and businesses have [also] put together a coalition to pay for cloud seeding in the Upper Snake River Basin" and believe they have seen positive results in their reservoirs.151 Even the Boise, Idaho airport has "long used" cloud seeding to reduce delays by eliminating fog for airplanes.152

V. THE LAW, LIABILITY, AND POTENTIAL DANGERS OF WEATHER MODIFICATION

Clearly cloud seeding and weather modification operations have taken place across the globe, but are they officially permitted? Or is the world of weather modification a legal wild west? One thing is certain: if a cloud seeding operation achieves what it seeks, weather will be modified, and affecting ecosystems means multijurisdictional consequences. Cloud seeding "has caused considerable controversy in recent years, with some saying that one area's success with rain means shifting moisture from one place to another."153

A. CLOUD AND WATER OWNERSHIP UNDER PROPERTY RIGHTS LAW

Who owns the weather? "Is weather modification a public function, analogous to military protection, postal service, or highway construction? Or is it a private, non-govern-
mental function? If the latter, is it a private function vested with public interest, as had been determined to be the case, for example, in rail or air transportation? American case law has given conflicting views on cloud and water vapor ownership. In a 1960s case, a Pennsylvania court determined that landowners have "a property right in the clouds and the water in them," but that weather modification may be subject to governmental regulation. But in Slutsky v. City of New York, the court held that property owners "clearly have no vested property rights in the clouds or the moisture therein."

Under much property law and existing common law, the rule of capture would put forth that he who accesses the cloud first, has rights to it. If traditionally property rights extend to the sky, then clouds would belong to the owners of the land below. But clouds are transient and temporary. And limitations on landowner rights already exist, as with the airplanes that fly over, and thus theoretically "into," private property.

In terms of international property law though, clouds are generally considered within a state's sovereignty when they are over that state's land. This naturally poses some problems because of the fleeting and unpredictable nature of clouds: they "constantly [change] shape, location, content, and size; [they] may divide into . . . more clouds; [they] may merge with other clouds; or [they] may evaporate entirely." Despite its inherent problems, this state sovereignty approach's "true justification lies . . . in the defense of the national security interests, [because] the danger for the security of the subjacent States is the same as in the case of the foreign aircraft overflight, regardless of the height." Furthermore, states have a national security interest in the water clouds produced because it is such a critical resource.

Perhaps the legal ownership of weather, or its mediums such as clouds, may be analogous in some respects to space. There is a public interest in weather and weather control, as it is wildly expensive and thus limited in experimentation to only certain small groups, and it has potentially huge implications for the masses. And as with the development of space law, innovations in technology serve as a catalyst to discussions and laws by state and international leaders. For example, in "[t]he year following the Sputnik launch, the United Nations created an ad hoc committee to consider the consequences, necessarily

156. Id. (citing Pa. Natural Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 10 Adams L.J. 10, 1968 WL 6708 (1968)).
157. Davis, supra note 155 (citing Slutsky v. City of New York, 97 N.Y.S.2d 238, 239 (1950)).
158. See Majzoub, Quilleré-Majzoub, Raouf, & El-Majzoub, supra note 28, at 324.
159. Cf. id.
160. Id. at 327.
161. Id. at 330.
162. Id. at 328.
163. Id. at 327-28.
international law consequences, of the first human activity in outer space,” and “[b]y 1963 the United Nations had adopted the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space.”166

Some suggest applying the laws of wild animals, at least as it is understood under U.S. law, to cloud ownership.167 Under this law of animals feræ naturæ, when animals are wild “they are common property; no one can claim rights in them,” but “when wild animals are first reduced to possession, they become the property of the possessor.”168 Under this model, clouds would be common property as wild and acquire owners when first “captured” by someone. Of course that association raises concerns because the application of the rule of capture to wild animals hinges on the idea that clouds can be “captured” and held. If the animals feræ naturæ law were to be applied to clouds in the context of cloud seeding, debates over the definition of possessing a cloud would ensue.

Others suggest applying the property and water law approach of “prior appropriation,” which advocates a “first in time, first in right” ownership basis: he who claims this first gains rights with regard to that water or cloud.169 Prior appropriation is a doctrine used more frequently in areas with scarcer water supply.170 Under riparian rights though, the owner has the right to use the water flowing by his land to the extent that such use is appropriate to his operations, free from interference by upstream riparian users; but he does not outright own the water.171 A reasonableness standard applied to that use might also be appropriate.172

B. Conflict and Regulation

1. Lack of International Regulation

How is cloud seeding regulated on the international stage? It’s not. “There are currently no international instruments, global or regional, related to the use of clouds of rain.”173 And the lone “legal instrument” on weather manipulation, the 1977 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, merely prohibits using weather control as a military tool.174 Serving as a basis for international law or agreement surrounding weather modification may be the Convention on the Non-Navigational Uses of International Watercourses (“the Convention”), which identifies “[g]eneralized legal principles for the management of transboundary waters.”175 The Convention sets out principles for “responsibility for cooperation and joint management,” but does not outline rules of operation of weather modification with clarity and specificity.176 The general basis of the Convention is the adoption of a doctrine of

166. Id.
168. Id.
170. Id.
171. Id.
172. Id.
174. Id. at 354.
175. Wolf, supra note 14.
176. Id.
“equitable utilization,” which is endorsed by the International Law Association, the U.N. General Assembly, and the International Court of Justice.\(^{177}\) Equitable utilization applies a concept of restricted sovereignty wherein states may take a share of the available water supply with “an obligation not to inflict unreasonable injury on water users in another state.”\(^{178}\)

Applying equitable utilization to cloud seeding presents several problems: (1) how to determine what water is considered “available” when it exists in the clouds and not on or under the ground; (2) what is considered a fair share when most states are cloud seeding in response to a drought or other water emergency; (3) what constitutes “unreasonable injury”; and of course (4) the overriding question of how to determine whether a state abused its water right when the effects of cloud seeding are so difficult to determine with any accuracy. Indeed, this “system is too informal, lacks precise rules, and also lacks the means of effectuating and enforcing such rules as it does have” and thus is “inherently unstable.”\(^{179}\)

But aside from the trouble with applying water laws to regulating weather modification, a fundamentally different undertaking, much existing law is out of touch with the reality of the global freshwater supply anyway and out of date in failing to incorporate weather modification technology. “Groundwater constitutes about thirty percent of global fresh water reserves—and yet nearly all of the rules of international law concerning shared freshwater resources were developed to govern surface water, the veritable tip of the iceberg of the world’s freshwater supply.”\(^{180}\)

In the United States, even though many states follow the riparian rights doctrine, which grants owners of land that abuts a natural watercourse a reasonable right to that water’s use, some states still require permits for weather modification.\(^{181}\) Of course, in countries around the world, cloud seeding is also directly commissioned by the government. “At one time or another, two-thirds of [U.S.] states . . . have had legislation focusing upon intended weather modification through cloud seeding,” including mandatory permits, licensing, and formal reporting.\(^{182}\)

2. A Classic Case of Conflict Resolution Over Water: United States and Mexico

In the late nineteenth century, Colorado farmers started an international controversy when they diverted water from the Rio Grande for irrigation, causing “a substantial drop in the flow of the river” according to Mexican farmers, and a 500-mile dry bed reported by a U.S. Army general.\(^{183}\) Mexico’s Minister in Washington expressed distress over the diversion’s implications, prompting a response by U.S. Attorney General Judson Harmon that became known as the “Harmon Doctrine.”\(^{184}\) Founded on the fundamental pillar of sovereignty, Harmon stated that the United States could act as it pleased on U.S. terri-

\(^{177}\) Dellapenna, supra note 20, at 69-70.
\(^{178}\) Id. at 69.
\(^{179}\) Id. at 72.
\(^{180}\) McCaffrey, supra note 15, at 329.
\(^{181}\) Davis, supra note 155, at 388; U.S. Dep’t of the Interior, supra note 169.
\(^{182}\) Id.
\(^{183}\) McCaffrey, supra note 15, at 326.
\(^{184}\) Id.
tory. His statement came after consultation with the Justice Department regarding international law, and Harmon even purported that former testimony regarding state sovereignty from U.S. Supreme Court Chief Justice John Marshall supported his statement. But ultimately the matter was resolved by a 1906 treaty, titled the Convention Concerning the Equitable Distribution of the Waters of the Rio Grande for Irrigation Purposes. The treaty professed to effectively divide use of the river between the United States and Mexico.

C. INTERNATIONAL COOPERATION

1. Treaties

While no single international body is charged with managing water and weather modification rules and rights, nations have established treaties to resolve disputes. Indeed, without such a body, "the only binding source of international environmental law would be treaties." Most of these over 3,000 identified treaties concern navigation of waters, and lack rules for monitoring. Therefore, while this system of treaties may have resolved some specific cases, it is not helpful in providing international agreement regarding cloud seeding. What brings these nations together is their shared interest in water. "[T]he development of a river that acts as a boundary cannot take place without cooperation; farmers, environmentalists, and recreational users all share an interest in seeing a healthy stream-system; and all riparian nations share an interest in high quality water." Indeed, one scholar points out that while India and Pakistan have formally been at war three times since 1948 over other issues, they "negotiated and implemented a complex treaty on sharing the waters of the Indus River basin, they did not target water facilities, and they carried through with the cooperative water management arrangements even during actual periods of full-scale war."

Another example of a treaty revealing nations' paramount interest in water is the Agreement Between Canada and the United States of America Relating to the Exchange of Information on Weather Modification Activities ("Canada-U.S. Agreement"). In the treaty, the countries agree to a reporting system between each other for weather modification programs that might affect the other, as well as to consult the other country when possible regarding planned weather modification programs.

185. Id. at 327.
186. Id. at 326-27.
187. Id. at 328.
188. Id. at 329.
189. See generally Wolf, supra note 14.
191. Wolf, supra note 14 (a listing of treaties may be found in The Transboundary Freshwater Dispute Database, http://www.transboundarywaters.orst.edu/database/ (last visited July 11, 2010)).
192. Id.
195. Id. art. II, art. V.
2. **International Collaboration**

Many of these treaties, such as the Canada-U.S. agreement, demonstrate the goal of nations with such meetings and agreements: working together. Collaboration has taken the form of various international agencies and research projects. The World Meteorological Organization (WMO) is an agency of the United Nations (UN) and "originated from the International Meteorological Organization (IMO), which was founded in 1873."\(^{196}\) The WMO, consisting of 189 Member States and Territories, tries to promote international cooperation through idea-sharing and natural disaster response planning and warning.\(^{197}\) While promoting a positive goal, the WMO does not claim exclusive managerial authority over weather modification or cloud seeding.\(^{198}\)

Other non-governmental groups also seek to raise awareness about world water supply and the possible dire implications of a water crisis. The World Water Council, created in 1996 "on the initiative of renowned water specialists and international organizations" states that it "provide[s] a platform to encourage debates and exchanges of experience . . . to reach a common strategic vision on water resources and water services management."\(^{199}\) The Council also organizes the World Water Forum, described on the Council's site as "a three year process of dialogue and reflection, culminating in the world's most important water gathering with over 20,000 participants."\(^{200}\) The most recent World Water Forum, the fifth of its kind, was held in March 2009 in Turkey and gathered over 25,000 participants seeking to "put wise water management higher on the political agenda."\(^{201}\)

D. **Legal Dangers and Consequences of Cloud Seeding**

1. **Liability and Injury**

Cloud seeding and weather modification also raise questions about liability when changed weather causes damage. These issues could arise when an individual or government causes extra rain, which then floods a neighboring state's field, or when cloud seeding forces rain out of clouds prematurely and that moisture does not fall over an adjacent state's drought-stricken land. Such concerns troubled early American cloud-seeder General Electric, who chose to avoid such tort issues by experimenting with cloud seeding in laboratories to avoid responsibility for damage.\(^{202}\) Alternatively, cloud seeding could generate unwelcome rain in neighboring lands, as is the concern with onion-growers fearing

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197. Id.
198. See id.
201. Id.
damage to crops in Nueva Ecija in the Philippines. “Precipitation is a precursor to streamflow and, according to the data from Metromex, rainfall is enhanced downwind from urban areas. To the extent that water is added to a stream, legal rights to use water from the stream are affected.”

In a more simple, visually apparent example: who is responsible when cloud seeding prompts a hailstorm that damages all the cars on a dealership’s lot?

The first major concern in any liability action will be the special evidentiary challenges because the effects of weather modification are so difficult to prove. Would the storm have happened “but for” the human intervention? If this question were answered in the negative, then the claimant would have to show a causal link. Successful claims of this nature are exceedingly rare. And the difficulty with establishing liability for injury rises to a new level of complexity on the international stage where a venue for claims regarding weather modification has not been established. Although the issue of liability for cloud seeding has not been specifically addressed, under principles of existing international tort law, “[a] state must commit a wrongful act [such as violating international law] in order to engage its international responsibility.”

2. Weather As a Weapon

As freshwater scarcity worsens, the value of water as political capital rises. Particularly in “arid and semi-arid environments [this] leads to intense political pressures, often referred to as ‘water stress.’” Access not only to freshwater, but to clean water adds to the need as “[w]ater demands are increasing, groundwater levels are dropping, surface water supplies are increasingly contaminated, and delivery and treatment infrastructures is aging” and “[m]ore than a billion people lack access to safe water supplies.”

Water conflict and manipulation have existed throughout history. “Examples . . . range from interstate violence and death along the Cauvery River in India, to California farmers blowing up a pipeline meant for Los Angeles, to much of the violent history in the Americas between indigenous peoples and European settlers.” Cloud seeding, when effective, has the potential for use in future conflicts of that sort.

204. Davis, supra note 155, at 387.
205. See generally id.
206. Id. at 385.
207. Id.
208. Id.
209. See generally Dellapenna, supra note 20.
211. Wolf, supra note 14.
212. Id.
213. Id.

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Some speculate that cloud seeding technology may be a springboard for a new kind of weapon. One potential weapon is an "unmanned stealth aircraft that could seed clouds above massing troops with fine particles of heat-absorbing carbon" to "produce localized flooding and create mud, which has been the bane of all of history's armies." In fact, the U.S. military began a cloud seeding operation dubbed "Project Popeye" in 1966, designed to slow supply delivery in Vietnam by extending monsoon season. The project continued for six years. Some Americans also suspected cloud seeding was used during the 1969 Woodstock Festival. Multiple attendees claim to have seen seeding operations being conducted by U.S. military and speculated those actions caused "the rain which lasted throughout most of the festival."

As previously stated, the U.N. General Assembly formally banned using weather modification as a weapon in 1977. But the effectiveness of such a declaration, particularly one drafted over thirty years ago and regarding a technique so difficult to prove, is likely marginal. In the 1990s the U.S. Air Force commissioned a report on weather modification, which concluded that "[o]ver the course of the next century, the weather will be our most powerful weapon. Weather modification can provide battlespace dominance to a degree never before imagined."

In a bizarre statement following Haiti's recent devastating earthquake, Venezuelan President Chavez again referenced man's possible control over the weather by accusing the United States of deliberately causing the earthquake that tore through Haiti. He claimed that the United States has an "earthquake weapon" that was also responsible for "a Jan. 9 quake in Eureka, Calif., and may have been behind the 7.8-magnitude quake in China that killed nearly 90,000 people in 2008." Chavez says that the quake was a ploy to occupy Haiti and a test run for a U.S. weapon designed to strike Iran. Such statements, while unlikely to be taken seriously by the international community, do serve to underscore the state of thorough research into weather modification. The scientific area, despite having existed for more than half a century, can still be considered in its infancy with regard to confirmed results.

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215. Id.
217. William Daniel Davis, supra note 216.
218. Cloud seeding, supra note 72.
219. Id.
220. Id.
221. Ravilious, supra note 29.
222. Id.
224. Id.
225. Id.

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VI. Conclusion: Where We Go From Here

As of early 2010, Chavez's cloud seeding efforts starting in November 2009 had not fended off drought.\(^{226}\) And the rationing and other severe measures instituted by Chavez have resulted in dramatic drops in popularity—"from 62% last February to the mid-40s" in early February 2010.\(^{227}\) Desperate measures are being taken. "State oil company Edelca has summoned all its workers to an hour long prayer meeting . . . titled: 'Clamor to God for the National Electricity Sector.'"\(^{228}\) On January 8, the Venezuelan President announced that the Guri Dam's water level was at thirty-three feet below last year's level.\(^{229}\) He added that if the level dropped another eighty-two feet, massive blackouts would begin and "[Venezuela] would be at a standstill."\(^{230}\) The situation in Venezuela and Chavez's immediate act of pulling resources, not only from his country but from Cuba as well, highlight the importance of more substantive research on the effectiveness of cloud seeding. The political implications are dangerous and complicated; Chavez announced in February that Cuban Vice President Ramiro Valdes even traveled to Venezuela "to head a Cuban team advising Venezuela on its efforts to reduce energy consumption."\(^{231}\) Although the practice has existed for sixty years, the case studies and examination above show cloud seeding has received scattered attention and been used before its effectiveness confirmed. Furthermore, coordinated research on cloud seeding will not merely confirm or deny its effect, but may lead to better, cheaper ways to control the weather through managing precipitation.

And beyond direly needed research, the potentially explosive consequences of the quiet poisoning of freshwater sources call for international discussion and agreement—eventually. For the time being, the action to be taken must be a renewed focus on research. Therefore the call to arms beckons the scientific community. The governmental and legal worlds join in that fight because they help fund and organize, and in some nations even wholly control, scientific study. Any international regulations of cloud seeding and weather manipulation would frankly be premature at this stage.\(^{232}\) The reality of world balance is that nations will, and should, look out for themselves. Although logic dictates that negative, even perhaps disastrous, implications of cloud seeding could occur—there is no evidence that has or will actually happen.\(^{233}\) The Gaza Strip serves as an example, where "[over] the 30 years the [region] was under Israeli occupation . . . [w]ater quality deteriorated steadily, saltwater intrusion degraded local wells, and water-related diseases took a rising toll on [the population]."\(^{234}\) With attention to the security risk posed by...
gradual water supply deterioration, the international community has an opportunity to prevent these conflicts before they arise.

Even very recent discoveries demonstrate how this research has the potential to unlock innovative solutions and possibilities in the realm of weather modification. In early 2010, Science magazine reported a study that found “water can freeze at different temperatures depending on whether the surface it rests on is positively or negatively charged.” This means that “[u]nder certain conditions, water can freeze as it heats up.” This finding shocked the scientists involved, and potentially provides a new way for man to control—either by stunting or jump-starting—the formation of ice in clouds.

If governments and multi-national groups do not coordinate, the private sector may also step in—unregulated. “The stakes in this legal, moral, and environmental dispute are far higher than people might think. Not only is the future price tag of cloud water at stake, but so are the benefits that could be gained from bulk cloud-trading and the expansion of a cloud credit scheme.” Although long-standing in practice, proven effective cloud seeding operations are in their infancy, and as discussed above are essentially considered a myth by some experts; but once research achieves definitive results, the demand will surely grow. And demand generates supply, whether to a farmer with starving crops or a smaller country without the airplanes and resources to seed their clouds. Regulations of industry exist around the world to ensure prices are not unconscionably high and to set standards of safety and consistency. Cloud seeding has the potential to become a true industry, and governments should be at the ready to respond to that development.

At a minimum, the international agreements should be drafted now to provide contingency efforts to respond to severe need or disaster in the world water supply, recognizing that scientific research has simply not reached threshold to call for regulation. Cloud seeding may be a valid part of that effort to minimize crises. One criticism of U.S. law may be applied globally: “[a]lthough current water laws seek to allocate rights to an ambient and variable resource, they have not always been flexible enough to satisfactorily manage extreme variations in supply.” Relief laws should be put into place to incorporate cloud seeding if possible. “Passage of relief laws is one way to mitigate losses from severe storms and other negative effects of inadvertent weather change.”

In short, the confluence of factors including a population boom, climate change, and an effectively inevitable freshwater crisis is a warning to scientific and political leaders across the globe. The world gaze should shift to realize the interconnectedness of these growing problems and the massive devastation a lack of response could fail to prevent. A freshwater crisis that could cause not just drought and economic distress—but even war—looms ahead. Cloud seeding and weather modification have the potential to be an effective tool in staving off that result.

236. Id.
237. See id.
238. Majzoub, Quilleré-Majzoub, Raouf, & El-Majzoub, supra note 28, at 333.
239. Davis, supra note 155, at 389.
240. Id.