The Rainmakers:

The Geo-Politics of Climate Change and Cloud Seeding

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This chapter discusses the climate forecasts for temperature and precipitation from the most recent IPCC report. It will probe the distribution of water resources and demands, and expected change in their profiles.

People have geo-engineered their environment for millennia and in the process re-routed water, molded terrains, and altered the mix of plants and animals in the eco-system. This chapter discusses the approaches to geo-engineering, including attempts to limit its use in conflict situations.

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a. Building a Multilateral Registry of Cloud Seeding Events
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Introduction: The Enduring Allure of Rainmaking

This research views significant climate change as a likely prospect since there will be no grand agreement to reduce or mitigate it. Global temperatures worldwide will exceed the 2°C maximum expected to cause widespread socio-economic and environmental disruption (probably by a lot). The European Union and other enities embrace this threshold so passing it will have a psychological affect and spur amny to do something to solve the problem. It is likely that higher temperature will lead to greater calls for the use of geo-engineering as an acceptable solution to a changing climate.

One geo-engineering tool, cloud seeding, is already employed on a large scale. While there is little evidence that cloud seeding significantly alters patterns of weather or climate, the perception by countries and their peoples in its efficacy can lead to conflict situations. Countries will need some transparent rules regarding use of geo-engineering, starting with cloud seeding. This rule making effort could begin by establishing a registry of cloud seeding events in order to study their affects more closely and to track their use.

1. Current Forecasts of Climate Change

In 2014, the Intergovernmental Panel on Climate Change (IPCC) released its latest review of forecasts for climate change over the course of this century (the AR5 report). This section examines those climate projections and the inferred influence on water availability.

a. IPCC AR5 Projections

The findings from the IPCC (AR5) updates climate change projections since four years ago. The Summary for Policymakers Report (September 2013) has high confidence that by the year 2100 temperatures will exceed those compared to 1986-2005. These projections are based on four Representative Concentration Pathways (RCPs) that show global temperatures increasing from 1.0°C (the RCP2.6 forecast) to 3.7°C (the RCP8.5 forecast).

Temperature increases, especially under the RCP8.5 forecast, show large continental interiors across the world could rise by 5-7°C, though this will not be uniform pattern. The inland portions of Eurasia especially and, to a lesser extent North America, will dramatically rise in temperatures such that bio-climate zones will completely change. Worldwide, about one quarter of the planet will shift in climate type. Arctic areas will decline precipitously, arid regions will substantially increase, and many continental climates will become temperature.

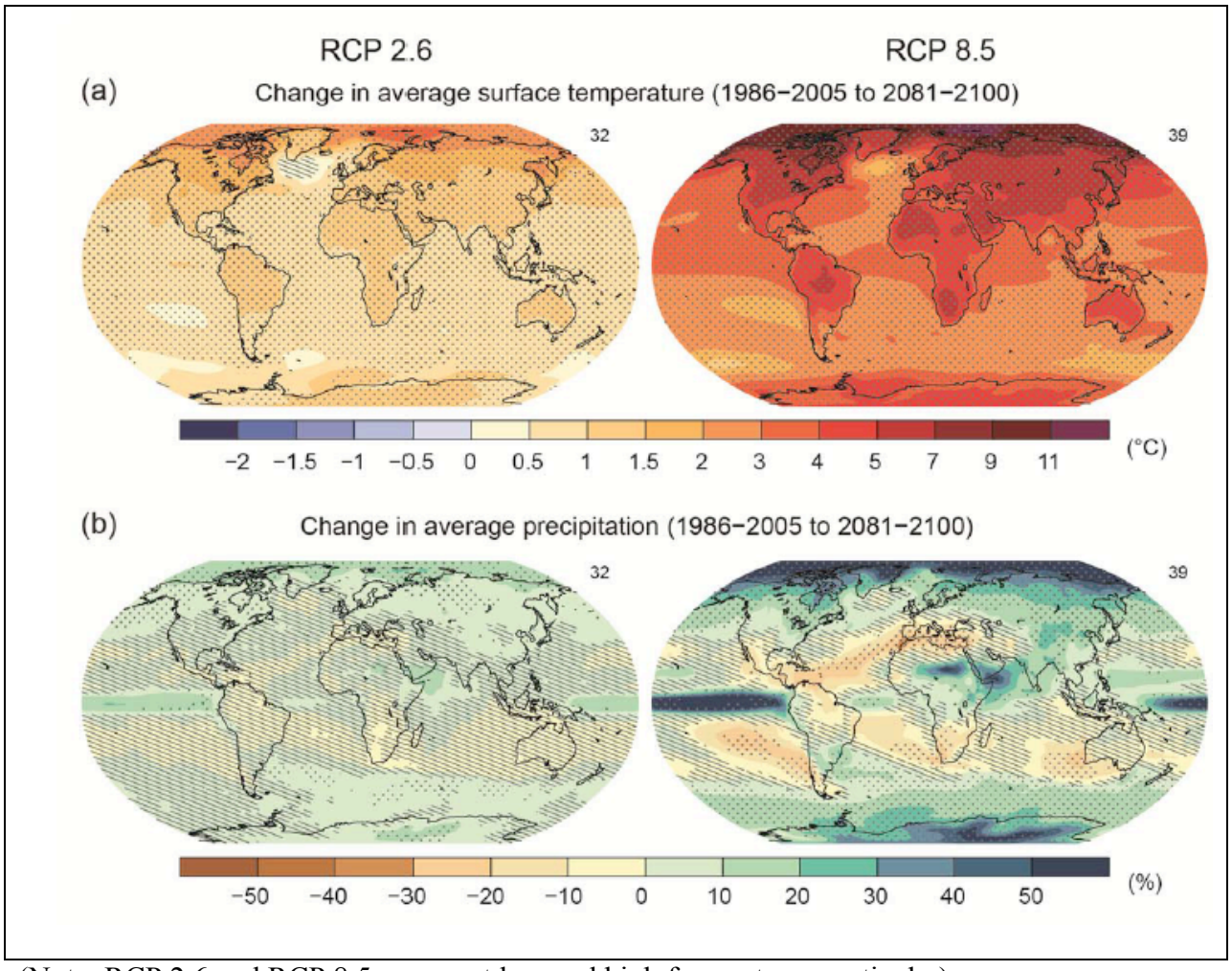
Northern areas of the planet are likely to show a temperature increase of perhaps around 10°C. There will be a corresponding rise in seasonal low temperatures, more so than a rise in high ones. "The Arctic region will warm more rapidly than the global mean, and mean warming over land will be larger than over the ocean (very high confidence)."[1] Every part of the world will experience some degree of warming.

Changes in precipitation patterns are difficult to predict (especially at a certain point in time). One decade may be wetter than another. However, overall declines in precipitation are expected

[1] IPCC, "Summary for Policymakers", September 2013, p. 13.

in Central America and northern South America, North Africa, the Middle East and the Mediterranean, and South Africa. Some areas will show a precipitation increase, particularly northern hemisphere areas and in Central Africa. By 2100, most of the planet's glaciers will have melted (see Figure 1). The report concludes that without large-scale changes in energy use, these forecasts will become increasingly likely.

Figure 1: IPCC AR5 Forecasts (from Summary for Policy Makers)



(Note: RCP 2.6 and RCP 8.5 represent low and high forecasts respectively.)

b. The Demand for Water

In addition to the noted precipitation declines, because of higher temperature (and aerosol emissions) greater transpiration will also reduce water availability. Given that higher temperature increases will most likely occur in the interior continental masses, two weather patterns could stand out. First, in the northern hemisphere, water will fall more often in the form of rain rather than snow and glaciers in these areas will witness serious melt-off. Second, in regions around the equator, higher temperatures may well cause serious declines in rainfall patterns and water retention.

> "Projected changes in the water cycle over the next few decades show similar large-scale patterns to those towards the end of the century, but with smaller magnitude. Changes in the near-term, and at the regional scale will be strongly influenced by natural internal variability and may be affected by anthropogenic aerosol emissions."[2]

At the same time of substantial water decline, especially in certain parts of the world, human requirements will intensify gaps between the procurement of water and the need for it. Water availability may well increase in northern, developed countries where populations are expected to stabilize if not decline. In equatorial, developing countries, the growing populations in water-deprived areas will sharply raise demands. Indeed, many of these regions already exist in a state of water scarcity.

[2] IPCC, "Summary for Policymakers", September 2013, p. 6.

By mid-century, the majority of the world's population will live in Sub-Sahara Africa and South Asia. Both of these regions already possess large populations that are water deficient, especially in the northern portion of Sub-Sahara Africa and western part of South Asia. Growing industrialization will take up a larger share of water use and agricultural production will need to expand to feed populations and serve as a major source of employment. A warming climate may put stress on drought-vulnerable crops that are often important to developing country economies.

> A one percent increase in temperature will reduce major cereal crop production (rice, maize, wheat) worldwide. The decrease will be between 0-2% per decade throughout the century. For increases above 4 degrees C, the gap between food production and demand will constitute a food security threat.[3]

2. Is Geo-Engineering a Solution?

People have geo-engineered their environment for millennia and in the process re-routed water, molded terrains, and altered the mix of plants and animals in the eco-system. This chapter discusses the approaches to geo-engineering, including attempts to use, and not to use, in situations of conflict.

a. Types of Terra-Forming

What is geo-engineering? One source says it includes techniques "for removing carbon dioxide from the air and technology that could rapidly change the amount of sunlight reflected back to

[3] IPCC, AR5, WG 2 Security.

space and cool the planet." This approach regards geo-engineering as a type of solar radiation management (SRM). But there are other approaches that include carbon sequestration or precipitation management, for example. This research will embrace this broader view that geo-engineering is the attempt to impose large-scale, purposeful, anthropogenic changes to the environment to achieve some type of social objective. Lines of research represent both the skepticism and the inevitability of a geo-engineering solution.

First, there are the skeptics of cloud seeding who are idealists. James Rodger Fleming explores the use of geo-engineering for rainmaking in *Fixing the Sky*. Fleming focuses on our ability to control the weather, a likelihood that is well off into the future. His goal is to provide an exhaustive history of the enterprise. He looks at ancient attempts and the scientific efforts starting in 1946 to produce rain. In the upcoming years, there will be attempts and claims about controlling weather that may or may not be true. The situation will be similar to states claiming to have WMDs when they do not (like Saddam Hussein in Iraq).[4]

Fleming looks closely at the development of rainmaking throughout history, calling the purveyors "rain makers and rain fakers".[5] There have been alleged instances of rainmaking gone amok and causing unintentional deluges (by the United States, Great Britain and the Soviet Union).[6] Besides questioning our technological abilities, Fleming also asks a moral question. Is the quest to create a global thermostat a claim to the right to control the weather? No doubt countries will fight over temperature settings on the global thermostat just as couples do.

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[4] James Rodger Fleming, *Fixing the Sky: The Checkered History of Weather and Climate Control*, New York and Chichester: Columbia University Press, 2010.
[5] James Rodger Fleming, *Fixing the Sky*, p. 11.
[6] James Rodger Fleming, *Fixing the Sky*, p. 12.

It is not the science of rain making that will upset politics, but the perception of the science. Atmospheric scientist William Cotton "warned that in times of drought or climate stress, politicians would emerge with the need to demonstrate they were doing something, that they were in control of the situation, even if they only enacted political placebos."[7] This statement resonates with the logic of this research in that perceptions may hold the key to conflict. Politicians may see benefit in fanning the belief in cloud seeding even when there is little scientific evidence.

Fleming poses four key questions about controlling the weather and climate that have political or conflict considerations.[8]

1. Who would control the thermometer and would there be conflict over that control?
2. How could one malevolent country be prevented from using it in a harmful manner?
3. Could impacts of geo-engineering be limited to localities or regions to avoid spillover impacts?
4. Could cloud seeding "exacerbate international tensions and trigger conflict"?

Much like climate change itself; there will be winners and losers from geo-engineering.[9] Those in control will surely try to be winners as often as possible. "Given the immense costs of miscalculation (or perception of miscalculations), who then would decide and who would implement climate modification and control schemes?" Thomas Schelling points out that

[7] James Rodger Fleming, *Fixing the Sky,* p. 262.
[8] James Rodger Fleming, *Fixing the Sky*, p. 232, 242.
[9] Fleming, *Fixing the Sky*, p. 234.

countries might possess climate control technology abilities but differ on the optimal climate. Thus, climate control could cause more global tension than climate relief.[10]

It will be difficult to foresee the least powerful countries controlling the agenda. Will the dividing line fall along traditional lines of geo-political power? The Tyndall Center for Climate Change Research wonders about equity issues, and the basis on which geo-engineering decisions will be made. It is clear that the capabilities for geo-engineering lie with the more developed countries.

It is not only countries that might use geo-engineering on a large-scale. Could a company or a group of individuals attempt geo-engineering without the involvement of governments? Joseph Fletcher speculates that perhaps as few as 60 aircraft could undertake cloud seeding in the Arctic by affecting cloud formation or dispersal and in the process significantly change thermal reflectivity.

Second, there are the realists who embrace the inevitability of geo-engineering. David Keith presents multiple sides in the debate, but in the end argues that it may be time to accept geo-engineering as one tool in the fight against climate change. This acceptance could be a specific type of climate engineering, such as injecting reflective particles in the upper atmosphere to cool the planet.[11] Keith lays out a measured research and testing program that would evolve over a

[10] Fleming, *Fixing the Sky*, p. 242-3.
[11] David Keith, A Case for Climate Engineering, MIT Press, 2013. Also see Jeff Goodell, *How to Cool the Planet: Geoengineering and the Audacious Quest to Fix Earth's Climate,* Houghton Mifflin Harcourt; First Edition (April 15, 2010).

long period. Geo-engineering should be explored not as a fait accompli, but as a hedge in the event we need such a tool at some point.

The technology however might be the easy part. The implementation of large-scale programs might become technologically feasible long before they are politically feasible. There is so much uncertainty in the technology that its use would clearly guarantee political conflict.

Jeff Goodell also looks at the rules on geo-engineering and covers a wider gamut of possible geo-engineering solutions, including short-term proposals such as dumping iron fillings into the oceans in large quantities. He agrees on solar radiation management as a most likely solution and comes largely to the same conclusion as David Keith.[12]

Solar management can be achieved in a variety of ways and Keith thinks it falls into a different category compared to climate solutions that focus on carbon reductions programs. Keith looks at the option of seeding the stratosphere with sulfates to produce droplets to obscure the sun's rays. This is not for the purpose of producing rain to make up for shorter-term deficits in precipitation. Rather, it is to lower solar inputs to the planet that alters the radiative balance: a shift that would involve a long-term commitment. This solution however might also reduce precipitation as a side cost.

Some researchers are quite apocalyptic about the use of planet-wide geo-engineering as a last resort that is becoming increasingly probable. If climate change were to exceed forecast

[12] Jeff Goodell, *How to Cool the Planet: Geoengineering and the Audacious Quest to Fix Earth's Climate,* Houghton Mifflin Harcourt; First Edition (April 15, 2010).

expectations, then such a decision will be needed in a relatively short time period, certainly before the year 2100.[13]

Long before dramatic, worldwide attempts, mammoth projects to control a climate out of alignment, will be many more subtle and slow-moving approaches to altering the climate.[14] While the efforts to influence weather and climate may never be of any large consequence there will be billions of dollars spent pursuing the question. The technical requirements and the complexity of weather and climate on a global scale are simply too difficult to model and implement with any real precision. Despite these scientific realties, the threats and use of ineffective geo-engineering technologies will cause an out-weighed political impact with serious conflict implications.

Are planetary wide solutions practical? If an agreement on limiting greenhouse gas emissions is seemingly out of reach, then a global consensus on deploying technologies to remediate change in the entire planet's climate seems more unlikely. Countries can voluntarily opt-in to an agreement regarding emissions, but actions by a limited number of countries could substantially alter the environments of countries that have no buy-in.

There are four reasons why the future focus of geo-engineering will be on rainmaking rather than on planetary-wide approaches or short-term fixes. Who knows what technology lurks on the

[13] Commenting on an article they published in *Foreign Affairs* in March/April 2009, "The Geoengineering Option: A Last Resort Against Global Warming?" http://www.foreignaffairs.com/articles/64829/david-g-victor-m-granger-morgan-jay-apt-john-steinbruner-and-kat/the-geoengineering-option?page=show

[14] There are several science fiction movies over time that have looked at geo-engineering, which usually causes something bad to happen, as in Godzilla who was released by nuclear testing.

horizon? The proposed solutions of Keith, Goodell and others may not be representative of the geo-engineering approaches that will be employed over the next century.[15]

1. **It's About Precipitation not Temperature**. People will react by trying to change precipitation patterns, more than on changing radiative balances related to temperature. The world's poorest people, still heavily dependent on agriculture, will want to create viable livelihoods that rely on dependable rains more than on cool temperatures.

2. **Global Solutions Are not Feasible.** There will be recoiling from the use of planetary wide solutions to climate change. Decision-making will be more local and more controllable. Inter-state solutions will become too complicated.

3. **Quick Fixes are Unacceptable**. Long-term solutions will be favored over shorter ones. Short-term solutions can also deliver short-terms crises and risks that are unacceptable to people and governments.

4. **Cloud Seeding is Here**. The research and useable technology for rainmaking is already a developed science on the verge of great increases in efficiency. Other geo-technologies will require brand new investments and long times in research development.

b. The ENMOD Treaty

[15] David G. Victor, M. Granger Morgan, Jay Apt, John Steinbruner and Katharine Ricke, "The Truth About Geoengineering: Science Fiction and Science Fact", *Foreign Affairs*, March 27, 2013.
http://www.foreignaffairs.com/articles/139084/david-g-victor-m-granger-morgan-jay-apt-john-steinbruner-kathari/the-truth-about-geoengineering

During the Cold War, the United States and the Soviet Union explored differing Weapons of Mass Destruction (WMD) that included the use of nuclear, biological, and chemical devices. In 1945, the mathematician John von Neumann met with other U.S. scientists to discuss the possibility of deliberately modifying weather as a tool of war.[16] Weather modification was believed to be a means for destroying Soviet agricultural harvests, thereby causing mass starvation, harming the economy, and inciting internal dissension.

About 1957 the United States began to see a potential arms race evolving in creating a weather machine that could also be a WMD. A Soviet proposal in 1957 to build a dam across the Bering Straits made U.S. officials aware of the power of weather power as a weapon and a tool of political warfare. [17]

Hysteria broke out at the time about falling behind in the ability to wage climate wars, eclipsed only by the fear of falling behind in the ballistic missiles race that John Kennedy used in the run-up to the 1960 election. There had not however been any proven existence of a Soviet program on creating tools for altering the climate. The allegations that there was such a program, and that it was substantial, was nonetheless argued as a reason to support U.S. activities and research. [18]

In the summer of 1974, U.S. President Nixon and Soviet General Secretary Leonid Brezhnev signed a summit communiqué entitled "Joint Statement Concerning Future Discussion on the Dangers of Environmental Warfare". After many years of further negotiation, the two leaders

[16] John von Neumann, "Can We Survive Technology?", *Fortune*, 1955.
[17] Milton Leitenberg, "Case Studies 2: Weather Modification", *Studies of Military R&D and Weapons Development*, Federation of American Scientists (FAS), http://www.fas.org/man/eprint/leitenberg/, pp. 6-11
[18] Milton Leitenberg, "Case Studies 2: Weather Modification".

agreed to watered-down language in the U.N. Environmental Modification (ENMOD) treaty that "implicitly legitimized the use of cloud seeding in warfare" and other small-scale weather modification techniques.[19]

There was widespread use of geo-engineering during the Vietnam War. Between 1967 and 1972, the United States ran Operation Popeye, a cloud seeding operation intended to disrupt transport of military supplies along the Ho Chi Minh trail and aimed at parts of South and North Vietnam, Laos and Cambodia. The operation occurred during the dry season when it was ordinarily easiest for the North Vietnamese to move men and materials south. Inducing rain, it was believed, would slow that effort. While the program was successful in causing heavy rains out of season, it was not successful in stopping the flow of men and materials southward. Heavy rains attributed to the cloud seeding program led to catastrophic floods in 1971 that caused a poor harvest in North Vietnam.

The disclosure of Operation Popeye led many to realize that such a tactic took the idea of "all-out war" to a new level, and one that was disturbing. As a result, in 1977 countries agreed to the "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques" (ENMOD). The treaty forbids the use of environment in hostile circumstances but supports the use of weather modification for peaceful purposes. Climate change is one of a number of environmental phenomena covered by this treaty.

> Earthquakes, tsunamis; an upset in the ecological balance of a region; changes in weather patterns (clouds, precipitation, cyclones of various types and tornadic storms); changes in

[19] James Rodger Fleming, *Fixing the Sky*, p. 184.

climate patterns; changes in ocean currents; changes in the state of the ozone layer; and changes in the state of the ionosphere.[20]

The treaty has never been invoked and two later review conferences met without much progress. A 1984 review unsuccessfully sought to expand the scope of the treaty. A 1992 review was the result of the Gulf War and questions regarding burning oil wells to cause belligerent environmental impacts. This resulted in adding more low-technology tools such as herbicides to the treaty list of banned practices/substances, but little more.

A re-confirmation of the ENMOD principles occurred at the U.N. Framework Convention on Climate Change (UNFCCC) and the 1992 Earth Summit in Rio de Janeiro. The statement suggests far-reaching implications in the jurisdiction of a nation's sovereign area.

> "States have... in accordance with the Charter of the United Nations and the principles of international law, the (...) responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."[21]

Most techniques covered by the ENMOD treaty are quite speculative. Causing earthquakes or tsunamis is far beyond the capacity of current technology. Cloud seeding, on the other hand, is a technology that is often used and has a history of limited effectiveness dating back more than 50 years.

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[20] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 1978.
[21] U.N. Framework Convention on Climate Change, 1992.

What would constitute a violation of the ENMOD treaty? Article I of the ENMOD treaty requires members "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party".[22]

The general intent of the treaty is to limit the use of ecology in a military context. It distinguishes between weather related actions (short-term) from those that are climate related (long-term). The key word is "or", meaning any one of the three is sufficient to cause a treaty violation. The "Understanding Relating to Article I" provides the three indicators of environmental modification covered by the treaty and de minimus levels of impact.

(a) Widespread: encompassing an area on the scale of several hundred square kilometers.

(b) Long-lasting: an act whose duration lasts months, or approximately a season.

(c) Severe: involving serious or significant disruption or harm to human life, natural and economic resources, or other assets.

The treaty is clear on what it forbids: widespread, long-lasting, or severe environmental modification. It is thus quite revealing to consider what the treaty allows. It does permit cloud seeding (or other actions) that may adversely affect a neighbor so long as it is undertaken without a military or hostile intent. Further, military personnel could carry out a non-hostile action providing it was without military intent. The treaty permits weather modification by the military even with a hostile intent when it is localized, short-term, and produces positive outcomes. These exceptions obviously can lead to ambiguous situations.

[22] U.S. State Department, ENMOD Convention.

First, widespread refers to the geographic scope covered by the treaty. Treaty violations occur when impacts exceed 300 square kilometers (or 186.4 miles), so a square of roughly 17.3 kilometers (or 10.7 miles) in length and width. Washington, DC (a partial square city) is 177 square kilometers in comparison, so these are not extremely large areas but they could be home to millions of people.

The second concept is long lasting, denoting time duration. One season corresponds to about three months. The chosen months however would produce differing impacts. If cloud seeding occurred during a planting season, it would mean the loss of an entire year of production. If cloud seeding occurred in the winter, to build snow pack for example, the impact may be benign or even positive.

The third premise focuses on a severe disruption to the environment and may be the most difficult concept to pinpoint. Specific indictors might use socio-economic indicators (such as income) or human health markers (such as infant mortality). Moreover, there may be a multiplicity of environmental impacts on several dimensions. A violation might significantly reduce ecological, economic or health indicators. A full understanding of impacts may not occur until long after the act occurred. Will there be a statute of limitations on claims under the treaty?

The treaty bans technology transfer related to the development of harmful or hostile ENMOD techniques. This implies avoiding the trade of materials, equipment, scientific knowledge, or expertise to parties that may act in a hostile manner. Export technology treaties also cover

materials that may have military application as a dual-use technology. The ENMOD Treaty suggests that exports of cloud seeding knowledge and tools may fall into such a category.

No country has invoked ENMOD, but there have been instances that might serve as possible candidates. During the 1991 Gulf War Iraqi forces burned oil wells on a large scale, placing huge amounts of particulates in the air that may have affected weather patterns in neighbor countries. Iraq also polluted the Persian Gulf with oil that caused environmental damage to other states, upset the regional ecological balance, and did serious damage to the Persian Gulf environment. China's destruction of a satellite in 2007 with a kinetic kill vehicle caused enormous space pollution (and a U.S. action in 1985) and posed a danger to spacecraft of other countries, including astronauts. The treaty could arguably cover these acts since they were for ultimately harmful purposes.

Given the potential for miscalculation or misperception due to the increasing use of cloud seeding technologies and capabilities, countries need to have some basic understandings of agreed upon behavior, mechanisms for dialogue, and registries of events for purposes of cataloguing and comparison. If a country or group had malevolent purposes, it is quite likely that geo-engineering could be used as a weapon of mass destruction.

3. The State of Cloud Seeding

Cloud seeding induces precipitation by introducing substances into cumulus clouds that cause condensation. Cloud seeding is one of several rain or snow making techniques. Most seeding uses silver iodide, but dry ice (solid carbon dioxide), propane, and salt are also used. People have attempted to make rain for millennia, but the first scientific demonstration of cloud seeding occurred in 1946 in the United States. A successful test of creating artificial rain took place in 1946 using dry ice and shortly thereafter. In 1947 Bernard Vonnegut did the same with silver iodide.[23] The use of cloud seeding has substantially grown over the last half century.

It is important to distinguish between climate change and weather. Weather is a state of the atmosphere over the short-term and more likely at specific points and places. Climate is a long-term phenomenon expressed as average weather patterns over a long period. Up to now, most cloud seeding has been used to influence weather.

Cloud seeding could affect climate only when carried out over a long period. An extended period of drought for example, will require an extended period of cloud seeding to counteract those trends. It is logical to assume that any effort to counteract climate change through cloud seeding will be a long-standing and expensive effort. It may well need to last for several hundred years, since climate change will not end in the year 2100.

[23] Milton Leitenberg, "Case Studies 2: Weather Modification", *Studies of Military R&D and Weapons Development*, Federation of American Scientists (FAS), http://www.fas.org/man/eprint/leitenberg/, pp. 6-11

The need for rainmaking may last for long periods, but there will be some adjustments needed along the way. Fluctuations in precipitation will still occur and there would clearly be no need to make more rain in years when there is already surplus. In fact, adding to the surplus may hurt the climate and the things that live in it. The timing of such adjustments will also be a matter of debate. Will it be like a 5-year program such as in planned economies?

Not only will there need to be constant adjustments for annual differences in precipitation, rainmaking will also need to simulate the seasons within a year. Thus there will be a need to water in some time of the year more than others and possibly in different types (long showers versus thunderstorms). Would it even mean that excess precipitation during usual dry periods might also be reversed and result in un-rainmaking, or ways to reduce precipitation?

Even if it were possible to use rainmaking to maintain our current climate as much as we can, there will be pressures, especially from economic interests, to use rainmaking to produce optimal agricultural output. These choices will be made on the basis of their importance to the economy, since rainfall during some periods for one commodity might be a good outcome, while for others it might be bad.

States will attempt to counteract and adapt to climate change. Cloud seeding is the oldest and most common form of environmental modification (a type of geo-engineering) and states will employ it to make up for lost water resources due to climate change. The most obvious usage would be in maximizing or optimizing precipitation. Cloud seeding may also be employed to

decrease temperature (for example, through generating more fog or clouds) or in lessening or diverting extreme events (for example, changing the track of typhoons or hurricanes).

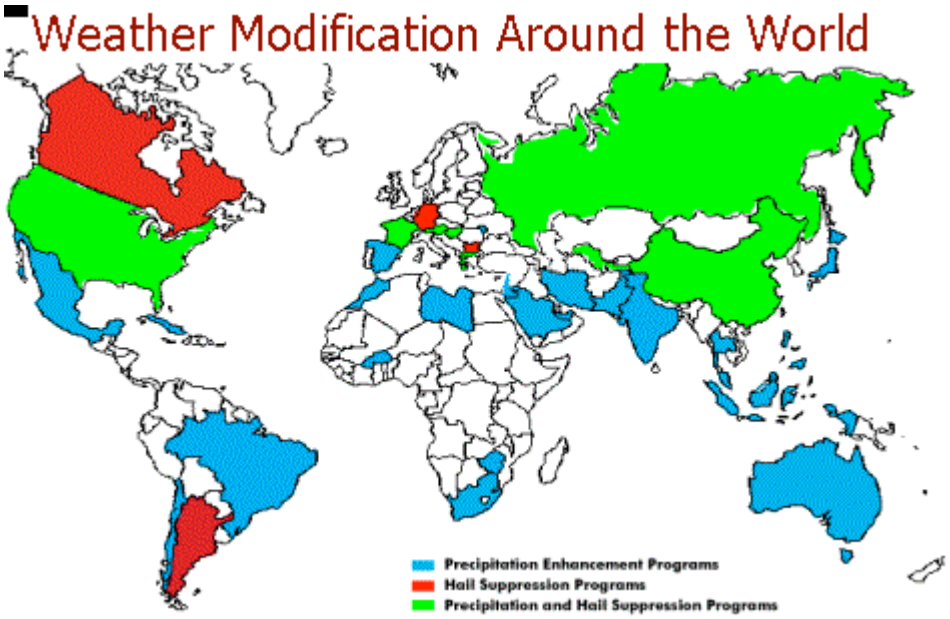
The efficacy of cloud seeding is very much in doubt. Some of the most optimistic estimates suggest it can at best increase precipitation by 10 percent or so. A report by the U.S. National Academy of Science (National Research Council, 2003) questioned the utility of cloud seeding and the extent of impacts outside of small localities. The report called for greater research into practices for understanding and improving cloud seeding effectiveness.

It is unlikely that one country could steal another country's water through cloud seeding, nor does it seem likely that cloud seeding will have substantial impact on extreme events. All of this of course assumes something approximating today's standards of technology, a reality that could change. Even if there were to be a technological leap, some question whether it should be used.

> It's quite a promise. Using existing technology, we could engineer clouds "to cancel the entire warming caused by human activity from pre-industrial times to present day". But cloud seeding, the latest of many geo-engineering proposals to mitigate climate change, has a drawback: get it only a bit wrong, and you make the problem worse.[24]

Figure 2: Weather Modification Around the World

[24] T. Storelvmo, J. E. Kristjansson, Helene Muri, Melissa Pfeffer, D. Barahona and A. Nenes, "Cirrus Cloud Seeding has Potential to Cool Climate", *Geophysical Research Letters*, January 4, 2013. Also see http://www.bbc.com/future/story/20130304-the-trouble-with-cloud-seeding.



("Overview of Weather Modification Programs Around the World", National Center for Atmospheric Research)

At least 50 countries have identified cloud seeding programs (See Figure 2 and Appendix A). Developed countries use cloud seeding widely, for a variety of purposes, as well as many of the newly industrializing or BRIC countries. Countries with high petroleum incomes in the Middle East have also begun embracing cloud seeding for some time. It is not surprising that the countries, which employ cloud seeding for hail suppression, are in the north and south parts of the planet and not around the equator. Around the equator, the goal is entirely for precipitation enhancement. The most notable gap is the low usage throughout Africa except in the far north and south. Below are some country case studies.

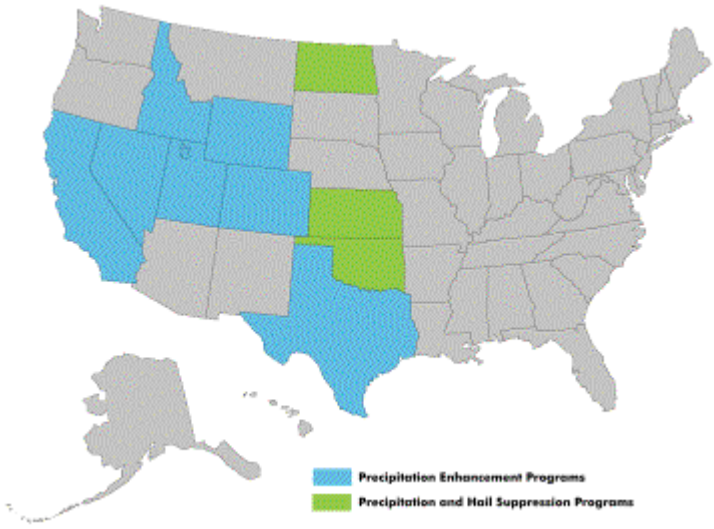
There has been extensive use of cloud seeding in the United States (see Figure 3). Cloud seeding programs concentrate on two geographical areas. First, there are several south central states, such as Texas, prone to dry conditions in the summer or during spring planting where precipitation enhancement is used. Even in these states, the benefits of cloud seeding are seen as

modest. The latest version of the Texas State Water Plan (2012) estimates that by 2060, weather modification could account for only 0.2% of the state's water needs.[25] Artificial precipitation is also used to ensure available rain during critical times in plant development. Spring is also a time when these areas are prone to hail, which can destroy young plants. Hail suppression is a concern more in the northern Midwest in Kansas, North Dakota, and Oklahoma. Idaho seeds clouds to increase fresh water and snow resources.

The second major nexus of cloud seeding use are the states in the Colorado River Basin, including Colorado, Wyoming, Utah, Nevada, and California, who use it to increase winter snowpack. Across California, water agencies and utilities spend $3-to-5 million a year on cloud seeding, which is estimated to boost runoff by around four percent.[26] During the recent intensive drought there, many called for cloud seeding as a counter-measure, but the results met with limited success in increasing the meager snow pack. The Desert Research Institute (located in Nevada), which took part in these operations, is also looking into using drones in this region, as a means for cutting flight costs.

Figure 3: Weather Modification in the United States

[25] "Water for Texas: Summary of the 2011 Regional Water Plans." Prepared by the TWDB for the 82nd Legislative Session. http://www.tdlr.texas.gov/weather/summary.htm (Part of water management plan).
[26] See KQED report, http://science.kqed.org/quest/audio/in-dry-year-california-looks-to-cloud-seeding/.



("Overview of Weather Modification Programs Around the World", National Center for Atmospheric Research)

When Hurricanes Katrina and Rita devastated the U.S. Gulf Coast, Senator Kay Bailey Hutchinson of Texas introduced S. 517 [109th Congress] the "Weather Modification Research and Development Policy Authorization Act of 2005". The measure never became law. It called for greater research and development into cloud seeding (Section 5, "Duties of the Board") with two key goals.

> (1) Improved forecast and decision-making technologies for weather modification operations, including tailored computer workstations and software and new observation systems with remote sensors; and
>
> (2) Assessments and Evaluation of the efficacy of weather modification, both purposeful (including cloud-seeding operations) and inadvertent (including downwind effects and anthropogenic effects).

China is preparing for all-out climate war by building a cloud-seeding fleet consisting of hundreds of planes. China used cloud seeding to induce rain before the 2008 Olympics to clean

out the smog and during the games to keep rain away. Chinese officials claim credit for a clouding seeding program in 2009 that led to massive snowstorms. In 2014, severe pollution in China led to the closure of many schools. The government proposed creating artificial rain in response.[27]

China has long experience with large-scale projects that aim to manipulate the environment, beginning with the ancient Great Wall and extending up to the modern Three Gorges Dam. They intend to follow a similar grand course with cloud seeding that may become a permanent policy as long as climate change and drought persist. This of course may last decades or hundreds of years. The only cost-effective means for undertaking such a long-term program is through the use of drones (more on this later).

Russia (and earlier, the Soviet Union) used cloud seeding to assure good weather during political events and for many years to produce a rain-free May Day parade (and other holidays). Russia uses both precipitation enhancement and hail suppression, especially with regard to its important wheat crop. There is a great degree of acceptance of cloud seeding in Russia. The mayor of Moscow proposed in 2013 to use cloud seeding to lessen winter snowfall and save the city money. A similar proposal in Western Europe would be ridiculed, but in Russia it was seen as a matter of cost effectiveness.

Canada primarily uses cloud seeding to prevent potential weather damages from hail. In 2010, a company used silver iodide to reduce the impact of a large hailstorm that was due to hit the city of Calgary (and later deemed successful). Like the intentions of the mayor of Moscow, this was

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[27] "Schools close in fog as China eyes artificial rain to fight pollution", RT News, December 5, 2013, http://rt.com/news/schools-close-cloud-seeding-china-768/

to save money. "The 15-year-old Weather Modification Inc. is paid by a consortium of insurance firms, which banded together as the Alberta Severe Weather Management Society in an effort to reduce the cost of claims associated with hail damage."[28] Since the hailstorm was hitting the city, the potential claims were not for agricultural losses, but losses to individuals and persons. Many of these losses were in dented cars and broken windows.

Many Middle Eastern countries are natural candidates for cloud seeding. France conducted tests in Algeria as early as 1952. Libya began testing in 1971, Jordan in 1986, Iraq under Saddam Hussein in 1989, and Syria in 1991. Israel has a long-standing cloud seeding program. Saudi Arabia has experimented with cloud seeding, beginning in 1990 and is increasing its programs, particularly in the southwest portion of the country near the Yemen border.

A UNEP report in the 1990s envisioned a cloud seeding program in the coastal mountains of the east Mediterranean, including parts of Syria, Jordan, and Saudi Arabia. It noted some positive experiments and a surely growing water deficit. It did worry about the inter-state implications that are of course a concern to Israel. The waters also flow into aquifers that lie in part under Israel and would have natural political implications. A 2014 controversy over a plane sighted near Jeddah that allegedly was spraying a gas that dispersed clouds (the Saudi government meteorology unit denied the story). The United Arab Emirates have been employing cloud seeding for 10 years with technical assistance from the United States and South Africa.

Iran has long experience with cloud seeding, especially around Yazd, the driest major city in Iran. "Statistical evaluation of the effectiveness of regular cold-cloud seeding operation, carried

[28] CBC News, 2010.

out over the project territory in the Central part of Iran…shows that from 0.7 to 1.9 km^3 of additional water was obtained" or about an additional 22-40% of the natural seasonal precipitation annual.[29]

In Latin America, cloud seeding is widespread and sometimes controversial. In 1996, the United States gave Mexico technical assistance on clouding seeding during a drought in the state of Coahuila. Seem believed it was actually a cover for a narcotics interdiction program. Brazil, Argentina, Chile and Cuba have extensive experience with cloud seeding for precipitation enhancement on a seasonal basis.

Malaysia and Indonesia have used cloud seeding to suppress haze from the numerous fires that have burned in those countries for many years. In Malaysia, these planes were diverted to look for the lost airliner of March 2014. But shortly thereafter "the National Security Council has recalled a Hercules plane from the MH370 search and rescue operations for cloud seeding duty which is expected to resume today…This comes in the wake of mounting public alarm over depleting water levels in dams as well as the current dry weather and open burning cases that are contributing to the choking haze over parts of the country."[30] The Philippines is using cloud seeding to counteract an El Nino-caused drought to increase precipitation in the Magat Reservoir watershed.

4. Cloud Seeding, Climate, Perceptions, and Conflict

[29] Khalili, "Results of Cloud Seeding Operations", 2008.
[30] http://www.thestar.com.my/News/Nation/2014/03/15/Cloud-seeding-op-to-resume-today-says-dept-Hercules-plane-recalled-from-search-and-rescue-duty/

The “Rainmaker” is a well-known 1956 American movie based on the play by N. Richard Nash. Bill Starbuck (played by Burt Lancaster) is a confidence man roaming the U.S. Midwest during the Great Depression that was also a time of severe drought (the Dust Bowl). Families often folded up and left and this was the premise of John Steinbeck’s *The Grapes of Wrath*. Starbuck preys on the fears of these people. He goes from town-to-town, claiming the ability to make rain, only to get run out of every place when his promises do not come true.

Starbuck shows up in Kansas at the Curry family homestead that consists of the patriarch H.C. and sons Noah and Jim and spinster Lizzie (played by Katherine Hepburn). The family is in turmoil. Drought has befallen their cattle farm and Lizzie’s marriage prospects have seemingly dried up as well. Starbuck promises rain and her father accepts the offer for a modest payment of $100, even knowing Starbuck is a fraud

Starbuck bangs big bass drums, lights fires, and paints an arrow on the ground to show the clouds where to go. He seemingly has no luck in creating rain. The two brothers differ on whether he is telling the truth about rainmaking and come to quarrel over him. Jim revolts against his domineering brother Noah. His arrival has also strewn conflict in the romantic life of Lizzie, who is been waiting for Deputy File to propose to her (after other lost chances to marry). Starbuck woos her and, unlike her family, praises her beauty. Starbuck cannot make it rain, but he can make tremendous turmoil in the Curry household, between the doubters and believers, and especially in Lizzie’s decisions about her future and what she believes.

Starbuck succeeds in changing her Lizzie's worldview of love and herself but prepares to leave town as the drought continues and his credibility is running out. As he leaves town, he tries to get Lizzie to leave File behind but she refuses. The rains then begin and Lizzie regains her self-worth and a future with Deputy File (despite the fact he is divorced). Starbucks collects his money, but the implication is that the payment was for his emotional efforts not his rainmaking ones. The perception of rainmaking was more powerful than the actual rainmaking abilities.

Rainmaking can lead to conflict through emotional, political, and perceptual differences on the efficacy of cloud seeding. Just as the Curry family is brought to conflict due to debate over cloud seeding, so too will countries find that cloud seeding engenders feelings of hostility.

It is possible to imagine three areas where cloud seeding might be linked to conflict: first, as a perceived factor in precipitation or extreme events; second, in building capacity for large-scale programs that may mask other intentions; and third, in battlefield instances where there are tactical uses of weather as a warfare advantage.

a. Conflict may occur if a one state's cloud seeding is perceived to be negatively impacting another state

The reality is that many countries practice cloud seeding and believe it works. Regardless of the scientific debate, the perception of the viability of cloud seeding can lead to dispute. Cloud seeding is likely to inflame existing conflicts rather than cause new ones. The line between hostile and peaceful uses of cloud seeding (and environmental modification in general) is

extremely thin and at times ambiguous. One country in the midst of a severe humanitarian emergency may perceive cloud seeding as a benevolent act. A neighbor country, encountering the same drought and humanitarian crisis, may perceive artificial rain as thievery. Cloud seeding primarily raises issues regarding fresh water resources, rights, and obligations. Access to water resources is a long-standing source of dispute between states, though by itself it has rarely led to conflict.[31]

Farmers in many countries over many years have blamed cloud seeding for a lack or rain. There is little or no likelihood that their beliefs were in founded in fact. Yet, there is the belief and some deeply held convictions. There is also an inverse relation between declines in precipitation and beliefs that cloud seeding is one of the causal factors. It is not conspiratorial or absurd to suggest that claims of cloud seeding during times of drought might be a trigger that sets off violence, though it may not be the structural or larger reasons that two countries may over time develop a conflictual or conflict-prone relationship. Here are three cases of cloud seeding that possess a conflict element.

First, states may use cloud seeding to counter cloud seeding by other countries. During a severe drought in September 2012, Iranian President Mahmoud Ahmadinejad blamed it on cloud seeding orchestrated by the United States and Israel during a trip to Golestan Province. The ministries of Environment and National Heritage echoed Ahmadinejad's claims. "Part of the

[31] Some companies also now trumpet their cloud seeding capabilities in just these terms. "Water resources are increasingly taxed by exploding demand and continued population growth. The world's population is projected to grow over 40% in the next 45 years." Weathermodification.com. Accessed March 25, 2014. The company provides commercial application of cloud seeding services, including increasing precipitation (increasing rain or snowfall), reducing hail, and dispersing fog from air and ground based systems.

drought is unintentional and due to climate change and part of it intentional and due to a war started by the enemy, which is emptying clouds before they reach our country."[32]

Second, states may perceive the transfer of cloud seeding technology as a threat to their own national security. In November 2009, Venezuela experienced El Nino conditions that led to severe droughts and water rationing in Caracas. Cuba provided technical assistance to Venezuela in implementing a cloud seeding program. This assistance caused national security concerns in the United States especially over possible technology transfer.

Third, cloud seeding may be employed to avert an extreme event. The Soviet Union employed cloud seeding during the Chernobyl nuclear disaster of 1986. In the immediate aftermath of the catastrophe, Soviet air force pilots seeded radioactive clouds over Belarus to prevent them from reaching Moscow and other major populated Russian areas. While Moscow was spared, Belarus and Ukraine received a significant amount of radiation.[33]

b. Conflict may result from the perception that the building of large fleets of aircraft, namely drones, to undertake cloud seeding operations may have a dual purpose in preparing for conflict

More than 50 countries practice cloud seeding, largely for seasonal rainmaking, spring hail suppression, and building snowpack. It is also used to diminish haze and pollution. It is widely practiced in the United States, Canada, Europe, Australia, and other developed countries. Drones will inevitably come into use in these places as a tool for cloud seeding. These drones could also

[32] Nasseri, "Ahmadinejad Accuses", 2012).
[33] Grey, "How we made the Chernobyl rain", 2007.

enforce laws, monitor traffic, report local weather, or upload real-time spatial video to Google Earth or Homeland Security.

Small-scale geo-engineering is going to take off over the next decade and China may well lead it. China has developed a line of Unmanned Aerial Vehicles (UAVs) called S-200 for the purpose of seeding clouds. The plan is to build a fleet of drone planes that will fly on a daily basis. They also plan to use the fleet to apply pesticides and to sow seeds using aerial capacity.

The drones could be means for weather modification and a variety of domestic and international intentions.[34] It could certainly act as a means to hide or disguise a military build-up in air conflict capabilities. Some question whether the S-200 is but a cover for other programs. The drone has some stealth features that are unnecessary for cloud seeding. There will be no need to evade clouds; rather the plan is to find them.

c. A country can develop capabilities to change weather patterns during conflict, particularly impacting precipitation patterns, to gain a short-term battlefield advantage.

An Air Force study called "Owning the Skies" looked at the ways and capacities for influencing weather during aerial combat. This capacity would mean enhancing the ability of friendly forces through precipitation avoidance, storm modification, managing space weather, and controlling and removing fog and clouds. For enemy forces, this would imply precipitation and storm enhancement, precipitation denial, disruptive space weather, and controlling and removing fog and clouds.

[34] Rawnsley, "Weather Machines", 2010.

The report called for shaping the aerial battlefield through weather modification and to develop such a capacity by the year 2025.[35] The report acknowledges the need for tremendous advances in the ability of technology to influence weather patterns, which are limited at the moment. The focus though would be on localized and short-term phenomena. It is argued that researching weather modification is needed at least to deter enemy forces from developing and deploying such abilities in a hostile manner.

5. Building a Multilateral Registry of Cloud Seeding Events

> ENMOD Article III, 2. The States Parties to this Convention undertake to facilitate, and have the right to participate in, the fullest possible exchange of scientific and technological information on the use of environmental modification techniques for peaceful purposes. [36]

Little scientific exchange seems to have resulted from the ENMOD Treaty. Exchanging information is of course a first step in a confidence building process in the development of a treaty. In cases of environmental modification, collecting information on activities is a necessary beginning point, starting with cloud seeding. A multilateral cloud-seeding registry, that is voluntary, can begin to reduce possible future ambiguities over weather modification by compiling and releasing reports of country activity.

[35] "Weather as a Force Multiplier: Owning the Weather in 2025", report to Air Force 2025 committee, August 1996.
[36] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 1978.

Registry information would need to be both instructive on practices as well as mindful of data collection costs and security issues. There could be several categories and types of reporting. These prescriptions might include include detail on the clouding seeding event, starting with the scope, intensity, and particular economic impacts on human health and economy. Countries might also report the type of chemical used to induce rain and the subsequent precipitation amounts in target and adjacent areas. The data collected would also include specific indicators of widespread, long-lasting, and severe impacts. But it would not be able at the beginning stages to collect data on every cloud seeding event. Rather, the initial focus should be on general programs.

The OECD countries might constitute a base of beginning data collection. They already collect environmental information across members and produce a bi-annual report. The categories of reporting could be incrementally introduced over time. The registry could be open to OECD affiliate members or to countries that have not joined ENMOD Treaty, including China, France, Nigeria, Indonesia, Spain, Mexico, South Africa, and Saudi Arabia.

A database of countries and some of their uses of cloud seeding are included in Appendix A. This preliminary list shows that at least 50 countries have used cloud seeding for precipitation enhancement, hail suppression, haze or pollution reduction, and other purposes. These reports give a taste of what types of information and events might be recorded. Here is what a registry might look like (see Table 1).

Table 1: A Proto-Type Cloud Seeding Registry

	State/Region	Goal	Type	Events	Impacts
Event Series 1*	Member states will determine the reporting region, which may be administrative or bi-geographic.	1. Rain 2. Snow 3. No Hail 4. Haze	1. Silver iodide 2. Dry ice 3. Liquid propane	Number and size of event area	1. Increase in rain or snow 2. Decrease in hail 3. Estimates of crop impact
Event Series 2					

Event Series 1*: Cloud seeding occurs as a series of events over a common geographic space for a specified period of time.

The effort will need cooperation of both governments and private entities and they may choose to participate at different levels of secrecy in revealing for example the compounds used. The registry will also need to establish some guidelines and guidance on how to estimate impacts on precipitation patterns. Estimating impacts could be quite imprecise and/or quite costly to undertake. Initial submissions might focus on a few in-depth studies of representative programs of geography and type.

One model for the registry might be the U.S. Toxic Release Inventory (TRI). The TRI came about in 1986 as a result of the Emergency Planning and Community Right-to-Know (EPCRA) provisions that were amended to Superfund legislation. The impetus for the action was the Bhopal disaster where inadvertent chemical releases killed many. TRI includes pollutants of certain industries only and with a certain minimum size. Since it's implementation many other countries have adopted such systems.

The registry can feed into a dispute resolution mechanism. The actual forum for adjudication might follow the model of the Law of Sea and the International Tribunal on the Law of the Sea

that hears and renders decisions on cases. These decisions could determine if there is cross-border damages that are the result of cloud seeding.

As climate change and technology proceed, the desire and the ability to claim fresh water will extend into the atmosphere and far underground. The search for water will not stop at the clouds but eventually claim every corner of the planet, and others, where water resides. The registry may be a means to offer transparency on uses of cloud seeding and avoid ambiguities that may be the basis for solving a variety of upcoming water disputes.

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Appendix A
Database of Cloud Seeding Countries

Use is Rain, Hail, or Both//Extent is High, Medium, and Low

Country	Use*	Extent	Notes	Source
Algeria	R	Low	France began testing in 1952	Arab Cloud
Argentina	H	Medium	Hail suppression for southern hemisphere spring planting	NCAR
Australia	R	High	Extensive use especially during current drought period, especially in Australian Alps	NCAR
Austria	B	Medium	Cloud seeding and hail suppression	NCAR
Bulgaria	H	Medium		NCAR
Burkina Faso	R	Low	Proposed	CILSS
Brazil	C	Medium	Extensive seasonal use	NCAR
Burkina Faso	C	Low		NCAR
Cambodia	R	Low	Cambodia is receiving technical assistance from Thailand	
Canada	H	Medium	Hail suppression for spring crops and also storm disbursement.	NCAR
Cape Verde	R	Low	Proposed	CILSS
Chad	R	Low	Proposed	CILSS
Chile	C	Low		NCAR
China	B	High	$100 million year, China building drone fleet. http://www.wired.com/dangerroom/2010/11/weather-machines-origami-drones-and-battlefield-dioramas-inside-chinas-big-air-show/	NCAR, Wired
Cuba	R	Medium and rising	Extensive seasonal use. Also assisting Venezuela due to drought there.	NCAR
France	C	Medium		NCAR
Gambia	R	Low	Proposed	CILSS
Germany	H	Medium	Hail suppression largely.	NCAR
Greece	B	Medium		NCAR
Guinea Bissau	R	Medium	Proposed	CILSS
Hungary	B	Medium		NCAR
India	R	High	Karnataka**,** Maharashtra, Andhra Pradesh are leading areas. In August 2012, the city of Mumbai paid to induce artificial rains because the Cauvery Basin Dam was low. Antara News, September 11, 2012, "Cloud Seeding in Riau, Jambi, and Central Kalimantan to suppress haze from Forest Fires"	NCAR
Indonesia	R	Low	Seeding used to reduce haze from fires	NCAR
Israel	R	Medium	Israel uses cloud seeding to increase	NCAR

			precipitation totals during rain events.	
Iran	R	Medium	Central Iran, Yazd, accusations the West is behind doughts	NCAR
Iraq	R	Low	Begin 1989	Arab Cloud
Japan	R	Medium	Used to counteract recent drought in Tokyo region	NCAR
Jordan	R	Medium	Begin 1986	Arab Cloud
Korea	R	Medium	Has been used for fog dispersal	
Libya	R	Low	Begin 1971	NCAR, Arab Cloud
Malaysia	R	Low	October 2012, Used in Bohol amid severe El Nino cycle. Fire haze suppression.	NCAR
Mali	R	Low	Begin in 2005	CILSS
Mauritania	R	Low	Proposed	CILSS
Mexico	R	Medium	Help from US, current drought has prompted calls for	NCAR
Morocco	R	Medium	Begin 1983	NCAR, Arab Cloud
Niger	R	Medium	Begin in 2005	CILSS
Pakistan	R	Low		NCAR
Philippines	R	Low		
Saudi Arabia	R	Medium	Begin in 1990, used in Southwest along the disputed Yemen border.	NCAR
Senegal	R	Low	Proposed	CILSS
South Africa	R	Medium		NCAR
Spain	R	Medium		NCAR
Russia	B	High	Used after Chernobyl to deflect radioactive rain prior to reaching Moscow.	NCAR
Syria	R	Low	Begin in 1991	Arab Cloud
Thailand	R	Low	Providing technical assistance to Cambodia	NCAR
United Arab Emirates	R	High	US NCAR project begins in 2000 **http://www.ral.ucar.edu/projects/UAE/** 2012, misting devices used to create localized rain in Abu Dhabi.	NCAR, Time
United States	B	High	Begin 1946, $15 million year. Extensively used in the west	NCAR
Uzbekistan	R	Medium		NCAR
Venezuela	R	Medium	Help from Cuba during drought has led to US fears of dual-use.	Article
Vietnam	R	High	Operation Popeye in Vietnam War	

Zimbabwe	R	Low		NCAR

* Cloud seeding for precipitation: rain and snow enhancement (R), hail suppression (H), or both (B).
Note: snow enhancement is used to build snow pack and to build snow for skiing.

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Africa cloud seeding
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CLOUD SEEDING IN IRAN: a possible dream or a distant illusion, 09/23/2012
"Cloud seeding is now being tied into political issues in Iran. Some government officials, including the president, have accused Western countries of reducing the level of precipitation in clouds as the approach Iran in order to cause droughts in the country.

Mahmoud Ahmadinejad, on a recent trip to Golestan Province, said the country is struggling with drought, and while part of this water shortage is unavoidable, parts of it are deliberate. He claimed that the enemy is depleting clouds that move toward the country and is thus engaged in an unbalanced human war. Similar statements have been made by the heads of the National Heritage and Environment Organizations. And some government officials have expressed belief in the idea that Iran's enemies are using modern technologies to create drought in Iran."
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http://newsinfo.inquirer.net/343737/nia-starts-cloud-seeding-over-magat-dam
January 20th, 2013
"The government has started cloud seeding operations over the watershed serving Magat Dam, hoping to mitigate the impact of the El Niño phenomenon this year, the National Irrigation Administration (NIA) said this week. "
October 2, 2012

"Cloud seeding in the UAE began 10 years ago when the government, together with the National Center of the Atmospheric Research (NCAR) in the USA and the University of the Witwatersrand in South Africa, ted a programme to introduce cloud seeding technology. And thus began what is called rainfall enhancement via hygroscopic seeding. So far, in terms of seeding events, as they are called, this year has been the busiest."
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