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The Checkered Past of Weather and Climate Control and Its Troubling Prospects

As alarm over global warming spreads, a radical idea is gaining momentum. Forget cuts in greenhouse gas emissions, some scientists argue. Instead, bounce sunlight back into space by pumping reflective nanoparticles into the atmosphere. Launch mirrors into orbit around the Earth. Make clouds thicker and brighter to create a „planetary thermostat." Deploy geoengineering – planetary-scale intervention technologies – to buy some time for mitigation to work. Capture and sequester the world's carbon emissions safely and economically for thousands of years. These ideas might sound like science fiction, but in fact they are part of a very old story rooted in human aspirations to control nature. For more than a century-and-a-half, scientists, soldiers, futurists, and charlatans have proposed (and in some cases tried) to manipulate and manage weather and climate, and like them, today's climate engineers wildly exaggerate what is possible. This article sketches the checkered and tragi-comic history of rainmakers, rain fakers, weather warriors, and climate engineers who have been both full of ideas and full of themselves. It demonstrates the power of history for uncovering hidden or forgotten assumptions and shows what can happen when geoengineering becomes a dangerous excursion into pseudoscience. It examines cutting edge issues of the day including health and navigation in the 1830s, agriculture and drought in the 1890s, aircraft safety in the 1930s, world conflict since the 1940s, and climate warming in recent decades.

Visionary schemes for weather and climate control have a long history, but with very few exceptions have never worked. In the 1840s James Espy, America's first national meteorologist, collected and mapped weather observations and developed a viable theory of storms powered by convection, but he went off the deep end with his weather control ideas. In his book „Philosophy of Storms" (1841), Espy proposed to imitate the effects of volcanoes by lighting giant fires each week all along the Appalachian Mountains. This, he claimed, would generate artificial rains, keep the rivers navigable, prevent hot and cold waves, and clear the air of miasmas. He claimed to be reviving the „art of making rain and wind" lost since the time of witches and magicians, but his ideas were ridiculed as being as dangerous as the misadventures of the sorcerer's apprentice (Anonymous 1841, p. 423).

Stimulated by casual observations during the Crimean War and the US Civil War, rain-making by concussion had its day in the mid-to late nineteenth century as various writers (none very scientific) speculated that cannonading the clouds

or setting off loud explosions could shatter the aetherial equilibrium, perhaps causing downpours or, in the right circumstances, disrupting hail-producing clouds. Robert Dyrenforth, with the support of the US Department of Agriculture, actually set out on a much-ballyhooed rain-making expedition to Texas in the summer of 1891 where his team detonated explosives, entertained the local citizenry with a „perfect imitation of battle," and claimed an extraordinary level of undocumented success (Fleming 2010, p. 64).

According to Daniel Hering's classic article on weather control, „[i]t is not in human nature to suffer from a prolonged or repeated evil without seeking for a remedy" (Hering 1924, p. 240). As an early example of being proactive when facing a threatening weather situation, medieval hail archers were ordered by the king to open fire on the clouds at the approach of a threatening storm. We can say in retrospect that this response was ineffective, but did it look this way to the participants?

In 1896 Albert Stiger, a vintner in southeastern Austria and burgomaster of Windisch-Feistritz, revived the ancient tradition of *hagelschiessen* (hail shooting) – basically declaring „war on the clouds" by firing cannon when storms threatened. Faced with mounting losses from summer hailstorms that threatened his grapes, he attempted to disrupt, with mortar fire, the „calm before the storm," or what he observed as a strange stillness in the air moments before the onset of heavy summer precipitation. Although official support waned after a decade, the practice lingered, for hope springs eternal, and on occasion the clouds did disperse following a bombardment. Given the enormous sense of relief felt by the grape growers, it was hard to convince them that their artillery had not shot the storm away. (Fleming 2010, pp. 80–83)

The dawn of aviation brought new needs and challenges, with fog dispersal taking center stage. In the 1920s, with concerns about aviation safety ascendant, independent inventor L. Francis Warren and Cornell chemistry professor Wilder D. Bancroft developed a scheme to dose the clouds with electrified sand delivered by airplane. Rainmaking and fog clearing were both on the agenda, but trials, supported by the US Army Air Corps, turned out to be less than promising. Two decades later during World War II, the British burned thousands of gallons of petrol in specially-designed burners surrounding military airfields to evaporate fog and light the way for returning aviators. This successful program, called FIDO, was deemed too expensive and impractical to continue after the war.

These early weather modification plans (some of surprisingly large scale) were couched in the context of the pressing issues and available technologies of their eras: Espy wanted to purify the air and make rain for the East Coast, Dyrenforth set out to solve the problem of drought in the West, Stiger was protecting his harvest, and Warren and Bancroft hoped to make rain and clear airports of

fog in the 1920s. During World War II, with national survival at stake, the British FIDO project succeeded, briefly but at great expense, in clearing fog from military airports.

The first of the modern geoengineering proposals that was not pure science fiction (but is indeed pure fantasy) belongs to Swedish scientist Nils Ekholm, who pointed out in 1901 that over the course of a millennium the accumulation in the atmosphere of CO2 from the burning of pit coal will „undoubtedly cause a very obvious rise of the mean temperature of the Earth." He thought that humanity might someday „regulate the future climate of the Earth and consequently prevent the arrival of a new Ice Age" by burning shallow coal seams or otherwise intervening in the carbon cycle – a process that would also fertilize plants (Ekholm 1901). Fifty years later Harrison Brown, the Caltech geochemist, eugenicist, futurist, and role model for the current US presidential science adviser John Holdren, echoed these ideas when he imagined feeding a hungry world by increasing the carbon dioxide concentration of the atmosphere: „We have seen that plants grow more rapidly in an atmosphere that is rich in carbon dioxide. [...] If, in some manner, the carbon-dioxide content of the atmosphere could be increased threefold, world food production might be doubled. One can visualize, on a world scale, huge carbon-dioxide generators pouring the gas into the atmosphere [...]. In order to double the amount in the atmosphere, at least 500 billion tons of coal would have to be burned – an amount six times greater than that which has been consumed during all of human history. In the absence of coal [...] the carbon dioxide could be produced by heating limestone." (Brown 1954)

Prospects for large-scale, even planetary intervention in the climate system arrived after 1945 with the dawn of nuclear power, digital computing, chemical cloud seeding methods, and access to space. It seemed as if technology was becoming powerful enough to allow human intervention in natural systems at a global level. That is, the ancient fantasy of controlling nature might become a reality, and humanity would soon engage in planetary geo-engineering. The Cold War added a sinister gloss to notions of control as the superpowers raced to weaponize nature.

In 1945, the prominent scientist-humanist-internationalist Julian Huxley, one of the founders of the United Nations Educational, Scientific and Cultural Organization (UNESCO), spoke to an audience of 20,000 at an arms control conference at Madison Square Garden about the possibilities of using nuclear weapons as „atomic dynamite" for „landscaping the Earth" or perhaps using them to change the climate by dissolving the polar ice cap (Kaempffert 1945, p. 77). But Huxley was just a talking head, right? No, serious scientists too were dazzled by the possibilities. In 1945, Vladimir K. Zworykin, the inventor of television and associate research director at RCA wrote an „Outline of Weather Proposal" (Zworykin 1945).

He announced that scientists were on the verge of developing digital computing equipment that could solve the equations of atmospheric motion, or at least search quickly for statistical regularities and past analog weather conditions. Zworykin suggested that „exact scientific weather knowledge" might allow for effective weather control. If a perfectly accurate machine could be developed that could predict the immediate future state of the atmosphere and identify the precise time and location of leverage points or locations sensitive to rapid storm development, effective intervention might be possible. A paramilitary rapid deployment force might then be sent to intervene in the weather as it happened – literally to pour oil on troubled ocean waters or use physical barriers, giant flame throwers, or even atomic bombs to disrupt storms before they formed, deflect them from populated areas, and otherwise control the weather.

Zworykin's proposal was endorsed by the famous mathematician John von Neumann who thought the digital computer „would provide a basis for scientific approach[es] to influencing the weather" (von Neumann 1945). It led to projects spearheaded by von Neumann in the US and by C.-G. Rossby in Sweden that produced the first weather forecasts via computer and developed conceptual foundations for the first general circulation and climate models.

Von Neumann warned against climate control in 1955, in a prominent article in *Fortune* magazine titled „Can We Survive Technology?" Reflecting on recent Soviet and American proposals for mega-engineering, he referred to managing solar radiation or changing the Earth's heat budget as a thoroughly „abnormal" industry that could have „rather fantastic effects" on a scale difficult to imagine. He pointed out that altering the surface reflectivity of specific regions or redirecting air masses in an attempt to trigger a new ice age were not necessarily rational undertakings. Tinkering with the Earth's heat budget or the atmosphere's general circulation, he claimed, „will merge each nation's affairs with those of every other more thoroughly than the threat of a nuclear or any other war may already have done." In his opinion, climate control could lend itself to unprecedented destruction and to forms of warfare as yet unimagined. It could alter the entire globe and shatter the existing political order. He made the Janus-faced nature of weather and climate control clear. The central question was not „What can we do?" but „What *should* we do?" As von Neumann stated: „The technology that is now developing and that will dominate the next decades [on a global scale such as nuclear weapons and climate intervention] seems to be in total conflict with traditional, and in the main, momentarily still valid, geographical and political units and concepts." This is „the maturing crisis of technology," a crisis made more urgent by the rapid pace of progress. (von Neumann 1955)

During the early Cold War, the General Electric Corporation (GE) developed methods for seeding clouds with dry ice and silver iodide, sparking a race of

sorts for commercial applications and military control of the clouds. Although field tests were inconclusive at best, Nobel Laureate Irving Langmuir hyped the possibilities, arguing that hurricanes could be redirected and that the climate might ultimately be controlled on a continental or oceanic scale with these techniques (Fleming 2010). At about this time the Soviet Union under Joseph Stalin was pursuing grandiose plans for controlling nature including reversing the flow of Arctic rivers, subjugating permafrost (the curse of the north), and opening up the Arctic Ocean by damming the Behring Strait. In the Soviet program, science was not just about observing and understanding nature; it was about exploiting and controlling it as well. There was a race for weather and climate control with the West. The program of the Communist Party of the Soviet Union declared in no uncertain terms: „The progress of science and technology under the conditions of the Socialist system of economy is making it possible to most effectively utilize the wealth and forces of nature for the interests of the people, make available new forms of energy and create new materials, develop methods for the modification of climatic conditions and master space." (Rusin and Flit 1962, p. 3)

The superpowers both engaged in reckless nuclear detonations in space. In 1958, University of Iowa physicist James A. Van Allen announced the discovery, by the Geiger counters on satellites Explorer 1 and Explorer 3, of Earth's magnetosphere. „Space is radioactive," noted Van Allen's colleague Erie Ray. This discovery was followed by the US military's Operation Argus, the detonation of three atomic bombs in space aimed at making space even more radioactive by contaminating the ionosphere with high-energy nuclear particles and radioactive debris. The goal was to disrupt enemy radio communications and possibly damage or destroy enemy intercontinental ballistic missiles.

The year 1962 was a busy one for geoengineering. The Soviets and the Americans detonated megaton thermonuclear devices in near space that year (Fleming 2011). The blasts came just at the peak of the Cuban missile crisis and during a time when meteorologists were trying to design and implement the peaceful sharing of data through the World Weather Watch. The tests led British radio astronomer Bernard Lovell, along with the International Astronomical Union, to protest that „[n]o government has the right to change the environment in any significant way without prior international study and agreement" (Saward 1984, p. 243). In a larger policy framework, the history of these space interventions and the protests they generated serves as a cautionary tale for today's geoengineers who are proposing heavy-handed manipulation of the planetary environment as a response to future climate warming. Undoubtedly Argus, Starfish Prime, and many of today's geoengineering proposals would fail ethical guidelines as articulated in the Belmont Report (1974).

Project Stormfury, a collaboration between the US Weather Bureau, the navy, and the air force, attempted to modify hurricanes between 1962 and 1983. Undaunted by earlier public relations disasters, the project involved a team of scientists and technicians flying into mature Caribbean hurricanes to seed them using military equipment. While the scientists involved were genuinely curious about the nature of storms, the navy's vision of weather control involved using fog and low clouds as screens against enemy surveillance, calming heavy seas, and redirecting violent storms both to enhance its own operations and to interfere with enemy plans and capabilities. The wish list included the capability to change the intensity and direction of hurricanes and typhoons; produce rain, snow, or drought as desired; and „modify the climate of a specific area" – all for the sake of military operations. As the navy saw it, the military problem in the field of weather modification and control was „to alter, insofar as possible, the environment surrounding the task force or target area so that the success of the naval operation is enhanced" (US Navy 1965, p. 1). In October 1962, the Cuban missile crisis brought the world to the brink of nuclear war and Fidel Castro accused the United States of having waged strategic weather warfare by changing the course of Hurricane Flora. Although the US claimed Flora was not seeded, its behavior was indeed suspicious. It hit Guantánamo Bay as a Category 4 storm and made a 270-degree turn, lingering over Cuba for four full days, with intense driving rains that caused catastrophic flooding, resulting in thousands of deaths and extensive crop damage (Simpson 1989).

Also in 1962, Harry Wexler, head of research at the US Weather Bureau, investigated the whole field of geoengineering and warned that a hostile power could detonate a chlorine or bromine „bomb" that would rip a giant hole in Earth's ozone layer. He had, in effect, identified catalytic ozone-depleting reactions that would later result in the awarding of Nobel prizes in chemistry. According to Wexler, „[Climate control] can best be classified as 'interesting hypothetical exercises' until the consequences of tampering with large scale atmospheric events can be assessed in advance. Most such schemes that have been advanced would require colossal engineering feats and contain the inherent risk of irremediable harm to our planet or side effects counterbalancing the possible short-term benefits" (Wexler 1962).

Meanwhile, between 1967 and 1974 operational cloud seeding was being used in a real war – over the jungles of Vietnam. The failure of Operation Popeye/Motorpool over the Ho Chi Minh Trail led to embarrassing revelations later in the Pentagon Papers and to a UN Resolution, ENMOD, outlawing environmental modification as a weapon of war (Fleming 2006). Cold War geophysicist Gordon MacDonald noted that the lesson of the Vietnam experience was not that rainmaking is an inefficient means for slowing logistical movement in jungle trails,

but „that one can conduct covert operations using a new technology in a democracy without the knowledge of the people“ (MacDonald 1975, p. 5).

In summary, we can say that after 1945 transformative technologies such as nuclear weapons, digital computing, chemical aerosols, and the space program fueled Cold War competition between the superpowers and encouraged speculation about and in some cases actual attempts at geoengineering. Some of this activity was motivated by scientific curiosity, but most was in the genre of weather and climate warfare. In 1992 the US National Academy report on Policy Implications of Greenhouse Warming contained a section on climate engineering suggesting that shooting sulfates into the stratosphere using naval guns would be a more cost-effective response to climate warming than carbon mitigation (US National Academy 1992). Committee member Robert A. Frosch referred to the technique as „designer volcanic dust put up with Jules Verne methods“ (Fleming 2010, p. 247).

Table I (p. 178) summarizes weather and climate control activities – proposed, actual, and warnings – in the past 175 years.

Recently, atmospheric scientist William Cotton pointed out the relationship between weather engineering and climate engineering, along with their systematic problems and structural differences. In weather modification experiments, the scientific community requires „proof „ that cloud seeding has increased precipitation. Following an intervention, such proof would include „strong physical evidence of appropriate modifications to cloud structures and highly significant statistical evidence“ – that is, effects that exceed the natural background variability of the atmosphere. But intervention is not control. In 1946, Kathleen Blodgett at General Electric told Irving Langmuir that intervening in or modifying a cloud was a far cry from attempting to control its subsequent motion, growth, or the characteristics of its precipitation. Having experienced the promise and hype of cloud seeding, and after having worked for fifty years in this field, Cotton admitted, „[w]e cannot point to strong physical and statistical evidence that these early claims have been realized.“ He went on to note that proof of success in climate engineering would be far harder to establish than in weather engineering. In fact, it would be impossible, for several reasons: climate models are not designed to be predictive, so there is no forecast skill; global climate experiments cannot be randomized or repeated and cannot be done without likely collateral damage; climate variability is very high, so the background-noise-to-signal ratio is overwhelming; and climate change is slow to develop because of built-in thermal lags due to oceans and ice sheets. What all this adds up to is that experimental „results“ could not be established even within the experimenters' life spans. Did I mention the chaotic behavior of the climate system? That alone would overwhelm any attribution of experimental interventions by climate engi-

Table I. Weather and Climate Control: Proposed (P), Actual (A), and Warnings (W). Source: Fleming 2010

Year	Status	Event
1841	P	James Espy proposes lighting giant fires to make rain
1891	A	Robert Dyrenforth claims rainmaking by concussion during Texas drought
1890s	A	Hail shooting widely practiced in Austria and across Europe
1901	P	Nils Ekholm proposes burning coal seams to prevent the return of an ice age
1920s	A	Experiments with electrified sand for fog clearing and rainmaking
1944	A	British FIDO project clears fog at military airfields
1945	P	Julian Huxley suggests nuclear weapons could dissolve polar ice cap
1945	P	Vladimir Zworykin proposes perfect prediction/control with digital computer
1947	A	Project Cirrus attempts diversion of Atlantic hurricane
1950s	P	Soviets “declare war” on permafrost and seek an ice-free Arctic Ocean
1954	P	Harrison Brown envisions CO2 generators and scrubbers to regulate climate
1955	P	Irving Langmuir proposes Pacific Basin cloud seeding
1955	W	John von Neumann warns of global climate control and nuclear war
1958	A	Project Argus, three atomic bombs detonated in magnetosphere
1962	W	Harry Wexler warns that 100 KT bromine bomb could destroy ozone layer
1962	A	Project Stormfury critiqued by Fidel Castro and government of Mexico
1962	A	Starfish Prime, H-Bomb detonated in magnetosphere. Similar Soviet tests.
1965	W	Gordon MacDonald warns that geoengineering could wreck the planet
1967	A	Monsoonal cloud seeding over Vietnam leads to UN ENMOD treaty (1978)
1992	P	US National Academy suggests shooting sulfates into the stratosphere
2006	P	Paul Crutzen’s „Modest Proposal“ (Crutzen 2006)
Since 2006	P	A plethora of proposals from geoengineers inspired by Heath Robinson, Rube Goldberg, and Dr. Strangelove including fertilizing the oceans, capturing and sequestering all CO2 emissions, genetically modifying crops, painting roofs white, making clouds brighter, suppressing cirrus cloud formation, putting reflective nanoparticles in the stratosphere, launching space mirrors, surrounding Earth with dust from a pulverized asteroid, and on and on … (Climate Engineering)

neers. Cotton warned that in times of drought or climate stress, politicians would emerge with the need to demonstrate that they were doing something, that they were in control of the situation, even if they only enacted what he called political placebos.

Weather and climate control have been proposed, and in some cases practiced, many times in the past. The checkered history of this field provides valuable perspectives on what might otherwise seem to be completely unprecedented challenges.

Yet the modern engineers err if they ignore this history. Some have falsely claimed recently that:

„We don't have a history of geoengineering to fall back on ..." — *Yes we do*.

„Things are moving quickly, so we don't have the luxury of looking at history." — *We must take the time*.

„We are the first generation to think about these things." — *History says otherwise*.

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