AD-A283 033

REPOR

Public reporting burden for this collecti gathering and maintaining the data nee collection of information, including sug Davis Highway, Suite 1204, Arlington, V

Form Approved
OMB No. 0704-0188

the time for reviewing instructions, searching existing data sources, omments regarding this burden estimate or any other aspect of this Directorate for Information Operations and Reports, 1215 Jefferson Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1993	FINAL

4. TITLE AND SUBTITLE
Weather Modification: The Ultimate Weapon

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
Unnumbered AWC research paper

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
PAPER IS WRITTEN TO FULFILL ACADEMIC RESEARCH REQUIREMNTS FOR AN IN-RESIDENCE SENIOR SERVICE PROFESSIONAL MILITARY SCHOOL.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS
Weather, Ultimate, Weapon

15. NUMBER OF PAGES
27

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLAS	UNCLAS	UNCLAS	UL

AIR WAR COLLEGE

AIR UNIVERSITY

Weather Modification: The Ultimate Weapon?

by

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A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE CURRICULUM

REQUIREMENT

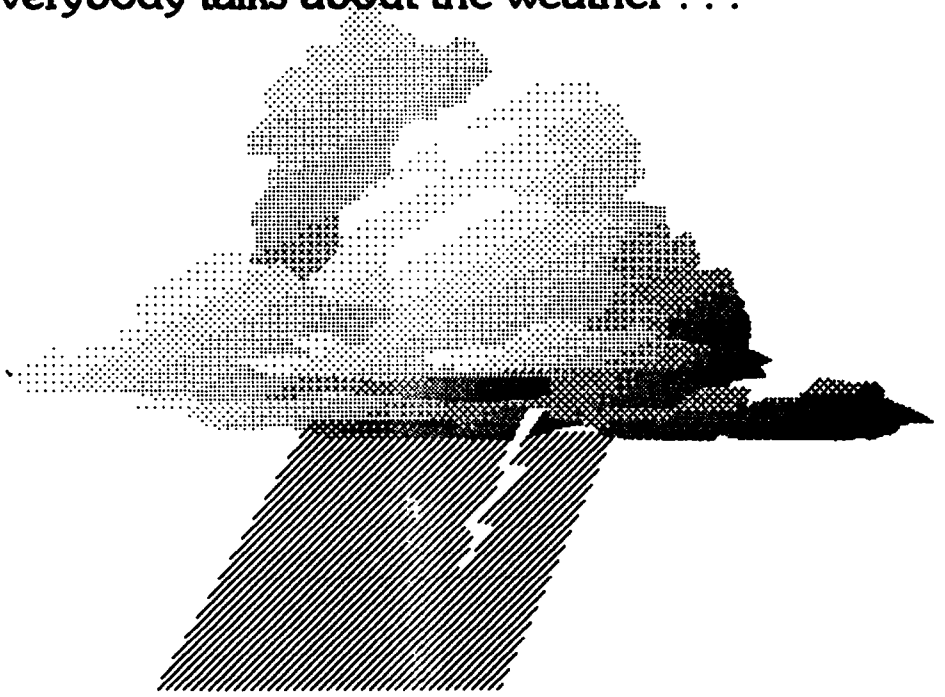
A Surprise piece of evidence, I guess as a first grade research paper on the subject

Advisor: Dr. Armin Ludwig

MAXWELL AIR FORCE BASE, ALABAMA

April 1993

Everybody talks about the weather . . .



but nobody does anything about it!

--Mark Twain

Introduction

Weather modification. The very words conjure up an image of quackery, charlatanism and trickery. Attempts to control or alter the weather are almost as old as civilization itself, ranging from the incantations of ancient priests, through the famous rain dances of North American Indians, to modern computer-supported experimentation and modeling. Yet, in spite of this long history, the credibility of these techniques has always remained rather low, due principally to the inherent problem of verifying results. However, while many obstacles remain to be overcome, considerable technological and scientific progress in weather modification has been made since the Second World War, to the point where it deserves serious consideration, especially in light of the potentially catastrophic consequences of its use.

Any examination of weather modification requires a careful definition of the subject since it is conceivably such a far-reaching technology that it tends to transcend many traditional scientific boundaries. For instance, there is the issue of intent. It has become increasingly obvious that mankind's activities have begun to significantly alter the ecological balance of the Earth's environment. Such phenomena as acid rain, the controversial "greenhouse effect," the depletion of the ozone layer, the destruction of tropical rain forests and desertification have come to the forefront of national and international environmental agenda. While there can be no doubt about the seriousness of these problems, they are not the result of deliberate attempts to alter the environment. Rather, they are undesirable

secondary effects from a variety of human activities and thus cannot be considered as legitimate weather modification techniques.

A distinction also needs to be made between weather modification and the larger question of environmental modification. Weather modification is essentially any artificially produced change in the composition, behavior, or dynamics of the *atmosphere*.[1] Environmental modification does include weather modification, but it also goes on to encompass some rather strange and horrific ideas. Among others, these include earthquake triggering, tsunami (tidal wave) generation, and icecap melting. There has even been a truly bizarre proposal to alter the electrical properties of the atmosphere over a region in order to interfere with the functioning of the human brain and thereby drive the affected population insane.[2] Many of these concepts are far-fetched, some are interesting, but none of them belong in any serious discussion of weather modification.

Similarly, environmental terrorism, such as Saddam Hussein's actions in Kuwait during the Gulf War, cannot be viewed as a legitimate form of weather modification. While the Iraqi actions did have serious climatological effects, it is not at all clear that these effects constituted the main objective, so there is a question of intent. Furthermore, the effects were more in the category of destructive pollution than environmental modification, *per se*.

Even within the topic of true weather modification, there is a considerable diversity of issues, not the least of which is the dichotomy formed by military and civilian interests. Civilian programs are predominately agriculturally-oriented, while the military tends to be more interested in using weather for hostile purposes. While each group may use similar techniques and suffer the same problems of practicality and effect, the military purposes raise

some thorny ethical questions which must also be considered.

With the foregoing in mind, the focus of this paper will be on the *deliberate use of weather modification techniques by the military.* The discussion will concentrate on the practicality and morality of weather warfare, with the aim of demonstrating that military weather modification may be technically feasible, but some of its forms may be difficult to justify on grounds of practicality and ethics.

The Potential

The first question that must be answered in examining the military use of weather modification is whether such techniques have any military utility. This question is very easily answered in the affirmative. Even the local manipulation of smaller weather systems holds great promise for the disruption of an enemy's operations at critical junctures. Perhaps the "fog of war" could someday become more than just a descriptive allusion to battlefield confusion.

Indeed, when one considers the crucial role that weather has played in many battles, it is clear that the ability to modify the weather would provide a tremendous advantage to any force possessing even a rudimentary capability. Examples of the weather influencing the outcome of a battle range from Washington's crossing of the Delaware under cover of a snowstorm, to the winter snows halting both Napoleon's and Hitler's invasions of Russia. The air campaign of the recent Gulf War was also hampered in its early days by an unexpected and unusual amount of foul weather.

Reflecting on the importance of weather to the Normandy invasion of World War II, General Eisenhower wrote:

> it was a tense period made even worse by the fact that the one thing that could give us this disastrous set back was entirely outside our control. Some soldier once said: "The weather is always neutral." Nothing could be more untrue. Bad weather is obviously the enemy of the side that wants to launch projects requiring good weather, or the side possessing the greatest assets such as strong air forces which depend on good weather for effective operations. If really bad weather should endure permanently, the Nazis would need nothing else to defend the Normandy coast.[3]

Even with the great advances in warfighting technology since those days, the weather remains a key component of success, especially for air power. The aid that bad weather might have provided the Nazis could also have been invaluable to Saddam Hussein in the Gulf War. Many of the weapons that were so effective at devastating the military infrastructure of Iraq depended on visual acquisition. Laser designators, electro-optical "smart" bombs, and TOW missiles are all subject to considerable operational degradation due to obscurations and restrictions to visibility.[4] This military potential of weather modification was even explicitly recognized in 1957, when the President's Advisory Committee on Weather Control, which included such scientific luminaries as Edward Teller, issued a report in which they warned that weather control could become a more important weapon than the atomic bomb.[5]

As one probes deeper into this question of weather modification for military purposes, it becomes evident that the techniques and methods fall into two broad categories of meteorological interventions: defensive techniques and offensive techniques. Another way to look at it would be to classify the techniques as involving either the suppression or the intensification of adverse weather.

More specifically, suppression weather modification is the use of palliative techniques in order to protect facilities and equipment from damage, as well as to facilitate operations that would otherwise be constrained by the weather. Examples of this type of activity include the dissipation of fog or cloud, the suppression of hail and lightning, and the attenuation of severe storms.

In contrast, offensive weather modification is the deliberate intensification or alteration of weather systems in order to disrupt the enemy's operations and destroy or damage his facilities or equipment. This is the use of weather as a weapon, which can include fog generation, storm intensification and guidance, precipitation augmentation and hail generation. It essentially involves the stimulation of latent instabilities in the weather system in order to achieve a desired larger effect.[6] This is an important point because the creation of significant weather phenomena from scratch is probably beyond human means. According to Edward Lorenz, a professor of meteorology at MIT, legitimate weather creation would require that the effects exceed natural variations. For instance, if the natural variation in summertime temperatures in a region is half a degree, you would have to do something that would cause more than half a degree change over a sizeable region. This would require the expenditure of an enormous amount of energy--more than that contained in several H-bomb explosions.[7] Unfortunately, these practical difficulties with weather *creation* are often falsely ascribed to weather *modification*, although the circumstances are entirely different.

Thus, there can be little doubt that weather modification has tremendous military potential. However, if that potential is to be realized, the techniques and technologies must be practical. In order to properly assess this question of feasibility, it is necessary to begin

with the technological history of weather modification.

The History

Weather modification has a long history, though much of it is decidedly unscientific. The Bible cites the case of Joshua who made the sun "stand still" at the battle of Gilboa so that he could finish destroying the enemy before dark.[8] In the April 5, 1839 issue of the *National Gazette and Literary Register* of Philadelphia, James P. Espey claimed that if large fires were lit, the resulting updrafts would create cumulus clouds and bring rain.[9] He proposed that a string of small timber lots along the western frontier from the Great Lakes to the Gulf of Mexico be set ablaze once a week . Espey claimed that this would result in a line of rain showers which would then travel eastward to the Atlantic.[10]

Another curious episode in the history of weather modification occurred at the end of the Civil War when Edward Powers, a civil engineer, published a book entitled *War and the Weather*, in which he postulated that the noise of battle had generated rainstorms. In 1890, Congress appropriated nine thousand dollars to test this theory. A series of massive nighttime explosions were detonated in Texas in the summer of 1891, but the results were inconclusive. The researchers, though, were undaunted and decided to repeat the experiment at Fort Myer, Virginia, across the Potomac from Washington D.C. This was a spectacularly bad choice of locale for the noisy explosions in the middle of the night provoked a storm of protest, but little rain. The project was subsequently quietly cancelled.[11]

Other famous weather experimenters included an American doctor named Leon

Chaffee, who flew above clouds in 1924 in order to bombard them with shovelfuls of sand. He claimed that his technique caused the clouds to disappear.[12] Realistically, though, serious and scientific investigation of weather modification dates from the end of World War II.

In 1946, Dr. Irving Langmuir and his laboratory assistant, Vincent J. Schaefer, discovered that dry ice fragments could induce nucleation in clouds of supercooled water droplets. Shortly thereafter, Dr. Bernard Vonnegut, working independently in the General Electric laboratories, discovered that silver iodide particles were even more effective at generating nucleation; the particles were surmised to be much more efficient nuclei than those occurring naturally.[13] This was an important milestone in the history of weather modification for

> without this artificial nucleation, thermodynamically unstable conditions may be checkmated by colloidal stability, and, therefore, pass on or dissipate without having produced the weather benefits of which they are capable; or they may become intensified until the ultimate spontaneous outbreak is vastly harmful.[14]

Vonnegut initially had no thought of using his discovery outside the laboratory, but the publicity surrounding his discovery and the Langmuir/Schaefer efforts soon led to a rapid growth in research projects.

The first major study which resulted from this increased interest was the U.S. government-sponsored Project *Cirrus* which began in 1947. It concentrated mainly on cloud seeding in order to induce precipitation, but notable experiments involving hurricane seeding were also undertaken. This led to some rather serious controversy, as in the following case:

> on October 13 [1947] a flight was made into the vicinity of a hurricane located about 350 miles east of Jacksonville, Florida. One of the spiral rain bands . . . was seeded. Project *Cirrus* flight personnel reported from visual observations that there was a pronounced modification of the cloud deck after seeding. Shortly after the seeding, the hurricane, which had been travelling northeastward, changed its course

> and headed almost straight westward to strike the coast of South Carolina and Georgia. There was much speculation concerning the possibility that the seeding was responsible for changing the path of the hurricane.[15]

This controversy was pivotal for weather modification research because it demonstrated that the possible legal consequences arising from the deliberate alteration of such damaging storms meant that little future experimentation could be carried out on any storms which had the potential to reach land. This was typical of the difficulties that were to plague weather modification research.

Project *Cirrus* continued on into the 1960s with a mixed record of successes and failures. As with all weather modification experiments, it soon became apparent that it was very difficult to verify the results of the seeding. In other words, did the precipitation occur because of seeding or in spite of it? Several studies were made of the project results, with the most thorough probably being that sponsored by the U.S. National Academy of Sciences during the period 1968 to 1973. They concluded that

> in certain meteorological situations not completely understood, seeding can increase precipitation from 10 to 30 per cent over what would have been expected. Hence, in the longest randomized cloud-seeding research project in the United States involving cold orographic winter clouds, it has been demonstrated that precipitation can be increased by substantial amounts and on a determinant basis.[16]

However, the most significant result of the project was the increased scientific legitimacy that it furnished to weather modification. This gave rise to a whole series of weather modification experiments, as well as spawning a commercial cloud seeding industry.

One of these new areas of research involved the suppression of hail; various experiments in this field were subsequently undertaken in many larger agricultural countries of the world, including Canada and the U.S.S.R. The basic technique consisted of saturating

hail-forming clouds with a super-abundance of ice crystal nuclei so that the available water would be used up, thereby inhibiting the growth of hailstones by riming. The Soviet Union claimed an incredible 70 to 80 percent reduction in hail damage in some areas due to these techniques, but there was considerable skepticism elsewhere concerning the statistical validity of their results.[17]

In the United States, Project *Hailswath*, conducted in 1966 near Rapid City, South Dakota also reduced hail damage but most scientists did not view the results as conclusive.[18] Other large projects in the U.S., Canada, and South Africa obtained an estimated 20 to 50 percent reduction in hail damage, although their findings were also controversial.[19]

Fog dissipation was another area which received considerable attention, primarily in support of airfield activities. In fact, there had been previous attempts to clear fog from runways during the Battle of Britain with ground-based thermal systems which were installed at 15 RAF aerodromes. These FIDO systems (Fog, Intensive, Dispersal Of) consisted of a series of pipes along the runways through which aviation fuel was pumped and ignited as it escaped through small holes. Despite some technical problems, the FIDO system was credited with assisting the landings of over 2,500 aircraft by the end of the war.[20]

After the war, most of the fog research concentrated on two main areas--the dissipation of cold fog using hygroscopic seeding techniques and the dispersion of warm fog through artificial warming. Several projects were funded by the U.S. military; most of them succeeded in dispersing fog to some degree. The most difficult problems remained the cost of such systems, as well as the dispersion of advection fog which is associated with a moving airmass and thus tends to fill any cleared area with more fog.

One of the more significant warm fog projects was the installation of the *Turboclair* system at Orly airport near Paris in 1970. This system consisted of a series of jet engines installed in underground chambers along the upwind side of the runway. Tests showed that the system could improve the visibility in the approach and touchdown portions of the runway to at least the minimums required for operations.[21]

In the case of supercooled fog, several experiments proved that dry ice seeding can be a cheap and effective dissipation technique. Thirteen American commercial airports were using it on an operation basis in 1973.[22] The USAF also conducted successful cold fog dispersion trials with a ground-based liquid propane dispensing system.[23]

Another project which aimed to alter the weather began in 1952 under the sponsorship of the U.S. Forestry Service. This was Project *Skyfire* which sought to prevent lightning from igniting forest fires. The basic principle was to try to cause artificial corona discharges between numerous tiny conductors introduced into the storm and thereby harmlessly dissipate its electrical potential.[24] Various agents were used, including silver iodide, dry ice crystals, and chaff. In comparing the results from 10 storms that were seeded against a control group of 18 unseeded storms, there appeared to be a 75 percent reduction in lightning strikes in the modified storms.[25] This was judged to be statistically significant although the experiments were not strictly randomized.

Space does not permit a discussion of many of the numerous other experiments in the history of weather modification, but one project stands out as probably the most famous undertaking and certainly the most germane to this paper. This was the cloud seeding operations carried out by the U.S. military over Southeast Asia from 1968 to 1972 with the

objective of inhibiting the logistical operations of the North Vietnamese along the Ho Chi Minh Trail. The operation came to be known by a variety of codenames: *Popeye, Intermediary, Compatriot,* and *Motorpool.* It was highly classified at the time and known only to the President, a few high-ranking military officers, and the assigned aircrew. We had come a long way since Mark Twain-- something was being done about the weather, but nobody was talking about it.

Most of the precipitation enhancement missions were flown out of Udorn, Thailand with WC-130s and RF-4Cs at the freezing level, at approximately 18,000 feet. A total of 2,602 sorties were flown over the five year span of the operation and 47,409 canisters of seeding agents were dispersed into clouds.[26]

When the details of this operation began to surface in the early 1970s, it not only caused a political storm but also provoked considerable controversy as to the efficacy of the program. Much of the criticism was based on the classic weather modification problem: verification of results. However, Defense Intelligence Agency officials estimated that rainfall had been increased up to 30 percent over certain areas, although their findings were likely somewhat biased.[27] It is also unclear whether the rain had any appreciable effect on the movement of enemy supplies. Nonetheless, in 1972, North Vietnam experienced a series of torrential rainstorms that continued well into the normal dry season. Roads and dikes were washed away and an estimated 10 percent of the rice crop was destroyed.

The USAF has also carried out several precipitation enhancement projects for beneficial purposes, with the largest operation being Project *Gromet II* in the Philippines in 1969. Other American military drought mitigation operations have been conducted in

Panama, Portugal and Okinawa.[28]

It is therefore evident that weather modification has a long and colorful history, but considerable doubts remain as to its effectiveness. Still, although the technology is in its infancy, enough legitimate research has been accomplished to allow some reasonable speculation on the feasibility of weather modification for military purposes.

The Feasibility

Research itself is one of the biggest problems associated with the provision of a definitive judgement on the effectiveness of weather modification. Early experiments were characterized by a haphazard approach to statistical analysis which tended to reduce both the internal and external validity of their findings. The basic problem has always been whether the observed changes in the weather were due to an intentional intervention or merely the result of natural fluctuations.[29]

Much of this confusion can be traced to an imperfect understanding of the weather processes involved. However, this problem is not insurmountable. Statistical methods designed to compensate for some of these difficulties have been developed in conjunction with the design and analysis of comparative experiments in biological and agricultural research in which large and only partially controllable variability is present.[30] Weather modification experiments have also benefitted from increasing knowledge of the physical properties of clouds and their natural variability.[31] Moreover, recent progress in computer technology has improved the computational resolution of numerical atmospheric models

thereby enhancing their usefulness for weather modification research.[32] For instance, a very active weather modification program in North Dakota, in operation since 1961, has used tracer chemicals with new high-speed analyzers to track the progress of silver iodide seeding in a cloud. The results have provided some interesting insights into which are the best clouds to seed, as well as when and where to do the seeding.[33]

Another experiment in Texas, headed by cloud physicist William Woodley, used sophisticated computer programs which analyzed weather radar imagery in order to provide definitive evidence of the effects of seeding. His results indicated that seeded clouds produced more than twice as much rain as their unseeded counterparts.[34] Still, in spite of this impressive progress in weather modification research, some fundamental climatic processes remain poorly understood, such as the transfer of heat to and from the oceans and how that heat is moved to different parts of the globe by ocean currents.[35]

Another problem, perhaps even more intractable than the operational validity of these experiments, is the contentious issue of legal liability. Weather modification experiments can be developed in the laboratory and simulated to some extent on computers, but, in the end, they must be attempted in the atmosphere. The problem then arises of unintentional civil damage from weather systems which had been subject to modification experiments, whether or not those efforts were effective. Imagine, for instance, if it was revealed that a government agency had been experimenting with Hurricane Andrew before it struck the Florida coast in 1992. Any government agency would have a tough time surviving a controversy of that magnitude, especially given the possibility of billions of dollars in compensatory and punitive damage awards.

A less hypothetical example occurred in 1972 in Rapid City, South Dakota. Project *Skywatch*, under the sponsorship of the Bureau of the Interior, seeded some clouds north of the city with over 500 pounds of nucleating salt. A tremendous storm followed which caused a flash flood that burst the Canyon Lake Dam. The result was 238 people dead and hundreds of millions of dollars in damage.[36] Subsequent investigations established that th seeding was not responsible for the specific storm that caused the flood. Public opinion polls also showed that the majority of the town's inhabitants did not blame the weather researchers for the disaster.[37] Still, such events do raise some interesting problems. The practical result has been a severe limitation on weather modification research where there is any likelihood of damage to property or personal injuries; this has virtually eliminated some types of experiments, such as hurricane modification.

These examples of projects gone awry also raise some profound questions as to the feasibility of *offensive* weather modification, for if such unforeseen consequences occur during relatively limited experiments, there is a significant possibility that a wider use of weather modification on the battlefield could result in significant fratricidal damage. The storm you send to strike your enemy may instead pounce on you. Of course, weather modification is still an emerging technology; presumably, as progress is made, such risks would diminish, but offensive weather modification will likely always remain a high-stakes wager. The payoffs can be enormous but so can the losses.

On the other hand, localized suppression modification--fog and cloud dissipation, hail suppression, and other such ameliorative techniques--offers greater technological promise and less legal risk. There is little potential for a successful lawsuit challenging the clearing of a

heavy fog, or the dissipation of a severe hailstorm. Furthermore, although suppression techniques are not as spectacular as the more overtly hostile offensive weather modification, the results can be important for the military, especially in an area like Western Europe which is plagued by bad weather and poor visibility.

In general, therefore, it must be concluded that the military feasibility of offensive weather modification is limited. The present technology is uncertain, research is difficult, and the results can be unpredictable to the point where the risk outweighs the possible gain. In contrast, the more defensively-oriented suppression techniques have a reasonably sound technological base, good potential for further research, and a reasonably high payoff. Nevertheless, there remains a question of ethics and morality in any use of weather modification, especially by the military. Does the military have the right to interfere with complex, poorly-understood weather systems in the name of national security?

The Ethics

The use of weather as a weapon by the military raises many questions that, at best, can only be partially answered. In many ways, offensive weather modification is a technology in which man's reach often exceeds his grasp. The capability to modify large and very powerful weather systems now exists, although the extent and effectiveness are debatable. More certain is the fact that the effects of human intervention are not well understood. Offensive weather modification is a very unpredictable weapon which, individually or in combination with natural phenomena, could cause terrible damage to the

world ecosystem through unforeseen and uncontrollable reactions. Even in the name of national security, it is very difficult to justify such a weapon.

Offensive weather modification poses another thorny ethical problem in that it would be difficult to determine responsibility for changes in the weather. Weather is generally assumed to result from natural forces; thus, offensive weather modification is a technology which lends itself to covert action, especially in the case of long-term climate modification which could be used to economically drain an enemy. Such actions could remain unknown to the general citizenry of both the victim and the aggressor nations. For example, one scientist has proposed fertilizing the Antarctic Ocean with iron in order to encourage algae growth which would draw carbon dioxide out of the atmosphere and result in global cooling.[38] While the scientific rigor of this particular theory may be debatable, it does serve to illustrate the potential for a covert climate modification project, with fearful consequences for which it would be difficult to assign blame.

Consequently, in spite of the tremendous military utility of offensive weather modification, its use must be viewed as morally repugnant. This does not mean that all research into the offensive use of weather modification should cease for there are a number of governments in the world who do not feel constrained by conventional morality. At the very least, one should have the means to detect attempts to modify the weather, and, hopefully, to counter the effects. In fact, during the early 1970s, Project *Nile Blue* of the U.S. Defense Advanced Research Project Agency had this weather modification detection mission as its primary objective.[39]

This leads to an area of military weather modification which is much easier to justify--

local suppression modification. As mentioned earlier, the technology is more predictable and since it seeks only to alleviate some of the destructive aspects of weather, it is much less controversial. The civilian applications of this technology are similarly beneficial and could be used as further justification for continued research.

Based on the foregoing discussion, it seems reasonable to conclude that offensive weather modification is neither practical nor very ethical as a military weapon; it is also apparent that suppression modification has much better potential. History, though, has often shown that if a new military technology is developed, especially one with the great possibilities of offensive weather modification, it will eventually be used unless it is proscribed by effective international agreements.

The Treaties

Concern about the possible detrimental effects of offensive weather modification began to grow in the 1960s, coincident with the increase in technological sophistication. Much of this concern was restricted to the scientific and environmentalist communities until 1972, when Senator Claiborne Pell and the Senate Foreign Relations Committee began to investigate the precipitation augmentation activities of the American military forces in Vietnam.

When the Vietnam weather modification operation was finally revealed to the public in 1974, the resulting controversy led to a series of hearings in the U.S. Senate. Shortly thereafter, the North Atlantic Assembly adopted a proposal that recommended that NATO

prohibit the use of environmental modification, "except for peaceful purposes and for the betterment of mankind, and for purposes which have no effect on the ecological balance."[40] In the United Nations, the Soviet Union proposed a resolution in 1974, later adopted by the General Assembly in 1977, to prohibit hostile use of environmental modification techniques. The resulting "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques" committed the signatories to refrain from any military or other hostile use of weather modification which could result in widespread, long-lasting or severe effects.[41]

Unfortunately, although these conventions represented significant progress, they contained many loopholes, not the least of which was the fact that they were limited to "widespread" effects, thereby allowing the tactical use of weather modification to escape the ban.[42] Similarly, the difficulties of verifying and enforcing such a ban soon became apparent. In the case of the United Nations convention, suspected violations are referred to the Security Council for investigation. While the recent end of the Cold War has engendered a new sense of cooperation in the U.N., the fact remains that the veto power in the Security Council has effectively emasculated this treaty in the case of any Great Power involvement.[43]

After this flurry of activity in the 1970s, international interest in this issue began to wane and little progress has been made in recent years, although local objections to weather modification programs in Canada and the United States has been growing along with general concern for environmental degradation. In fact, even in regions where cloud seeding has been used for 25 years, there is now an organized and vocal opposition.[44]

The Future

Predicting the future of weather modification is almost as difficult as accurately predicting tomorrow's weather. U.S. research is continuing, albeit at a decidedly lower pace than during the heyday of the immediate post-Second World war era. The emphasis has also shifted from overt experimentation on the atmosphere to efforts to produce a realistic computer simulation that could be used for forecasting and experimentation. In the United States, federal money for modification research has dropped from $25 million per year in 1981 to a few million per year.[45] Worldwide, the trend is somewhat different, as the World Meteorological Organization has estimated that in 1989 there were 118 active weather modification programs in 32 countries, compared with 80 projects in 1983.[46]

In spite of these impressive figures, most of the active weather projects in the world (at least the ones of which we are aware) appear to be civilian. The world's military forces do not seem to be very interested in pursuing the use of weather as a weapon, although that could quickly change, especially given the vulnerability of some precision-guided munitions to adverse weather. The often unstable leadership of the military forces of the Third World may also see opportunities in offensive weather warfare where most other nations would only see disaster.

In contrast, there seems to be good potential in the military use of suppression techniques to reduce vulnerabilities and facilitate operations, although many problems remain to be solved. Consequently, this area will likely receive the bulk of serious attention. Nevertheless, the conceivably calamitous effects of offensive weather modification militates

against a complete abandonment of research in this field, if only to be able to detect hostile meddling. Perhaps the best solution would be an international body, similar to the International Atomic Energy Agency, which could provide the proper supervision, as well as a registry for weather modification operations in order to reduce suspicion between governments.[47]

At present, international interest in weather modification treaties is relatively limited compared to the heated debates of the 1970s, but the largely tacit agreements already in place are far from complete and the issue could once again spring into prominence if any significant attempts to use weather modification in a hostile context are revealed. Moreover, recent conferences, such as the Earth Summit in Rio de Janeiro, have focussed worldwide attention on the deleterious environmental effects of routine human activities. Public opinion has become highly sensitized to environmental issues, rendering it a dangerous area for involvement by Western military forces, even if only for research purposes. Unfortunately, there are many regimes in the world who do not feel similarly constrained.

Conclusion

Military weather modification is not a fantasy--it is a fact. Both offensive and suppression techniques have already been employed by military forces engaged in various conflicts ranging from the Second World War to Vietnam. The success of these operations is controversial, the ethics somewhat doubtful and the practicality is questionable, but they have still occurred.

Many of the doubts have been focussed on offensive weather modification wherein the techniques are more unreliable and the results less predictable. With this limited practicality, as well as the ethical problems associated with hostile weather modification, it does not seem to be a viable military weapon. Nonetheless, its potential is so enormous that theoretical research must continue into offensive weather modification in order to understand its effects if one should ever become its victim.

In marked contrast, however, the use of local suppression techniques to improve the weather shows great technological promise and is much easier to justify. The elimination or dissipation of fog, lightning, hail and other damaging phenomena would not only aid military operations, but could also prove immensely beneficial to the civilian populace. Furthermore, since these techniques are inherently defensive, there should be much less reluctance to share the results of this research so that friendly nations can also benefit.

Finally, the entire issue of deliberate environmental modification deserves greater international attention than it has received in the recent past. The present treaties are inadequate, poorly defined, and full of loopholes. Offensive weather modification for military purposes should be banned in all forms, and strict limits should be placed on the military use of suppression techniques.

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