Management of Weather and Climate Disputes*

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I
INTRODUCTION

We are accustomed to thinking of weather conditions in one area in isolation from those in another. However, we increasingly find that our activities affect the weather of others, and that our weather is in turn affected by what happens elsewhere. In recent years, we have begun to acquire the ability to change weather or climate, both intentionally and unintentionally. As we become increasingly responsible for influencing weather conditions, the risk of substantial conflict among people and between people and their institutions becomes significantly greater. Awareness of the possibility of conflict creates a responsibility to anticipate and prevent harms where feasible, and to compensate for losses caused by the activities.[1]

The new technology of weather modification is an infant one. It includes techniques for dispersing fog, increasing rainfall or snowpack, suppressing hail, lightning, or tornadoes, dispersing cloud cover, and diminishing the force of hurricanes.[2] Only fog

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1. For a discussion of the liability of states for weather modification, *see* Weiss, *International Liability for Weather Modification*, 1 CLIMATIC CHANGE 267 (1978).

2. Weather modification is essentially the stimulation of those energy points in the atmosphere which will trigger the release of large amounts of energy and alter weather conditions. Techniques for dispersing "supercoded" fog—fog below 0°C—are operational. Fog is seeded with dry ice or silver iodide crystals, which serve as nuclei on which water vapor can deposit to form ice crystals. When the crystals become sufficiently heavy, they drop to the ground and create openings in the fog.

Cloud seeding to increase rainfall or snowpack involves introducing particles into clouds. This process triggers the growth of cloud droplets or ice crystals to precipitation size. If the cloud is a warm cloud (above 0°C), drops of water or large hygroscopic particles are used. If the cloud's temperature is below 0°C, artificial ice nuclei

dispersal has become widely accepted as a scientifically effective technology. Most other activities today focus on cloud seeding to enhance precipitation or to suppress hail.

Despite considerable scientific efforts, we are generally still unable under most conditions to show that weather modification has made a discernible, quantitative difference in weather patterns.[3] Nevertheless, cloud-seeding experiments and operations continue throughout the world, especially during periods of dry weather. Small commercial companies conduct many of these cloud-seeding operations, particularly within the United States. If researchers can perfect the techniques of weather modification so that such techniques are reliable, substantial economic benefits may be gained from weather modification.[4]

The power to trigger changes in the weather or climate will politicize our weather and climate systems, in that weather and climate will become new factors leading to possible conflicts between states or individuals. Whereas we have formerly attributed natural meteorological disasters to acts of God or whims of nature, we may well be inclined to blame people and their institutions for such harms. A government that intervenes to lessen a severe storm may be blamed if the storm instead intensifies, even if the intensification is in fact due to natural causes. Conversely, if a

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or materials with similar properties, such as silver iodide, are used. Seeding is done either from airplanes or ground generators.

The primary technique for suppressing hail is to seed with silver or lead iodide, thereby increasing the number of ice particles available for the water to accrete upon and hence reducing the size of the hailstones. Efforts to suppress lightning and tornadoes also involve seeding with one of several materials. There are two primary ways to attempt to modify hurricanes: 1) modifying the physical processes in convective clouds by seeding them with ice nuclei; and 2) modifying the rate of transferring heat from the ocean to the atmosphere, possibly by spreading monomolecular films on the ocean's surface. For a comprehensive analysis of these techniques, *see* 1 WEATHER MODIFICATION ADVISORY BOARD, THE MANAGEMENT OF WEATHER RESOURCES (1978) [hereinafter cited as MANAGEMENT OF WEATHER RESOURCES].

3. In 1976 the World Meteorological Organization (WMO) launched a major international experiment to determine the extent to which cloud seeding increases precipitation. This Precipitation Enhancement Project (PEP) has focused on choosing a suitable site in Spain to carry out a randomized cloud-seeding experiment. The PEP Board recommended in 1982 that the WMO not proceed with a cloud-seeding experiment in Spain at the present time, but rather undertake additional preliminary studies of the site. For the most recent results of this program, *see* WEATHER MODIFICATION PROGRAMME, REPORT OF THE SIXTH SESSION OF THE PRECIPITATION ENHANCEMENT BOARD, PEP REPORT No. 27 (WMO Apr. 1982) [hereinafter cited as PEP REPORT]. For a comprehensive assessment of the success of weather modification, *see* 2 MANAGEMENT OF WEATHER RESOURCES, *supra* note 2, at B-1 to B-13.

4. *See* 1 MANAGEMENT OF WEATHER RESOURCES, *supra* note 2, at 123-38; B. ATKINSON, THE WEATHER BUSINESS 141-67 (1969).

government does not try to mitigate severe weather conditions when people perceive that it has the ability to do so, people might blame the government for the damage. In other words, although people cannot sue God or nature for misfortunes, they can sue other people, and in some cases, their institutions.

The potential for conflict from human activities that unintentionally change the weather or climate will likely depend on whether the source of the change can be identified. For example, a single large-scale project designed to create large dams or to divert rivers within a state may also inadvertently alter weather or climate patterns in other states, thereby generating as much conflict as a project designed primarily to modify the weather. On the other hand, inadvertent changes in weather and climate caused by pollution from many diffuse sources may generate less conflict, since responsibility is difficult to pinpoint.[5]

With both deliberate and inadvertent changes in weather and climate, the *perception* of what changes human intervention has caused is usually more important than what has in fact occurred. Scientific knowledge of both the global climatic system and of local atmospheric patterns is still fairly primitive. Consequently, artificial changes in weather and climate are difficult to distinguish from natural variations. Both from a political and legal perspective, there is insufficient data in most cases to prove either that the change *was* caused by man's activities, or, conversely, that the change was *not* due to man's activities. Thus, if we were to use weather and climate modification techniques for hostile purposes, it would greatly politicize the global weather system, and would make it more difficult to shape people's perceptions of weather and climate so as to minimize political conflict.[6]

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5. Such cases may range from changes in rainfall over cities to global changes in climatic patterns.

6. *See* Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, *opened for signature* May 18, 1977, 31 U.S.T. 333, T.I.A.S. No. 9614, which prohibits military or hostile uses of techniques "having widespread, long-lasting or severe effects." *Id.* at art. I. For a discussion of the military implications of weather modification, *see* Weiss, *Weather as a Weapon*, in AIR, WATER, EARTH, FIRE, THE IMPACT OF THE MILITARY ON WORLD ENVIRONMENTAL ORDER 51 (1974); *Prohibiting Military Weather Modification, 1972: Hearings on S. Res. 281 Before the Subcomm. on Oceans and International Environment of the Senate Comm. on Foreign Relations*, 92d Cong., 2d Sess. (1972); *Weather Modification, 1974: Hearings Before the Subcomm. on Oceans and International Environment of the Senate Comm. on Foreign Relations*, 93d Cong., 2d Sess. (1974). For details on U.S. military use of weather modification in Southeast Asia, *see id.* at 87-123 (briefing on Department of Defense Weather Modification Activity). (This portion of the hearing was originally top-secret but was subsequently declassified.)

II
SCENARIOS OF CONFLICT

I outline here scenarios in which changes in weather and climate could generate conflicts between states.[7] They are intended merely to suggest classes of activities which could cause conflict. Because weather modification technologies are still largely undeveloped, and those in existence are still used only sporadically, some of the problems posed are necessarily hypothetical.

A. Deliberate Modifications

1. Increasing Rainfall

One state's seeding of clouds to increase rainfall may affect the rainfall of neighboring countries.[8] Scientific knowledge does not yet permit accurate determinations of the effects of cloud seeding downwind, or even laterally in most instances.[9] If we assume that a cloud-seeding program could increase rainfall downwind, at least up to 100 miles,[10] neighboring countries within this distance

7. "States" as used in this article refers to countries. This article focuses primarily upon international conflicts. Much of the analysis, however could also apply to states within a country, counties, or even municipalities.

8. For early discussion of techniques for seeding clouds to stimulate rainfall and of the downwind effects, *see* NATIONAL ACADEMY OF SCIENCES, WEATHER AND CLIMATE MODIFICATION (1973) and M. NEIBURGER, ARTIFICIAL MODIFICATION OF CLOUDS AND PRECIPITATION (WMO Tech. Note No. 105) (1969).

9. For more recent evaluations of the success of cloud-seeding programs, *see* PAPERS PRESENTED AT THE THIRD WMO SCIENTIFIC CONFERENCE ON WEATHER MODIFICATION, VOLS. I & II, Clermont-Ferrand, France (July 1980) [hereinafter cited as THIRD WMO SCIENTIFIC CONFERENCE]; 2 MANAGEMENT OF WEATHER RESOURCES, *supra* note 2, at B-1 to B-13; *Policy Statement of the American Meteorological Society on Planned and Inadvertent Weather Modification*, 62 BULL. AM. METEOROLOGICAL SOC'Y 87 (1981) [hereinafter cited as *AMS Policy Statement*]; Kerr, *Cloud Seeding: One Success in 35 Years*, 217 SCIENCE 519 (1982). The American Meteorological Society concluded in its most recent statement that "there is increasing evidence that the modification of fog, some stratus and orographic clouds, and some convective clouds is feasible provided that the conditions are right." *AMS Policy Statement*, *supra* this note, at 87. Israeli cloud-seeding experiments are generally agreed to be the only ones which have consistently yielded increases in rainfall. For the results of these experiments, *see* Gagin & Neumann, *The Second Israeli Randomized Cloud Seeding Experiment: Evaluation of the Results*, 20 J. APPLIED METEOROLOGY 1301 (1981); Gagin & Neumann, *The Second Israeli Randomized Cloud Seeding Experiment, Final Evaluation of Results*, in 1 THIRD WMO SCIENTIFIC CONFERENCE, *supra* this note, at 159. *See also* PEP REPORT, *supra* note 3.

10. Although evidence suggests that significant downwind effects from seeding may extend for 100 to 200 miles, evidence is not yet clear as to what such effects will be. The United States Weather Modification Advisory Board examined the data on downwind effects from several summer cumulus cloud-seeding projects and concluded that the overall picture was "far from clear." 1 MANAGEMENT OF WEATHER

that need water would likely benefit from this program.[11] This offers an opportunity for states to cooperate in developing a regional cloud-seeding program to augment water supplies for the area. However, when hostility and wide disparity in economic development exist between states, neighboring states might perceive that the state seeding the clouds could benefit disproportionately from the additional water. If water resources are scarce, increases in rainfall could also generate or renew conflicts over allocation of water, with downwind neighbors charging the upwind state with taking too much rainfall.

If cloud seeding decreases rainfall downwind, or perhaps increases rainfall immediately downwind but decreases it still further downwind, severe conflicts could arise over the allocation of water resources.[12] If an unusually severe drought were to occur, downwind neighbors could blame the cloud-seeding program for natural fluctuations in the weather. Therefore, the primary goals should be to ensure that before the operation takes place there have been appropriate consultations, that arrangements have been made for monitoring the effects of the program, and that there are means for compensating losses if appropriate and feasible.

Similar scenarios may occur under other conditions. A state may undertake a short-term emergency program of cloud seeding to relieve a drought,[13] and other states may perceive that the program has adversely affected their already meager rainfall; a state may try to suppress hail, and others may perceive that the activity affected their rainfall, or that it increased hail;[14] one state may try

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RESOURCES, *supra* note 2, at 57. Much more research is required on the effects of seeding on areas near the target area.

11. Results from a Colorado State University study of downwind effects from the Israeli cloud-seeding operations in Lebanon, Syria, and Jordan showed increases in rainfall of 20% to 30%. The study found no evidence of decreases in rainfall. Kerr, *supra* note 9, at 519. For an analysis of downwind effects of cloud-seeding projects in the United States and in the Eastern Mediterranean, *see* Brier, Grant & Mielke, Jr., *An Evaluation of Extended Area Effects from Attempts to Modify Local Clouds and Cloud Systems*, PROCEEDINGS OF THE WMO/IAMAP SCIENTIFIC CONFERENCE ON WEATHER MODIFICATION 439 (1974). The Israeli program's positive downwind effects on rainfall in neighboring countries has allowed the program to proceed smoothly.

12. *But see supra* note 11.

13. During a severe drought in September 1973, Niger hired a United States commercial company to seed clouds to stimulate rainfall and relieve the drought. Other states in the Saheil have indicated their interest in using cloud-seeding techniques for this purpose. S. BROWN, N. CORNELL, L. FABIAN & E. WEISS, REGIMES FOR THE OCEAN, OUTER SPACE, AND WEATHER 219 n.4 (1977) [hereinafter cited as S. BROWN].

14. In Colorado, barley growers abandoned plans to have a commercial company

to mitigate lightning, and neighboring states may perceive that their rainfall has been adversely affected, or that they are getting more lightning;[15] one state may carry out fog dispersal operations along another state's border, and the other state may perceive that additional sunshine purportedly resulting from the fog dispersal has adversely affected its crops or that moisture on the pavement from the fog dispersal operations has caused more traffic accidents.[16]

Other disputes can arise from charges that commercial operators have deliberately falsified data from cloud-seeding operations. Without a proper monitoring system, a commercial operator could claim success in seeding the clouds to enhance precipitation, when the rain actually falls before the cloud-seeding planes takes off.[17] Clients paying for such operations contingent on the operation's success should be compensated by the operator for fraud in falsifying the data.

2. Mitigating Severe Storms

In the last two decades there has been interest in finding ways to mitigate the adverse effects of severe storms such as hurricanes, typhoons, and cyclones.[18] Current knowledge is inadequate to

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seed clouds to suppress hail because ranchers and other farmers in the area feared that seeding would adversely affect rainfall. The objections to the operation were vociferous; the weather modification operators' trailer was even bombed. *See* Carter, *Weather Modification: Colorado Heeds Voters in Valley Dispute*, 180 SCIENCE 1347, 1349 (1973).

Seeding may increase rather than decrease hail. When cold fronts were seeded in Argentina, hail damage decreased by 70%. When warm fronts were seeded, hail damage increased 110%. Iribarne & Grandoso, *Results of the Five-Year Experiment on Hail Prevention in Mendoza (Argentina)*, in PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON CLOUD PHYSICS 454, 454-55 (1965).

15. Silver iodide seeding to suppress lightning may reduce rainfall. *See* Stow, *On the Prevention of Lightning*, 50 BULL. AM. METEOROLOGICAL SOC'Y 514 (1969).

16. Fog dispersal near Orly airport outside Paris produced light snow, but signs warning of icy roads kept auto accidents down. *See* Kahan, *Weather Modification Effects on Man's Environment*, in MAN AND THE QUALITY OF HIS ENVIRONMENT: WESTERN RESOURCES PAPERS 81 (1968). If highway departments in some areas were to keep roads free of fog, certain nearby crops might be harmed by too much sunshine. *See* Morris, *The Law and Weather Modification*, 46 BULL. AM. METEOROLOGICAL SOC'Y 618, 620 (1965).

17. This may already have occurred in a cloud-seeding operation abroad. Personal interviews by author (1970-1972).

18. For a report on the most promising experiment in hurricane modification, *see* Gentry, *Hurricane Debbie Modification Experiments, August 1969*, 168 SCIENCE 473 (1970). Results indicated a 31% decrease in winds on the first day of seeding and a 15% decrease in wind speed on the second day of seeding. *Id.* at 475. A subsequent study by the Stanford Research Institute in the United States recommended that hur-

predict exactly the consequences of trying to mitigate such storms. However, this lack of knowledge in itself may lead to conflict between states. If one state successfully seeds a typhoon to reduce the storm's force and to mitigate both property damage and loss of life, no dispute should arise, except perhaps over allocation of the costs of the operation between the states sharing the benefits. However, conflict could arise if seeding causes the speed of the typhoon winds to increase rather than to decrease.[19] The situation could be subtle: the seeding may have actually kept wind speeds lower than they would have been without the seeding, but because another state experienced an increase in wind speed following the seeding program, it would be difficult to convince that country that the seeding operations had been beneficial rather than detrimental.

Even if wind speed were reduced for the state that seeded the typhoon, the typhoon could subsequently intensify and hit states in its path with extraordinary force, causing extreme damage, or could divert its path toward other states in the area, or do both. These states may well suspect that the country carrying out the typhoon modification operations acted aggressively. In any event, they may well demand compensation. The country carrying out the seeding operations would then need to demonstrate that the operations did not increase the force of the winds, or change the path of the storm.

If reliable technology did exist for seeding typhoons to decrease their wind speed,[20] and if a country did not use such technology, affected states could react by charging that the state that neglected to seed the typhoon intentionally inflicted damage upon other countries. This rationale again politicizes nature.[21]

These problems suggest that appropriate arrangements must be worked out with countries in potentially affected areas before un-

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ricane seeding become operational for the United States on an emergency basis. *See* Howard, Matheson & North, *The Decision to Seed Hurricanes*, 176 SCIENCE 1191, 1201 (1972). In the mid-1970's, the Philippines expressed interest in undertaking its own program of typhoon modification, but such a program never materialized. Although the United States has considered typhoon-seeding programs in the Pacific, the National Oceanic and Atmospheric Administration has recently cancelled the United States hurricane modification program. Thus, no storms are now being seeded. Kerr, *supra* note 9, at 520.

19. After the Hurricane Debbie modification experiments, the Stanford Research Institute assessed as small the probability that seeding would intensify storms. Howard, Matheson & North, *supra* note 18, at 1195.

20. *See supra* note 18.

21. *See supra* text following note 4.

dertaking operations to mitigate storms. These problems also indicate that satisfactory evidence of the effects of typhoon modification must be available before an operation is undertaken, and the issue of liability for damage must be addressed before undertaking any operation.

3. Large-Scale Modifications: Melting the Arctic Ice Cap

Several methods have been discussed for intentionally altering global weather and climate conditions by removing the Arctic ice cap. Scientists have proposed that the Arctic ice cap could be melted by 1) damming the Bering Straits, 2) dispersing lampblack over large portions of ice to absorb heat, or 3) creating high-level clouds over the Arctic to trap heat.[22] The effectiveness of any of these proposals is highly controversial and the practicality in dispute. However, if one state did initiate melting of the ice cap, severe adverse consequences to the weather and climate of many states could ensue. Once the melting of the ice had passed the critical threshhold, the ice might melt at an exponential rate, and the melting process would likely be irreversible.

Schemes such as this one for intentionally altering global weather and climate raise problems. Means must be provided to evaluate the potential effects of proposed large-scale experiments;[23] to ensure that certain experiments are not carried out, or, if carried out, that certain conditions first be met; and to obtain the consent of those countries that might be adversely affected. Such safeguards are particularly necessary for large-scale inten-

22. For elaboration of these proposals, *see* Fletcher, *Controlling the Planet's Climate*, 19 IMPACT SCI. SOC'Y 151, 162-63 (1969); Atlas, *Activities in Radar Meteorology, Cloud Physics, and Weather Modification in the Soviet Union (June 1965)*, 46 BULL. AM. METEOROLOGICAL SOC'Y 696 (1965); Wexler, *Modifying Weather on a Large Scale*, 128 SCIENCE 1059 (1958); Staff of the Weather Modification Research Project, Rand Corporation, *Weather-Modification Progress and the Need for Interactive Research*, 50 BULL. AM. METEOROLOGICAL SOC'Y 216 (1969). Both American and Soviet scientists have raised the possibility of covering the Arctic ice with materials which absorb heat, such as lampblack or some other carbon. Wexler, *supra* this note, at 1059-60; Atlas, *supra* this note, at 702. This method has been used successfully to melt ice in Chile, although there may be insurmountable problems in trying to melt the ice on such a large scale as in the Arctic. *Dusting a Glacier in Chile*, 96 SCI. NEWS 330 (1969).

23. Large-scale experiments are defined as those that directly affect more than one million square kilometers. MASSACHUSETTS INSTITUTE OF TECHNOLOGY, STUDY OF MAN'S IMPACT ON CLIMATE, STOCKHOLM, 1970 INADVERTENT CLIMATE MODIFICATION 18 (1971) [hereinafter cited as SMIC]. Other large-scale projects that have been proposed include changing the course of certain ocean currents and removing Arctic sea ice. *Id.* at 159-65.

tional modifications of weather and climate, because such drastic modifications may irreversibly change weather and climate, rendering compensatory mechanisms totally inadequate.

B. Inadvertent Modification

1. Altering Weather

Air pollution can affect weather, particularly rainfall. Industrial pollution from one or more countries in a weather region may cause the rainfall in another country in that region to increase or decrease.[24] However, the state affected may be unable to identify the distant sources of pollution or to determine the extent to which these foreign sources of pollution rather than domestic sources are responsible for the change in rainfall. Nevertheless, increases or decreases in rainfall may have adverse economic consequences, many of which would be difficult to measure. The country affected would need to develop means to prevent further injury or at least to reduce the severity of such anticipated harm.

Similar scenarios could occur, for example, if nuclear power plants were built in a river valley bordering two or more states, and the cooling tower of the nuclear plant generated considerable fog in surrounding areas, or if agricultural practices in one state created so much dust that they inhibited rainfall in an adjoining state.[25]

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24. In 1980 the American Meteorological Society issued an assessment of inadvertent weather modification in the United States, which concluded that

> [t]here is increasing evidence that many types of human activities such as urbanization, industrialization, power plant operations, irrigation, and changes in land-use practices in general result in inadvertent modification of local and regional weather The heat island phenomenon of urban areas is well established and understood, as are the alterations of wind speed and direction in and around cities. Significant increases in summertime precipitation and storminess have been documented to occur in downwind areas of major urban-industrial conurbations
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> Large-scale changes in visibility and in the chemical composition of both the air and precipitation from anthropogenic influences have been well established However, there is no direct evidence that large-scale or global changes in temperature, cloudiness, or precipitation have yet occurred.

AMS Policy Statement, *supra* note 9, at 88. For early scientific reports on inadvertent weather changes caused by pollution, *see* Hobbs, Harrison & Robinson, *Atmospheric Effects of Pollutants*, 183 SCIENCE 909 (1974); Changnon, *The La Porte Anomaly—Fact or Fiction?*, 49 BULL. AM. METEOROLOGICAL SOC'Y 4 (1968); and Schaefer, *The Inadvertent Modification of the Atmosphere by Air Pollution*, 50 BULL. AM. METEOROLOGICAL SOC'Y 199 (1969). For recent critiques, *see* Changnon, *More on the La Porte Anomaly: A Review*, 61 BULL. AM. METEOROLOGICAL SOC'Y 702 (1980); Clark, *A Hydrologic Reanalysis of the La Porte Anomaly*, 60 BULL. AM. METEOROLOGICAL SOC'Y 415 (1979).

25. Peterson & Bryson, *The Influence of Atmospheric Particulates on the Infrared*

2. Altering Climate: The Single Project

A state modifying land or ocean surfaces on a large scale for reasons other than intentional climate modification may as a by-product affect weather and climate by producing an increase or decrease in the rate of heat transfer from the surface to the atmosphere. This in turn may affect atmospheric circulation patterns. At least four kinds of projects may cause such changes: 1) creating large lakes by damming one or more rivers;[26] 2) destroying topographical features such as mountains and forests;[27] 3) using monomolecular films to suppress the transfer of heat from the ocean surface to the atmosphere;[28] and 4) creating "thermal mountains" on land to melt glaciers.[29] It has been estimated that a heat anomaly of about ten percent of the net solar energy of the sun available at the earth's surface, taken over several million square kilometers for at least one month, would be sufficient to cause a change in climate.[30]

A discrete project might initiate large-scale changes in weather and climate in other ways. For example, diverting of rivers from the Arctic Ocean southward would mean that the fresh water which normally flows into the Arctic and freezes more rapidly

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Radiation Balance of Northwest India, in PROCEEDINGS OF THE FIRST NATIONAL CONFERENCE ON WEATHER MODIFICATION 153, 153 (1968). *See* Bryson & Wendland, *Climatic Effects of Atmospheric Pollution*, in GLOBAL EFFECTS OF ENVIRONMENTAL POLLUTION 130, 134-35 (S. Singer ed. 1970). Years ago the Rajputana desert in northwest India was a fertile agricultural area. Although it is in the path of the southwest monsoon, it is now a desert. According to Bryson, great amounts of dust (as from bad farming practices) have formed a layer in the atmosphere which inhibits precipitation. Bryson & Baerreis, *Possibilities of Major Climatic Modification and Their Implications: Northwest India, A Case for Study*, 48 BULL. AM. METEOROLOGICAL SOC'Y 136, 136-37 (1967).

26. These include proposals such as damming the Congo River at Stanley Canyon, or damming the Ob, Yenisei, and Angara Rivers in the Soviet Union. Fletcher, *Controlling the Planet's Climate*, 19 IMPACT SCI. SOC'Y 151, 163 (1969).

27. These are often grandiose schemes, such as deforestation for settlements or other development of a large area like the Amazon, which would change the degree to which the surface reflects sunlight and the rate at which the moisture evaporates; this could affect climate. MASSACHUSETTS INSTITUTE OF TECHNOLOGY, MAN'S IMPACT ON THE GLOBAL ENVIRONMENT, REPORT OF THE STUDY OF CRITICAL ENVIRONMENTAL PROBLEMS (SCEP) 214 (1975).

28. This might be done to conserve water supply. For application of the technique to hurricanes, *see supra* note 2.

29. *See supra* note 22 for application of this technique to melting Arctic ice. *See also Dusting a Glacier in Chile*, 96 SCI. NEWS 330 (1969).

30. Sawyer, *Notes on the Possible Physical Causes of Long-Term Weather Anomalies*, in WMO-IUGG SYMPOSIUM ON RESEARCH AND DEVELOPMENT ASPECTS OF LONG-RANGE FORECASTING 227-29 (WMO Tech. Note No. 66) (1964).

than salt water would no longer flow into the Arctic Ocean.[31] It is theorized that this could initiate melting of the Arctic ice cap.[32]

While consequences of these and other projects are uncertain, our knowledge of the physical interdependencies in the global climatic system indicate that such projects could affect the weather conditions in many countries. These cases differ from those of projects deliberately intended to modify weather and climate on a large scale in that, by hypothesis, they are initiated primarily for other purposes, such as domestic economic benefits, and in many cases could be initiated entirely within the borders of a country.

3. Altering Global Climate: Cumulative Effects

Perhaps the most difficult problems arise when global climatic change occurs from the cumulative effects of numerous diffuse sources of pollution caused by man's activities.

The most important example is the build up of carbon dioxide in the atmosphere, which is predicted to raise the temperature of the earth. The higher temperature may in turn trigger major changes in the global climate, ocean levels, and growing seasons.[33] The increase in carbon dioxide in the atmosphere is caused primarily by the use of fossil fuels, and to a lesser extent by deforestation and poor management of soils. If atmospheric carbon dioxide does cause significant climatic changes, it will generate serious political conflict, whether or not the changes in the long term benefit any of the countries affected. Developing countries in particular lack the resources to adapt quickly and easily to major changes in temperature and precipitation.

Moreover, to the extent that cumulatively our activities change global circulation patterns and cause more intense and more frequent anomalies in the weather, such as droughts and floods, our activities may generate extraordinary economic and political disputes. There is a need to identify when such changes are occur-

31. For proposals in the U.S.S.R. to divert rivers, *see* Biryukov, *Rerouting Rivers*, 6 NEW TIMES 26 (1971); *Water in Wrong Places*, 231 NATURE 140 (1971); Shabad, *Soviet Diverting Rivers to Grain Land*, N.Y. Times, Oct. 29, 1973, at 55, col. 1

32. *See supra* text accompanying note 22.

33. For scientific assessments of the carbon dioxide build up, *see* NATIONAL RESEARCH COUNCIL, CHANGING CLIMATE (1983); NATIONAL RESEARCH COUNCIL, CARBON DIOXIDE AND CLIMATE: A SECOND ASSESSMENT (1982), and NATIONAL RESEARCH COUNCIL, CARBON DIOXIDE AND CLIMATE: A SCIENTIFIC ASSESSMENT (1979). *See also* U.S. ENVIRONMENTAL PROTECTION AGENCY, CAN WE DELAY A GREENHOUSE WARMING? (1983); CARBON DIOXIDE REVIEW: 1982 (W. Clark ed. 1982); and U.S. COUNCIL ON ENVIRONMENTAL QUALITY, GLOBAL ENERGY FUTURES AND THE CARBON DIOXIDE PROBLEM (1981).

ring and to ensure that such impacts do not continue into the future, or at least to mitigate the effects of these impacts.

III
PRIORITIES

Unfortunately, importance of the posed problem involving weather changes is inversely correlated with the ease with which the problem is adaptable to procedures for avoiding or adjusting disputes. Inadvertent global climate modification caused by man's activities potentially raises the most severe conflict and should receive policy makers' top priority, but may be the most difficult environmental problem to manage. Conflicts over adverse effects from hail suppression operations and similar operations will be far less serious and widespread, but are probably most amenable to processes for avoiding or adjusting disputes.

Of the scenarios outlined above, four raise the most visible and politically explosive conflicts: intentional large-scale modifications; inadvertent changes in climate from discrete projects; inadvertent changes in climate from the cumulative effects of diffuse sources; and mitigation of severe storms.

Priority must be given to developing processes which will prevent disputes over weather and climate changes. This is essential to minimize the politicization of the weather and to encourage the use of weather modification techniques for beneficial purposes. In many cases, prevention is the only possible effective action on behalf of states potentially adversely affected. There is no way adequately to compensate a state or individual adversely affected by many of the artificial changes in weather because damages are difficult to identify, prove, and quantify. In certain cases it is impossible either to stop or to reverse the complicated feedback mechanisms in the weather system and consequent changes in weather and climate which have been set in motion by the weather modification operation.

For cases of inadvertent modification of weather or climate, priority must be given to establishing processes to warn potentially affected states of impending changes and to facilitate consultations by states on ways to avert or lessen the impact.

IV
PROCESSES FOR AVOIDING OR ADJUSTING DISPUTES

A. The Common Interest

States need to recognize their common interest in weather and climate systems as resources and to develop processes for managing disputes in light of this shared relationship. Traditionally we have established separate legal regimes for oceans, space, and land.[34] Since weather is often identified with the clouds in the atmosphere above the earth, we may be tempted to apply the "airspace" distinction enunciated by several conventions. However, this represents a fundamental physical misconception. Weather and climate are products of interactions between air, water, and land; indeed, scientists are increasingly convinced that the oceans are the critical storehouse of energy of the global climate system. In developing procedures for managing disputes for weather and climate modification, states must treat weather and climate as strongly interacting systems which all states share in common.

B. The Information Network

There is a fundamental need to understand more fully how the weather and climate systems work. Until we do, it is difficult to know exactly how human activities may modify weather and climate, both beneficially and adversely. An international network for gathering and disseminating information about weather and climate is basic to the management of weather and climate disputes.

International networks for gathering and disseminating data on weather and climate, as well as international research on weather and climate systems, are essential to dispute management for several reasons: 1) to anticipate pending changes, particularly in climate, which could be politically explosive, or to identify current changes; 2) to make technical assessments of the likely effects of proposed operations; and 3) to monitor and evaluate the effects of deliberate weather and climate modification programs or programs which inadvertently affect weather and climate. The data from these evaluations would, in turn, be fed into the information

34. For examples of conventions dealing only with air space, *see* Convention Relating to the Regulation of Aerial Navigation, *signed* Oct. 13, 1919, 11 L.N.T.S. 173; Convention on International Civil Aviation, *opened for signature* Dec. 7, 1944, 61 Stat. 1180, T.I.A.S. No. 1591.

network and used to increase our capability to perform other functions.

Currently the main institutional vehicle for gathering and transmitting data on the weather is the World Weather Watch (WWW), which is designed to facilitate weather forecasting. The WWW was established in 1968 under the auspices of the World Meteorological Organization and is now in its seventh three-year period, from 1984 to 1986.[35] Currently, we have considerable skill in predicting daily weather patterns during periods of up to forty-eight hours. The theoretical limit for useful prediction of day-to-day changes in weather is believed to be about one to two weeks, but present forecasting skill does not reach beyond ten days.[36]

Thus far, there has been good exchange among states of data on the weather. Nearly all states have routinely provided information on weather conditions, unless at war with each other. There are indications, however, that as some states become more independent in their ability to gather global meteorological information, the present international pattern of cooperation may give way to a more complex pattern of nationalizing, or in some cases regionalizing, weather information. An essential step for developing processes to manage disputes is to ensure that information about weather and climate is handled as a global resource. This means expanding the common network for observing, processing, and transmitting meteorological data, and ensuring that states have access to this network.

In managing disputes over large-scale modifications, it will be particularly important to have access to data on both the atmosphere and the oceans, and to understand the interface processes between the two. The systems for observing and monitoring the atmosphere and the oceans have traditionally operated separately, as have research efforts.[37] Indeed, until the last decade there was only minimal coordination and standardization of information

35. For a basic description of the World Weather Watch, *see* WORLD METEOROLOGICAL ORGANIZATION, THE ESSENTIAL ELEMENTS OF THE WORLD WEATHER WATCH (1966). For the current program, *see* WORLD METEOROLOGICAL ORGANIZATION, WORLD WEATHER WATCH, THE PLAN AND IMPLEMENTATION PROGRAMME 1980-1983, (WMO No. 535, July 1979).

36. *Policy Statement of the American Meteorological Society on Weather Forecasting*, 60 BULL. AM. METEOROLOGICAL SOC'Y 1453, 1454 (1979).

37. The World Meteorological Organization has primary responsibility for observation, monitoring, and global research programs for the atmosphere. The Intergovernmental Oceanographic Commission, which is linked to the United Nations Educational, Scientific, and Cultural Organization, has similar responsibility for the oceans. The Global Environmental Monitoring System under the United Nations

gathered about the oceans. There is still a need to coordinate and standardize the information, and to make integrated data available to those assessing large-scale modifications in weather and climate.

V
DELIBERATE MODIFICATIONS

A. Large-Scale Modifications

One of the most important needs is to regulate, or prohibit altogether, large-scale experiments which modify weather and climate. These experiments pose the greatest threat to the interests of all states in the global climate system. We should agree to prohibit large-scale experiments unless the likely effects are foreseeable and clear, and unless all potentially affected states have consented to the proposed experiment. As early as 1971, the Study of Man's Impact on Climate (SMIC)[38] recommended that "an international agreement be sought to prevent large-scale (directly affecting over 1 million square kilometers) experiments in persistent or long-term climate modification until the scientific community reaches a consensus on the consequences of the modification."[39] We are still awaiting such a consensus. Recommendation 70 of the United Nations Conference on the Human Environment[40] provided that governments undertaking activities "in which there is an appreciable risk of effects on climate" should:

> (a) Carefully evaluate the likelihood and magnitude of climate effects and disseminate their findings to the maximum extent feasible before embarking on such activities;
>
> (b) Consult fully other interested States when activities carrying a risk of such effects are being contemplated or implemented.[41]

The recommendation is directed at activities which may incidentally affect climate as well as those designed primarily to change climate.

Environment Programme (UNEP) is expected, among other things, to provide some coordination between these efforts.

38. SMIC, *supra* note 23.

39. *Id.* at 18-19.

40. The text of the recommendations appears in SENATE COMM. ON FOREIGN RELATIONS, 92D CONG., 2D SESS., UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT (Comm. Print 1972) [hereinafter cited as CONFERENCE ON THE HUMAN ENVIRONMENT].

41. *Id.* at 36.

To manage effectively disputes over proposed large-scale modifications, governments should consider creating a scientific advisory panel to evaluate the consequences of proposed experiments.[42] States would bring proposed experiments to the attention of the panel, or the panel itself could initiate consideration of proposals members felt to be of sufficient magnitude and risk. Experts in relevant meteorological specialties would constitute the panel's permanent membership, with consultants from related fields available as needed. The composition of any panel evaluating a discrete proposal would be determined on an ad hoc basis according to the specific problems raised. The panel could operate under the auspices of the United Nations Environmental Programme or the International Council of Scientific Unions, working jointly with the World Meteorological Organization.

There is precedent for such an approach to international evaluation of proposed projects. In 1962, the Consultative Group on Potentially Harmful Effects of Space Experiments (COSPAR)[43] was established as part of the International Council of Scientific Unions. COSPAR consists of a panel of scientists responsible for determining whether proposed scientific experiments in outer space will have harmful effects on earth. Members may make recommendations, but have no other formal authority.[44] Similarly, the proposed scientific advisory panel for large-scale weather and climate modification projects would initially serve an advisory function. However, such a panel would be more useful if an agreement required parties to seek the panel's advice on proposed experiments and provided mechanisms to ensure that the advice of the panel were followed. States, international organizations, and other interested persons should be able to bring proposed experiments to the attention of the panel; the panel could also initiate consideration of proposals members felt to be of significant magnitude and risk.

In evaluating proposed modification efforts, panel members will face difficult problems in determining whether they have sufficient knowledge to identify and confidently assess the effects. Since we can never predict with 100% confidence the effects of a proposed

42. *See* S. BROWN, *supra* note 13, at 229-32.

43. Charter of COSPAR, Int'l Council Scientific Unions Y.B. 73 (1965). 1965 Y.B. OF AIR AND SPACE LAW 625, 625-38. For a discussion of the purpose of COSPAR and an update on its activities, *see* N. MATTE, AEROSPACE LAW: TELECOMMUNICATION SATELLITES (1982).

44. *See supra* note 21.

project, we need to develop guidelines as to what probabilities short of absolute certainty constitute sufficient assurance that we know what the effects will be. The level of certainty required should vary with the seriousness of the potential consequences. For example, if any of the effects might be disastrous, states might not be willing to accept any risk at all that they would occur.

Once large-scale operations are undertaken, we will need processes to monitor the operation and to evaluate the effects. Provisions should be made for giving the international scientific community access to the data as quickly as possible. Data from the operation would be used to increase our understanding of the climate system and to aid in future assessments of programs designed to modify weather and climate.

In cases of large-scale modification, priority must be given to measures designed to prevent disputes. All concerned parties must have a voice in the processes established for undertaking the project. Acts designed to modify weather and climate on a large scale may trigger complicated interactions and feedbacks in the global climate system, which will produce effects that cannot be measured or quantified. Therefore, it will be difficult, or even impossible, to provide full compensation for damages that may be inflicted.

We should, however, explore the possibility of compensating for certain adverse effects from large-scale experiments, to the extent that such effects can be measured and reduced to monetary terms. In accordance with Principle 21 of the Declaration of the United Nations Conference on the Human Environment,[45] states should acknowledge responsibility for damages created by their activities,[46] and should consider the cost of this damage as part of the cost of the operation. One potential option would require that the state undertaking the operation post a bond or other financial guarantee from which claims for damage could be settled. Interest earned on the bond might be used to support post-evaluation of the experiment. The interest could be viewed as a fee paid to

45. The Declaration was passed as part of the United Nations Conference on the Human Environment. SENATE COMM. ON FOREIGN RELATIONS, 92D CONG., 2D SESS., UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT 14-18 (Comm. Print 1972).

46. Principle 21 of the Declaration of the United Nations Conference on the Human Environment provides that states have "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." CONFERENCE ON THE HUMAN ENVIRONMENT, *supra* note 40, at 18.

the international community for the right to conduct the experiment. This method of providing limited compensation will be discussed more fully in connection with arrangements for handling disputes arising from the mitigation of severe storms.[47]

B. Other Deliberate Modifications

To avoid disputes from other forms of deliberate modification of weather and climate, states need to agree on guidelines for appropriate weather modification procedures when the effects may cross national borders.[48] If meteorologists predict that there is a significant probability that an activity will cause adverse effects in other countries, we should require the prior agreement (explicit or implicit) of potentially affected states. Provisions should be made for monitoring the operation to assess its effects and to evaluate the results for use in future modification programs in the area.

Where it is anticipated at the outset of an operation that some states may benefit at the expense of others (e.g., increasing rainfall or diverting hurricanes), I propose establishing a conciliation commission to which affected parties could appeal prior to the proposed operation to challenge the timing, location, and other conditions incident to the operation. A conciliation commission could be established at the international level, with one or more such commissions functioning on a regional basis for a specific program of modification, such as a typhoon modification program in the Pacific Ocean.

Under the proposed procedure, a party contemplating a weather modification operation would register the operation with the World Meteorological Organization and provide information on its plans to any neighboring states that might be affected.[49] If

47. *See infra* text accompanying and following note 70, and following note 73.

48. For a commendable initiative in this direction, *see* WORLD METEOROLOGICAL ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, DRAFT PRINCIPLES OF CONDUCT FOR THE GUIDANCE OF STATES CONCERNING WEATHER MODIFICATION (1978). These principles call for "adequate and timely" notice of prospective activities, *id.* at art. IV, an assessment of environmental consequences, *id.* at art. V, timely consultation with concerned states, *id.* at art. VII, and the conduct of weather modification activities "in a manner designed to ensure that they do not cause damage to the environment of other States," *id.* at art. VI. The draft principles were discussed at an intergovernmental meeting convened under the auspices of WMO/UNEP, but countries never reached agreement on final principles. *See* WMO, UNEP, REPORT OF WMO/UNEP MEETING OF EXPERTS DESIGNATED BY GOVERNMENTS ON THE LEGAL ASPECTS OF WEATHER MODIFICATION (Sept. 17-21, 1979).

49. The World Meteorological Organization now maintains a registry of national

one of these states believed that it might be harmed by such an operation, it could approach the conciliation commission and attempt to work out a solution with the modifying state which might damage its interests less. For example, in a proposed program to increase rainfall, it might be possible to allay the fears of downwind harvesters that increased rainfall would ruin their crops by postponing the experiment until after the harvest or by shifting the location.

The conciliation commission could consist of a panel of experts available to serve as conciliators. The panel members would include persons with meteorological expertise. Several existing conventions provide for drawing up and maintaining lists of experts to be used in conciliation or arbitration proceedings.[50] Meteorological experts chosen by the International Council of Scientific Unions or jointly with the World Meteorological Organization might agree to serve as mediators on technical issues in pre-operations disputes.

Procedures for adjusting disputes arising from weather modification operations and for compensating for damage caused could be initiated at the national, regional, or international level.

Considerable precedent exists for handling weather modification disputes, at least in the first instance, through the national courts.[51] Two or more countries could agree that whenever one

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weather modification projects. Countries notify the WMO on an annual basis. The registry for 1981—the one most recently published—lists 104 weather modification activities reported by 28 countries. Twenty-five of the projects were initiated in 1981, the rest were continued from previous years. WORLD METEOROLOGICAL ORGANIZATION, REGISTER OF NATIONAL WEATHER MODIFICATION PROJECTS (1981). The United States maintains its own national registry of weather modification activities. For the most recently published registry, *see* U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, SUMMARY OF WEATHER MODIFICATION ACTIVITIES REPORTED IN 1981 (May 1982).

50. The Convention Relating to Intervention in Cases of Oil Pollution, *done* Nov. 29, 1969, arts. III and IV, 26 U.S.T. 765, T.I.A.S. No. 8068, calls for maintaining a list of independent experts with whom a state may consult before taking measures to mitigate harm expected to arise from oil pollution casualties. The Convention on Settlement of Investment Disputes, *done* Mar. 18, 1965, arts. 12-15, 17 U.S.T. 1270, T.I.A.S. No. 6090, also provides for establishing panels of conciliators and arbitrators to settle investment disputes between states.

51. The International Civil Aviation Organization Hijacking Convention of December 1970 leaves action against hijackers to the states and provides for extradition of persons accused of hijacking. Convention for the Suppression of Unlawful Seizure of Aircraft, *done* Dec. 16, 1970, arts. 2-8, 22 U.S.T. 1641, 1644, 1646, T.I.A.S. No. 7192. The Narcotic Drug Convention of 1961 also leaves to the states the punishment of offenders. Single Convention on Narcotic Drugs, *done* Mar. 30, 1961, art. 36, 18 U.S.T. 1407, 1425-26, T.I.A.S. No. 6298. The Whaling Convention provides that the

state has a claim for damage against another arising from a weather modification operation, it can sue in the courts of the state allegedly causing the damage.[52]

The advantage of a national approach for handling compensation claims from weather modification operations is that it operates on the lowest possible level and avoids the stigma of delay and ineffectiveness often associated with international mechanisms for dispute resolution. The case might be brought either in the courts of the state causing the damage or in the courts of the state suffering the effects.[53]

However, there are a number of disadvantages in leaving weather modification claims to national courts. The problems are best illustrated by a brief survey of the weather modification cases arising in United States courts.

There have been fewer than two dozen cases in the United States claiming damage from weather modification operations or seeking injunctions to halt weather modification operations.[54] In only one case did the court decide in favor of the plaintiffs against the weather modifiers.[55]

The most effective defense has been that the plaintiff has not shown that the weather modification operations more probably

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government which has jurisdiction over an offense shall prosecute the offenders. International Convention for the Regulation of Whaling with Schedule of Whaling Regulations, *done* Dec. 2, 1946, art. IX, 62 Stat. 1716, 1720, T.I.A.S. No. 1849.

52. For example, the Nordic Environmental Protection Convention, *done* Feb. 19, 1974, art. 3, 13 INT'L LEGAL MATERIALS 591 (1974), gives a contracting state injured by environmentally harmful activities the right to sue in the courts of the state engaging in such activities.

53. The *Lotus* case before the Permanent Court of International Justice in 1927 is precedent for a state claiming jurisdiction where the effects of an action are felt in the country or by a country's citizen. S.S. Lotus (Fr. v. Turk.), 1927 P.C.I.J., ser. A, No. 10 (Judgment of Sept. 7) (Turkey was not precluded under international law from prosecuting a French citizen for involuntary manslaughter of a Turkish citizen, when a French steamer, the Lotus, collided with a Turkish collier on the high seas).

54. All of the cases have involved cloud seeding. For articles analyzing early cases, *see* Johnson, *Legal Implications of Weather Modification*, in WEATHER MODIFICATION AND THE LAW 76, 82 (H. Taubenfeld ed. 1968); Davis, *Legal Uncertainties of Weather Modification*, in LEGAL AND SCIENTIFIC UNCERTAINTIES OF WEATHER MODIFICATION 32 (W. Thomas ed. 1977).

55. Southwest Weather Research, Inc. v. Duncan, 319 S.W.2d 940 (Tex. Civ. App. 1958) and Southwest Weather Research, Inc. v. Rounsaville, 320 S.W.2d 211 (Tex. Civ. App. 1958), *both aff'd sub nom.* Southwest Weather Research, Inc. v. Jones, 160 Tex. 104, 327 S.W.2d 417 (Tex. 1959). Texas ranchers sought to enjoin hail suppression operations on the ground that they needed precipitation in any form and the hail suppression operations reduced precipitation. The Supreme Court of Texas affirmed the trial court's grant of an injunction restraining the cloud seeding in the airspace over the ranchers' lands.

than not caused the changes in the weather which damaged the plaintiff's property.[56] Defendants have usually been able to offer testimony of meteorological experts detailing the scientific uncertainty regarding the effects of weather modification operations.[57] In certain cases, defendants may be able to argue that consent was obtained from those likely to be affected and compensation was either arranged in advance or waived. Finally, in considering injunctive relief, courts have accepted the argument that, particularly during droughts, the public interest takes precedence over the private interest.[58]

As weather modification technology becomes more reliable, the careful gathering and evaluation of data will enable the formulation of statistical probabilities for the results of weather modification operations. Courts may then rely on these probabilities, at least to create an assumption in the burden of proof reflecting the likely consequences of the operation. Probability statistics do not, of course, eliminate uncertainty as to whether a particular operation, such as cloud seeding, caused particular damage. An increase in average rainfall of twenty-five percent over a five-year period of cloud seeding indicates little about the effects of a particular operation. On any given day of cloud seeding, rainfall may have increased by fifty percent or not at all. Even if rainfall did

56. For example, the problem of cause and effect was the crucial issue in Adams v. The State of California (No. 10112, Sutter County Sup. Ct., 1964). Property owners damaged by the floods on the Feather River contended that cloud seeding by an electric utility had caused flooding. The court rejected the plaintiffs' contention. For an analysis of the case, *see* Mann, *The Yuba City Flood: A Case Study of Weather Modification Litigation*, 49 BULL. AM. METEOROLOGICAL SOC'Y 690, 708-09 (1968). Pennsylvania Natural Weather Ass'n v. Blue Ridge Mountain Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 762 (1968) (C.P. Fulton County) (court denied an injunction against defendants' weather modification activities, finding that plaintiffs had not shown more than a possibility of future harm).

57. This uncertainty requires that we rely on statistical evidence to establish causality in such situations. "We have imperfect knowledge of storms and we have imperfect knowledge of what happens when we attempt to modify them. . . . Therefore, we do not and will not operate in a situation in which we can predict with great confidence on a case-by-case, storm-by-storm, mountain-by-mountain basis. We must learn to live with results that are statistical in nature." Firor, *The Legal Uncertainties: A Scientist Responds*, in LEGAL AND SCIENTIFIC UNCERTAINTIES OF WEATHER MODIFICATION 65, 65 (W. Thomas ed. 1977). Dr. Firor was then Executive Director of the National Center for Atmospheric Research.

58. See Slutsky v. City of New York, 197 Misc. 730, 97 N.Y.S.2d 238 (1950) (court denied an injunction against defendants' rain-making experiments, finding that the remote possibility of harm to plaintiffs' resort was not outweighed by New York City's need to maintain its water supply in the face of a drought).

increase by twenty-five percent on the target day, the injured party must still establish that the increase in rainfall caused its damage.

Weather modification cases brought before courts in the United States present a number of problems. It is almost impossible for juries to understand the scientific and technical evidence adduced at trial. In a trial before a judge rather than a jury, the judge may be able to grasp the scientific and technical aspects with considerable study, but there is likely to be little consistency in decisions by different judges. Finally, litigation is so expensive and time-consuming that people with relatively small claims for damages are unlikely to go to the effort and expense of litigation.[59] As a result, such damages may never be compensated.

Several additional problems emerge with foreign claims of damage through national courts. Some countries may not have a national court system competent to handle such claims. In such a situation, claimants would likely sue in the court of the country whose governmental agency or commercial operator conducted the weather modification program (usually the United States if the program is commercial).

However, if the United States government is involved as an operator, there will be difficulties in bringing such claims. The Federal Tort Claims Act[60] may shield the United States from liability to suit. The Act expressly excludes claims against the United States government based on the exercise of a "discretionary function" of the government, even if the discretion involved is abused.[61] The decision to undertake weather modification operations would likely be regarded as a discretionary function of the government and hence government operators would be immune to suit.[62] More importantly, the Federal Tort Claims Act excludes

59. The class action suit allows injured parties to reduce litigation costs by litigating collectively claims of damage caused by weather modification operations. But Saba v. "Nine Counties," 307 N.W.2d 590, 594 (N.D. 1981), rejected a class action suit which alleged negligence in cloud seeding, on the ground that each class member's claims required individual consideration as to proximate cause and amount of damage.

60. 28 U.S.C. §§ 2671-2680 (1982).

61. By passage of the Federal Tort Claims Act (FTCA), 28 U.S.C. §§ 2671-2680 (1982), the United States has waived its sovereign immunity in certain areas. The provisions of the Act, however, do not apply to actions based upon the exercise or performance of a "discretionary function." 28 U.S.C. § 2680(a) (1982).

62. *See* L. JAYSON, 2 HANDLING FEDERAL TORT CLAIMS, at §§ 245-249.07 (1984), discussing the discretionary function exception to the FTCA. This exception has often been interpreted by the courts to exclude tort actions in public works project cases. *Id.* § 249.06, at 12-130 to 12-133. For a discussion of the liability of the federal government and state governments for erroneous weather forecasts, *see* Weiss, *The*

recovery for damage which occurs in a foreign country.[63] Thus under current law it would be impossible to resort to national courts to bring claims of weather modification damage against the United States.[64]

On the other hand, United States courts might be used with some success to bring suit against United States commercial companies who in conducting weather modification operations in no way act as employees or independent contractors of the United States. However, such suits would encounter the difficulties mentioned previously in bringing weather modification damage claims in the courts.[65]

If we rely primarily upon national courts, decisions will inevitably vary within the same country and, more importantly, from one country to the next. No uniform standards for providing compensation are likely to be established. This lack of uniformity will complicate long-range planning for global protection of the climatic system and use of weather modification technology.

Weather modification disputes and damage claims can be handled at a regional level.[66] For example, such arrangements might emerge when countries integrate weather modification technology into their economic planning for developing water supplies in an international river basin. Treaties governing international river basins provide in many instances mechanisms for dispute resolution.[67] Such arrangements might be applied to resolving disputes arising from weather modification operations. Regional approaches to dispute adjustment could also be established in areas

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Value of Seasonal Climate Forecasts in Managing Energy Resources, 21 J. APPLIED METEOROLOGY 510, 515-16 (1982).

63. 28 U.S.C. § 2680(k) (1982).

64. For an analysis of the effect of the FTCA on United States liability, *see* A. ROSENTHAL, H. KORN & S. LUBMAN, CATASTROPHIC ACCIDENTS IN GOVERNMENT PROGRAMS (1963). *See also* Weiss, *supra* note 62, at 515-16.

65. *See supra* text accompanying notes 55-59.

66. "Region" indicates a large geographic area, such as Europe or North America.

67. The Indus Water Treaty of 1960 between India and Pakistan sets up a four-step procedure for dispute resolution. First the dispute goes to the permanent Indus Commission. Either commissioner may find that the matter falls within twenty-three designated areas of "difference" and may refer it to a neutral expert, such as an engineer. If the matter is a dispute rather than a "difference," states may negotiate with the aid of mediators. At the request of either party, the dispute may go to a court of arbitration. Indus Waters Treaty, *signed* Sept. 19, 1960, India-Pakistan-International Bank for Reconstruction and Development, 419 U.N.T.S. 125, 150, 152. The Niger River Agreement calls for the Niger Commission to examine complaints and promote settlement of disputes, but provides no details. Agreement Concerning the Niger River Commission and the Navigation and Transport on the River Niger, *done* Nov. 25, 1964, ch. I, art. 2, para. g, 587 U.N.T.S. 19, 23.

where there is already cooperation in handling claims regarding resources common to more than one country.[68] For the most part, however, regional mechanisms for dispute adjustment will be limited to a handful of geographic areas in which states have already shown a willingness to work together, and will probably be useful only for claims and disputes involving inadvertent weather modification and small-to-medium-scale deliberate weather modification operations, particularly cloud-seeding operations to increase rainfall.

Developing dispute resolution processes at the international level requires consideration of what process could best meet the problems arising from a particular kind of weather modification dispute. For those operations that might result in unanticipated damage, such as hail suppression operations which inadvertently increase hail,[69] we could establish a claim adjustment board. Such a board would provide compensation from a common fund consisting of "insurance fees" contributed by states engaged in weather modification.[70] Commercial operators might receive

68. For example, the United States-Canadian International Joint Commission might handle weather modification claims by referring them to an arbitral tribunal. The Trail Smelter Case was before an arbitral tribunal, which took both remedial action and positive action to prevent a recurrence of the same damage in the future. Trail Smelter Arbitral Tribunal (U.S. v. Can.), 35 AM. J. INT'L L. 684, 717-32 (1941).

69. *See supra* note 14 and accompanying text.

70. There is some precedent for establishing a compensation fund for weather modification in the discussions after the Brussels Convention on the Liability of Operators of Nuclear Ships, May 25, 1962. Szasz, *The Convention on the Liability of Operators of Nuclear Ships*, 2 J. OF MAR. L. & COM. 541 (1971). For the text of this convention, *see* International Atomic Energy Agency, International Conventions on Civil Liability for Nuclear Damage, Legal Series No. 4 (1976) at 34-42. The Standing Committee studied the "setting up of an international guarantee fund or a system of mutual guarantees that would ensure and facilitate the prompt settlement of claims on States" arising from the Convention. Szasz, *supra* this note, at 557 (citing IAEA Doc. CN-6/SC/13, para. 2(1)). The portions of the committee's deliberations relevant to establishing a fund are cited in Szasz, *supra* this note, at 556-58. Experience with "trust" funds in hazardous waste management can provide guidance for development of compensation funds. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9601-9657 (Supp. V 1981), established the $1.6 million federal "Superfund" which is financed by a feedstock tax imposed on the petroleum and chemical industries. This fund is used to finance federal cleanup action and to provide compensation for damage to natural resources. *Id.* at § 9611. Many individual states have developed variations of the federal Superfund. California, for example, has created a Hazardous Substance Account comprised partially of fees imposed on the generators of hazardous waste. CAL. HEALTH & SAFETY CODE §§ 25300-25333 (West 1984). The fund can be used for purchasing cleanup equipment, *id.* at § 25351(a)(3), for costs of removal and remedial actions incurred by the state, *id.* at § 25351(a)(4), health effects studies, *id.* at § 25351(a)(6), and natural resource restoration, *id.* at § 25352(a), and for compensat-

fund coverage by paying a premium to an association of underwriters such as Lloyd's of London. The proposed compensation fund rests on the belief that an evaluation of the risks from weather modification operations will become possible through statistical estimates. Some disputes, such as a claim that an increase in rainfall is untimely and therefore has actually harmed a neighboring state rather than benefited it as expected, may require the intervention of a mediator or arbitrator for settlement. Compensation would be made from the fund proposed above.

In those cases involving potentially large-scale damage, the state planning the weather modification operations could post a bond before undertaking the project. Any claims for damage would be paid pursuant to the bond procedures agreed upon. Such an approach should be considered for typhoon and hurricane modification operations.

The proposed claims adjustment board would function in a manner similar to an insurance claims adjustment procedure.[71] As a result, such an institution could offer a relatively quick and nonpolitical means for obtaining compensation for damage. It would avoid having to place blame squarely upon an individual or state for the damage, thereby rendering payment of compensation to victims of weather modification operations more politically acceptable. The board would compensate victims who prove that weather modification damaged their interests, but do not know who caused the damage.

A number of questions arise in connection with establishing such a board. Who could bring a claim to the board? Should claimants be limited to states which have been injured by other states or by commercial companies from other states? Or should

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ing for medical expenses, lost wages, or business income losses suffered by victims of hazardous waste releases, *id.* at § 25375. For other examples of state "Superfunds," *see* N.Y. STATE FIN. LAW § 97-b (Consol. 1983) and N.Y. ENVTL. CONSERV LAW § 27-0923 (Consol. 1983), creating a hazardous waste remedial fund financed by assessments imposed on persons who generate, store, treat, or dispose of hazardous wastes; and N.J. STAT. ANN. § 58.10-23.11 (West 1982 & Supp. 1983), establishing the New Jersey Spill Compensation Fund to cover all cleanup and removal costs and all direct and indirect damages caused by discharges of hazardous substances. *Id.* at § 58:10-23.11g. The fund is financed by a tax imposed on owners and operators of hazardous substances facilities and vessels. *Id.* at § 58:10-23.11h.

71. *See generally* R. MEHR & E. CAMMACK, PRINCIPLES OF INSURANCE 719-39 (5th ed. 1972); Bickelhaupt, *Automobile Insurance Coverages*, in GENERAL INSURANCE 715-21 (9th ed. 1974) (discussing the claims adjustment provisions of a family automobile policy); and Craig, *Claims Administration*, in LIFE AND HEALTH INSURANCE HANDBOOK 1007 (D. Gregg & V. Lucas eds., 3d ed. 1973) (discussing the claims administration process of life and health insurance companies).

individuals, producer cooperatives, or private associations and groups also have the right to approach the board for compensation? The latter issue becomes particularly thorny when we consider that one interest group in a country, such as wheat growers, may have benefited from another country's weather modification operations, while another interest group, such as resort owners, within that country may have suffered adverse consequences from the operation. Where several countries cooperate in a common weather modification program, such as cloud seeding to increase the water supply in an international river basin, provision should be made before the program begins to compensate potentially adversely affected interest groups within a country.

A second question concerns financing of the compensation fund. Who will be required to pay an insurance fee? Should all countries pay such a premium, whether or not they have any weather modification projects? Should commercial operators also pay a premium? Should the amount of the premium vary from country to country and from operator to operator, and, if so, what criteria should determine the amount of the premium? These are difficult questions, and resemble in part those questions raised in apportioning financing of many international activities.

An additional question concerns the method used to determine whether a claim has merit and whether the aggrieved party should be compensated from the fund. Once again we face the problem of showing cause and effect. Theoretically, a claims adjustment board should be better able to handle the problem than the courts since members of the board would presumably be familiar with the scientific arguments and evidence advanced and the board could develop continuity and consistency in its decision making. This expertise and consistency would be difficult to obtain under other systems. The board would also have access in difficult cases to the best global expertise available on the problem.

For those claims which could not be handled conveniently by a claims adjustment board, parties would have the option of approaching a conciliator, and, if the conciliator were unsuccessful in mediating the dispute, of going to an arbitration commission. Parties could also approach the arbitration commission directly without first participating in conciliation or mediation proceedings. This proceeding is particularly designed for cases of deliberate modification which do not fall within the normal rubric of the claims adjustment board and for cases of inadvertent modification. The arbitration commission could also handle the more dif-

ficult claims. For example, it could resolve a dispute arising because an increase in rainfall has actually harmed a neighboring state rather than helped it.[72] An arbitration commission should have the power to issue an injunction against continuing an activity for which the party is being held liable in damages. This authority would supplement the commission's power to decide the case on the merits and to determine the amount of damages. There is precedent for injunctive power in this kind of case in United States equity law, and in the decision of the Trail Smelter Arbitral Tribunal, which enjoined a polluting Canadian company from sending high volumes of noxious fumes across the United States-Canada border.[73]

In cases such as modification of hurricanes or typhoons in which it is anticipated that some states may benefit at the expense of others and that damages will likely be costly, the modifying state could post a bond or other financial guarantee from which to settle claims for damage. The proposed mechanism is similar to requirements that companies post bonds guaranteeing performance, that money be placed in escrow until a dispute is settled, or that earnest money be paid into a court.

A financial guarantee of damage payment has several advantages in handling compensation claims from such operations. Most importantly, it requires a state to acknowledge responsibility for the damage caused by its activities and to consider the cost of this damage as part of the cost of the operation. Second, the posting of a bond before undertaking the operation may reduce the political nature of providing compensation for damage after the fact. Instead of fighting to make a state admit to liability for damage it caused, the state that suffered the loss would recover under the guarantee, minimizing opportunities for conflict between states. Third, since the money is guaranteed, and since experts would decide on the merits of the claim, the approach should expedite compensation. The major disadvantage of the proposal is that it might tie up large sums of money. We would need to work out satisfactory financial arrangements to lessen this shortcoming. At a minimum, mechanisms might be designed to ensure that the money earned interest while tied up in the fund. We should con-

72. *See supra* text accompanying notes 10-13.

73. *Trail Smelter*, *supra* note 68. For domestic cases, *see, e.g.*, United States v. Reserve Mining Co., 380 F. Supp. 11 (D. Minn. 1974), *stayed*, 498 F.2d 1073 (8th Cir. 1974), *application to vacate stay denied*, 419 U.S. 802 (1974), *modified and remanded*, 514 F.2d 492 (8th Cir. 1975), *further proceedings*, 408 F. Supp. 1212 (D. Minn. 1976).

sider requiring that any interest earned be applied to evaluating the results of the operation.

International institutions created to resolve disputes and provide compensation for damage could be placed under the International Court of Justice or under a new international center for environmental disputes which would also cover other environmental cases.[74] While the adjudicatory system could be housed in one location, members could also travel to adjust disputes, much like circuit judge riders who travelled from community to community in earlier days in the common law system.

The question of compliance and enforcement has been given too little attention in international law.[75] A state complies with provisions for adjusting disputes because it perceives that doing so will further its self interest. In weather modification, the motivations for states to comply with international arrangements to manage disputes are a) the recognition by states that the weather system is a common resource and that they must cooperate to preserve its value, and b) the recognition that cooperative arrangements may facilitate the application of weather modification technology to enhance the value of the weather.[76]

Thus far, we have focused on holding weather modifiers responsible for compensating injured parties. However, there are alternative methods for compensating such victims. One option is to provide state aid to persons who have been injured or who have suffered property loss from natural weather phenomena such as floods and droughts. Legislation in Victoria, Australia, adopts this approach for weather modification.[77] This system does not afford complete compensation. The phenomenon causing the damage may or may not be included within a program that focuses on floods, droughts, and other major weather phenomena, and the state aid provided may be less than is needed to compensate fully for the damage caused.

A second proposal is state insurance of major crops against all

74. For an analysis of the potential role of the International Court of Justice in environmental disputes, *see* Jessup, *Do New Problems Need New Courts?*, 65 AM. SOC'Y INT'L L. PROC. 251 (1971).

75. For a comprehensive analysis of the problems with compliance, *see* R. FISHER, IMPROVING COMPLIANCE WITH INTERNATIONAL LAW (1981).

76. *See* Weiss, *International Responses to Weather Modification*, 29 INT'L ORG. 805, 806-13 (1975). *See generally* T. SCHELLING, THE STRATEGY OF CONFLICT (1960).

77. Rain-Making Control Act of 1967, No. 7637, 1968 VICTORIA GOV'T GAZETTE 707.

unusual losses. These unusual losses could be specified to include losses caused by weather modification operations. Canada, Ceylon, Japan, Mexico, the United States, and India have been experimenting with crop insurance.[78] The major advantage of crop insurance is that losses could be compensated regardless of whether a direct cause and effect relationship between the weather modification project and the damage could be satisfactorily proven in a court of law. International lending agencies could be approached to support national or regional crop insurance programs.

The major limitation of this approach is that it covers only crops. To cover fully the damage from weather modification operations, the program would need to provide insurance for all possible forms of loss (e.g., for damage to crops, homes, and personal property). It would probably prove more difficult and costly to provide such insurance than to establish mechanisms by which those who effect changes in the weather could compensate persons harmed by such operations.

VI
INADVERTENT MODIFICATIONS

A. Altering Weather

Problems of inadvertent changes in weather call for procedures to manage disputes over an extended period of time. For example, to resolve disputes arising from increased or decreased rainfall in an area downwind from industrial pollution, we will need to engage in a continuous process of monitoring, assessment, consultation, regulation, and compensation. Each measure taken in turn feeds back into the dispute management process.

Basic to management of disputes is a system of monitoring weather conditions so that we can detect when inadvertent changes in weather have occurred or when conditions indicate that if the trend continues, we can expect changes in weather. We also need to monitor the transport of pollutants across national borders and to assess the extent to which changes in weather conditions can be attributed to these pollutants.[79]

To manage disputes over inadvertent changes in weather, we need procedures for intervening at three different phases: 1) to

78. For a proposal to establish crop insurance schemes in developing countries, *see* Oury, *Weather and Economic Development*, 6 FIN. & DEV., June 1969, at 24.

79. *See supra* text accompanying and following note 24.

prevent damage from occurring in the first instance; 2) to prevent additional damage; and 3) to compensate those injured by damage that has already occurred.

The case of the single activity or industrial plant which affects weather conditions downwind across national borders is probably most analogous to the problems raised by weather modification projects. It may be possible to prevent injury by requiring that the party building such a plant notify any state that could be affected, by providing for assessment of the potential effects downwind upon weather, and by giving those who believe they might be adversely affected an opportunity to consult with the party building the plant to work out more suitable arrangements.[80] If there are indications after a plant is built that its discharge is altering weather patterns downwind, procedures should be available for consultation between concerned parties and for preventing further damage and compensating those already damaged.

In some cases the critical issue will be assessing whether current pollution trends will lead to changes in weather. Procedures should be available for states to consult and take preventive action before pollution patterns cause changes in weather conditions.

In many cases the problem will be determining whether changes in weather have resulted from human activities and identifying particular pollutants that are responsible at least in part for these changes. In these cases we will be concerned with avoiding further adverse changes in the weather and with compensating those already injured.

The dispute management procedures proposed for projects which are intended to modify the weather are also relevant to cases of inadvertent modification.[81] The conciliation commission proposed above[82] could be equally useful for resolving problems caused by inadvertent modification. It would offer a vehicle for consultation between all concerned parties and for negotiation of reasonable adjustments in activities to lessen, or stop, their adverse effects on weather conditions. In many cases the conciliation commission could be established at a regional level or even

80. The Nordic Environmental Protection Convention, *supra* note 52, is a useful precedent for regions where states have developed patterns of cooperation among themselves. The Convention requires persons to obtain permits before engaging in certain activities, and to give notice of this permit to all contracting states affected. *Id.* at art. 6.

81. *See supra* text accompanying notes 42-78.

82. *See supra* text accompanying notes 49-50.

between two states. The services of an international conciliation commission on weather modification would be useful where it is not feasible or appropriate to establish the commission at a more local level.

The discussion of compensation for parties injured by intentional weather modification projects[83] applies in part to cases of inadvertent weather modification as well. Parties will encounter similar problems in tracking changes in weather conditions to specific sources of pollution[84] and in reducing the damage to quantifiable, monetary terms.

The compensation fund proposed for intentional weather modification projects,[85] however, is unlikely to be suitable for many cases of inadvertent weather modification. Although those engaging in discrete activities with a high probability of causing changes in weather conditions could be required to contribute to a compensation fund as a condition for carrying on their activities, requiring payment from all those who may in some minimal way contribute to producing a change in the weather would be vastly more difficult. For the latter, a fund would work only in the context of a broad environmental tax on all industrial and agricultural activities which could contribute to altering weather conditions. Thus, for problems of inadvertent weather modification, a panel of arbitrators, similar to that proposed for intentional weather modification,[86] should be available to resolve issues of compensation for injuries that have already occurred. Central to the power of an arbitral commission would be authority to enjoin continuation of projects which were causing inadvertent weather modification,[87] and the establishment of a regime which would set standards for continuing such projects and monitoring their effects.

Particularly in cases of inadvertent weather modification, a net-

83. *See supra* text following notes 46 & 71, accompanying note 77, and accompanying and following notes 70 & 78.

84. For example, in a major breakthrough in this area, the United States National Academy of Sciences recently concluded that a reduction of sulphur dioxide and sulfate emissions will produce a proportional reduction in the concentration of sulfate in precipitation. COMMITTEE ON ATMOSPHERIC TRANSPORT AND CHEMICAL TRANSFORMATION IN ACID PRECIPITATION, ACID DEPOSITION, ATMOSPHERIC PROCESSES IN EASTERN NORTH AMERICA 10 (1983). However, the scientists of the Academy panel indicated that they were not yet able to attribute acid precipitation in one location directly to emissions from sources in another. *Id.* at 10-11.

85. *See supra* text accompanying and following note 70.

86. *See supra* text accompanying notes 72-73.

87. *See supra* note 73 and accompanying text.

work for monitoring any arrangements made in the course of adjusting a dispute is essential. This will allow changes in regulatory measures to be made as appropriate and consideration to be given to ways of handling new sources of pollutants which may be affecting weather conditions.

Efforts to manage local disputes over inadvertent changes in weather should be coordinated at the international level. While cases of inadvertent weather modification may initially arise as discrete problems specific to an area or region, their cumulative effects may create an international problem that may stimulate broad-scale disputes between countries.[88] Several meteorologists, for example, have referred to the danger that global belts of pollution may emerge in the northern hemisphere as a result of continuing pollution.[89] Under such circumstances, the oceans, which normally cleanse the atmosphere of pollutants, will no longer be able to fulfill their cleansing function, resulting in increasingly higher concentrations in the pollution belt.[90] This problem can be identified, assessed, and managed only at an international level.

B. Altering Climate: The Single Project

Proposals which have a significant risk of indirectly affecting climate, such as damming large rivers or otherwise changing topographic features on a large scale, raise problems similar to those raised by projects specifically designed to effect changes in climate. The primary distinction is that the project will be for purposes other than altering climate. Thus, it may be more difficult to subject the project to procedures for managing disputes arising over climatic changes.

If we are to regard the climatic system as a global resource, as we must, all experiments and activities in which there is a significant risk of affecting climate beyond national borders should be submitted for evaluation and assessment to the scientific advisory panel proposed previously for large-scale experiments intended to

88. *See supra* text accompanying and following note 33.

89. Neiburger, *The Role of Meteorology in the Study and Control of Air Pollution*, 50 BULL. AM. METEOROLOGICAL SOC'Y 957, 964 (1969); Schaefer, *supra* note 24, at 199; Hubbs, Harrison & Robinson, *supra* note 24, at 912.

90. Pollution is diluted and removed from the air as the air passes over areas which contain no pollution sources, such as the oceans. The ability of such areas to dilute and remove pollution, however, is finite. If the rate of emission of pollution continues to increase, this dilution and removal process will not be as effective. Neiburger, *supra* note 89, at 958, 963-64.

modify climate.[91] Provisions outlining the functioning of this panel and the conditions under which states could undertake deliberate large-scale modifications would also apply to these projects.[92] This would implement Recommendation 70 of the United Nations Conference on the Human Environment to assess the climatic effects, to disseminate such findings before embarking on the activities, and to consult fully with all states which have an interest in the activity.[93] The United Nations Environment Programme, which grew out of the Conference on the Human Environment, could serve as the "climatic watchdog" for all large-scale projects and could bring to the attention of the proposed scientific advisory panel and the international community those projects in which there is a significant risk of effects on climate.

Since many of these projects may take place entirely within a country's borders, difficulties may arise in preventing the projects from going forward even if the scientific advisory panel foresees an appreciable risk of adverse climatic effects in other areas. Thus, provisions must be made for monitoring the climatic effects of the project and assessing its implications for all affected areas. Procedures should be provided whereby those parties who believe that a particular project adversely affects their climate may approach the offending party and attempt to work out mutually acceptable arrangements for averting some of the climatic effects. The forum discussed below for consultation between states on problems of inadvertent climatic change from cumulative effects could also serve as a forum for discussion of measures to alleviate climatic effects of large-scale projects.

C. Altering Global Climate: Cumulative Effects

To manage disputes about climatic changes caused by the cumulative effects of industrial and agricultural practices, we need to establish international dispute resolution processes and to develop constituencies within the international community which are concerned about such climatic changes. As in other kinds of weather and climate modification, a sophisticated system to monitor climatic change and means to disseminate the data internationally are necessary. Similarly, there is a need for an international scientific advisory panel to assess climatic change. However, the primary function of the panel in these cases should be to warn of

91. *See supra* text accompanying notes 42-44.
92. *See supra* text accompanying notes 38-47.
93. *See supra* notes 40-41 and accompanying text.

impending changes, to identify critical threshholds for climatic disasters in the most fragile parts of the climatic system,[94] and to assess the impact of man's activities on specific climatic changes. If a general scientific advisory panel on weather and climate modification were established, one or more ad hoc panels devoted to climate change could be established under its auspices.

States concerned with potential or actual adverse climatic changes which may be attributed at least in part to the activities of other states need a forum in which they can consult with all concerned parties and take appropriate regulatory or redistributive measures. To the extent that certain classes of activities can be identified as contributing to specific changes in climate, states could initiate measures to regulate these activities. In other cases, states may face difficult disputes over reallocating goods and resources between states in response to man-induced climatic changes.

When measures are taken to ameliorate climatic trends, provisions must be made to monitor and assess the effectiveness of the measures. This information must be widely disseminated and carefully evaluated, and then fed into ongoing efforts to observe and understand climatic change.

Inadvertent climate modification arising from many diffuse sources of pollution will raise the most difficult disputes for the international community to manage. Such modifications may involve significant scientific uncertainty about serious effects which may be triggered now but which may not be felt for several decades or more. Management of these disputes will ultimately be possible only through the establishment of international processes which create an international constituency motivated to assess the problems fully and accurately, and motivated to agree upon measures to minimize their impacts upon the global human community.

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94. The Arctic and Antarctic represent particularly vulnerable points in the stability of our climate system. These areas are fragile in the sense that once we cause a sufficiently large change in them we can trigger major changes in global weather and climate patterns. For an excellent description of the physical processes that cause climatic changes, *see* U.S. COMMITTEE FOR THE GLOBAL ATMOSPHERIC RESEARCH PROGRAM, NATIONAL RESEARCH COUNCIL, UNDERSTANDING CLIMATIC CHANGE 13-28 (1975).

VII
CONCLUSION

There is still much scientific uncertainty regarding our ability to alter weather and climate patterns, whether intentionally or inadvertently. However, it is realistic to expect that at some point in the future advances in technology will permit people to alter weather and climate reliably. We must act now even in the face of uncertainty. It will be far better to take initial steps to establish processes for managing weather and climate disputes now than to wait until serious conflicts arise. Since it will often be impossible to compensate adequately those who may suffer harm from weather modification, efforts must focus on preventive rather than remedial measures. Our priority must be to develop mechanisms for avoiding or at least mitigating disputes over weather and climate changes.