

## WEATHER MODIFICATION AND THE MAN-ATMOSPHERE RESOURCE COMPLEX

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These comments are motivated by a growing sense that the time man will be able to control or modify regional, and perhaps global, weather and climate in significant ways may not be so far away. The time scale would appear to be decades, and perhaps not many decades.

Among some atmospheric scientists there is a "moving in for the kill" sense of excitement, as exemplified by recent comments by Dr. Walter Roberts [1] as follows: "The enemy is hail, blizzards, droughts, hurricanes," "Our objective is mastery of these excesses." Vern Suomi [2] has been quoted as follows "It's time for us to quit apologizing to everyone that our goal is atmospheric modification and to get on with the job in all ways we know how and with all the manpower and talent we can muster." In these comments we find identification of a natural enemy—certain properties of atmosphere itself—and a statement of intent to conquer or subdue this enemy. Other comments reflect greater sobriety. From the newly released report of the National Science Foundations Special Commission on weather modification [3] "An appraisal of the prospects for deliberate weather and climate modification can be directed toward the ultimate goal of bringing use of the environment into closer harmony with its capacities, and with the purposes of man, whether this be for food production, relief from floods, assuring the continuance of biologic species, stopping pollution, or for purely aesthetic reasons. How, by artificially inducing deliberate changes in the environment may man act to control or develop changes in the atmosphere considered to be desirable by society?"

Questions of what is "good" and "bad" in weather are extremely complex. Many of us in meteorology, being involved in a relatively young science, tend perhaps to view the atmosphere's weather as being composed of good and bad events, and the mission of eliminating the bad things has considerable appeal. This appeal may be particularly strong in those with forecasting backgrounds in that the frustrations of trying to predict the bad events might be relieved at last, simply by doing away with these events altogether.

But, the conclusion that the natural wilderness of weather is not as suitable an environment for man as a more innocuous, man-controlled atmosphere is not one to be reached lightly. Nor does it seem appropriate that such conclusions be limited to so small, and perhaps biased group, as a few dozen meteorologists. The atmosphere may be the object of our study, but it belongs to all people; it supports, at least indirectly, all life on this planet.

The physical scientists can help with the question "What can we do," but it's everyone's responsibility to consider "What ought we to do."

#### A Historical Opportunity

If the time-scale estimate of decades is correct, we have an opportunity unique in our history of mastery over our natural environments. This opportunity is time, time with which to gain understanding of the full spectrum of our requirements and dependencies on our atmosphere. This time should be utilized to fullest possible extent, for as Dr. Von Neuman [4] warned, "we should not deceive ourselves, once possibilities of weather control become actual, they will be exploited." Our safest assumption is that we will indeed be unable to adopt a "hands off" attitude toward our atmosphere and therefore resolve now and begin to prepare ourselves adequately for a new magnitude of responsibility which may soon be our burden.

#### A Backward Glance

A backward glance may raise some pertinent questions.

Man's emergence as the ecological dominant on this planet, must in some part be attributed to his ability to adapt to an unstable atmospheric environment; he is a product of the pliestocene ice age—that period in the earth's history when the climate was most unstable and severe. The anthropological writer Robert Ardrey [5] calls man the "Bad Weather Animal." Some claim that man's ecological success was achieved because of the great climate stresses: Others are more inclined to feel our rise was achieved in spite of the difficult climates. S. F. Markham, in "Climate and the Energy of Nations" sees in recorded history a suggestion that climate is a powerful environmental influence on the fortunes of men and nations. Many historians and geographers also attribute powerful influences to weather and climate. Their most common thesis is that climatic stress is shown by history to be generally beneficial.

Our success, in an evolutionary sense as well as a historical sense, must be due in some significant measure, to our ability to adapt to our natural surroundings, particularly to our atmosphere.

The natural atmosphere, a wilderness in both space and time, has in some still mysterious ways, helped determine where we are, and what we are today.

It would appear that subjugation of this last natural environmental wilderness is a step best taken with humility, and wisdom. We would not be the first species on this earth to inadvertently cut off its own environment needs. Our roots extend back through a million or so years of wild weather, it has not yet been demonstrated that our needs would now be better served by some kind of programmed weather.

## Man's Adaptation to the Atmosphere

How does modern man, in his urban-industrial-social culture, relate to his atmospheric resource?

A simple framework for examining current man-atmosphere relationships has been suggested by James Hibbs [6] of the ESSA.

Hibbs points out that our responses may range from passive acceptance of all weather/climate conditions, through conscious actions to avoid or exploit atmospheric conditions, to control over weather and climate.

The responses may be classified as follows and can be considered as overlapping resource processes.

- (1) Passive Acceptance—non-adaptation—no available information,
- (2) Meteorological Adaptation Responses—based on weather information, forecasts, warnings.
- (3) Climatological Adaptations Responses—based on climatological information. These include insurance, site selection, design of buildings, clothing, vehicles, zoning, and so on.
- (4) Direct Atmosphere Control—currently limited to possible slight effects on rainfall, hail and lightening, but potentially involving large scale atmospheric processes affecting the climate.

What concerns us are the potential impacts of major changes in man-atmosphere relationships from meteorological and climatological adaptations, to significant modifications or controls.

## A Framework for Resource Use Criteria

What are the appropriate criteria for determining which of these four modes of response will best serve our requirements of the atmosphere? Is there a framework within which the criteria may be determined.

To the best of my knowledge, an adequate framework for determining criteria for resource use does not exist for the atmosphere, but it may be helpful to borrow from other resource-use studies, such as land or water use.

Walter Firey [7], in his book "Man, Mind and Land" suggests three sets of criteria guiding the adoption of resource processes:

- (1) Those processes which are ecologically possible
- (2) Those processes which are ethnologically adoptable
- (3) Those processes which are economically gainful

And, Dr. Firey points out that these three processes do not necessarily coincide. Any existing resource process may therefore not be the most ecological possible, the most culturally adoptable, or the most economically gainful, but it must be, at least in some degree,—possible, adoptable, and gainful. Any resource use which is or becomes economically non-gainful, culturally not adoptable or economically not gainful cannot persist, without disasterous consequences.

Can the atmosphere, be viewed in this resource-process context? Can valid criteria for shifting from atmospheric adaptations to atmospheric controls be derived within this framework?

### The Hurricane

It may help if we diagnose how we relate to a particular weather event, the hurricane; one of Dr. Roberts' specified "enemies." Let's consider first what may be the most economically gainful response or combination of responses to the hurricane.

What about Passive Acceptance? Obviously not.

What about meteorological adaptation? The hurricane forecast and warning system and the subsequent defensive actions by the public represent this response mode. How economically gainful is it?

Arnold Sugg [8], of ESSA, estimates annual average hurricane losses in the United States to be about 300 million dollars. He further estimates that the hurricane warning system keeps these losses from going perhaps 5 percent higher. From this average annual saving of perhaps 15 million dollars the cost of the warning service should be subtracted. However, part of the cost, perhaps the major part, should be charged to the social benefits of saving lives. In any case, our meteorological adaptation to hurricanes is not particularly gainful, economically, when viewed in terms of the total hurricane dollar loss.

What about our climatological adaptations?

Perhaps one half of hurricane damages are covered by insurance, that part caused by direct action of wind rather than direct action of water. While this does not prevent any loss to the total economy, it does spread the cost of damage so as to prevent countless financial hardships or disasters for individuals, families or companies. Insurance is economically a highly gainful adaptation for the individual or the economic or social unit where the stakes are highest.

Other climatological adaptations, such as strengthened building codes and zoning regulations are estimated to have very substantially reduced hurricane losses, particularly in Florida where these adaptations are most advanced. I have been told much of the hurricane-proofing of dwellings is accomplished at about an 8% increase in dwelling costs. But although 8 percent seems a small price to pay, economically it will be gainful only if expected hurricane losses are greater than the amortized cost of dwelling improvements. The expected hurricane loss for a dwelling in Florida is about 30 dollars, while the 8 percent cost of hurricane proofing, amortized over 20 years, would be more than twice that amount, based on an average dwelling cost of \$12,000.

Some combination of good construction to meet the hurricane threat and insurance to cover the occasional serious loss appears to be a reasonably stable climatological adaptation to the hurricane as it is economically quite gainful, more gainful than meteorological adaptations.

#### What Can We Say Now About Hurricane Controls?

Do controls offer the potential for an even more economically gainful response? Hendrick and Friedman [9], made some rough estimates of potential reduction of property loss from quite modest controls of hurricanes.

The arithmetic showed that a 10 percent reduction of hurricane frequency, a 15 percent reduction in intensity and a steering capability of 10 degrees in direction might reduce average annual property losses by two thirds, or from 300 million to 100 million dollars.

Against this very substantial savings must be balanced the costs of the control operations, about which we know little, but they would probably be relatively small if they were based on some kind of seeding. In addition, there may be certain economic benefits derived from hurricanes which would be lost. Rainfall is the most obvious. George Cry [10] of ESSA is studying rainfall distributions to determine to what extent annual rainfall patterns in eastern United States are dependent on the passage of hurricane-type storms. He reports "The conclusion is reached that tropical cyclone rainfall is an important component of the precipitation patterns and consequently of the climatology and hydrology of the eastern United States."

A question that comes to mind is the economic value that might be attached to full reservoirs for Springfield, Boston and other New England cities, if hurricanes had passed this way this last summer or fall and filled them up. So there are, of course, some economic benefits that accrue as a result of having hurricanes around, and these should be studied and then included in any attempt to measure just how economically gainful hurricane control might be, or to determine what degree of controls might be economically the most gainful. So, we don't really know yet which resource process is potentially the most economically gainful, whether it be better adaptations, new controls, or some combination of these.

## Ecological and Ethnological Criteria for Hurricane Control

As mentioned earlier, what may be economically most gainful may not necessarily be ecologically most possible or culturally most adoptable. Almost no study has been addressed to these questions. Hurricane control could conceivably eliminate loss of human life, but better forecasts and warnings could do the same thing. How would hurricane control, and also more general forms of potential weather modification, affect not only the ecology of man but the ecology of all biological systems. How will man, the Bad Weather Animal, fare without bad weather? Are we pre-stressed for bad weather in some way that gives us ecologic advantages? Do we have a need for some environmental uncertainty which only the atmosphere can now provide? Do we need the population check currently provided by the atmosphere, or should we manipulate the atmosphere in ways which would permit further explosive population growths. In short, does man yet have the wit and wisdom to improve the ecological fitness of his atmosphere? It appears doubtful, but research directed toward the right questions may help.

Questions as to the adoptability, the acceptability, of controlled versus natural weather and climate need equal attention. Perfect weather may prove to be quite unacceptable. How do people perceive their weather environment? There have been no weather perception studies. The following is quoted from the recent report of the special commission on weather modification of the National Science Foundation:

“A beginning at changing storm or lightening raises the question of how far the human spirit is enriched by the uncertainty and wonder and exhilaration that come with the restless, violent movements of the atmosphere. Any effort to assess the social consequences of weather and climate modification must give weight to the esthetic and spiritual as well as the purely material rewards.”

It has been our modern experience that the taming of a wilderness leads, among other things, to a nostalgia for the wild. Neither naturalness, nor surprise, are any longer commonly found in our land, water or biotic environments. For most of us, the wilderness of weather is the last of the purely natural environments, and this only where air pollution is not yet omnipresent.

### Conclusion

We are, with all our science and technology, moving ineluctably toward control over our atmosphere. This will represent entirely new dimensions in power, power over all living things. If we are to be prepared as trustees of life's air resource, new ways to exercise such a vital stewardship must be found. The research framework I've suggested here, borrowed from an approach to land resources, may not be appropriate, but some framework, some approach, must be found which can guide our efforts to make weather control a truly managed enterprise, managed for man as well as by man. Such an enterprise merits the concern of all men, not only the few who see in natural weather a set of enemies; or the even fewer who, like myself, happen to delight in the more robust variations of our atmosphere.

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