REGIONAL IMPACTS OF GLOBAL WARMING

How society has reacted in the past to regional climate change should offer lessons on possible responses to a serious greenhouse effect.

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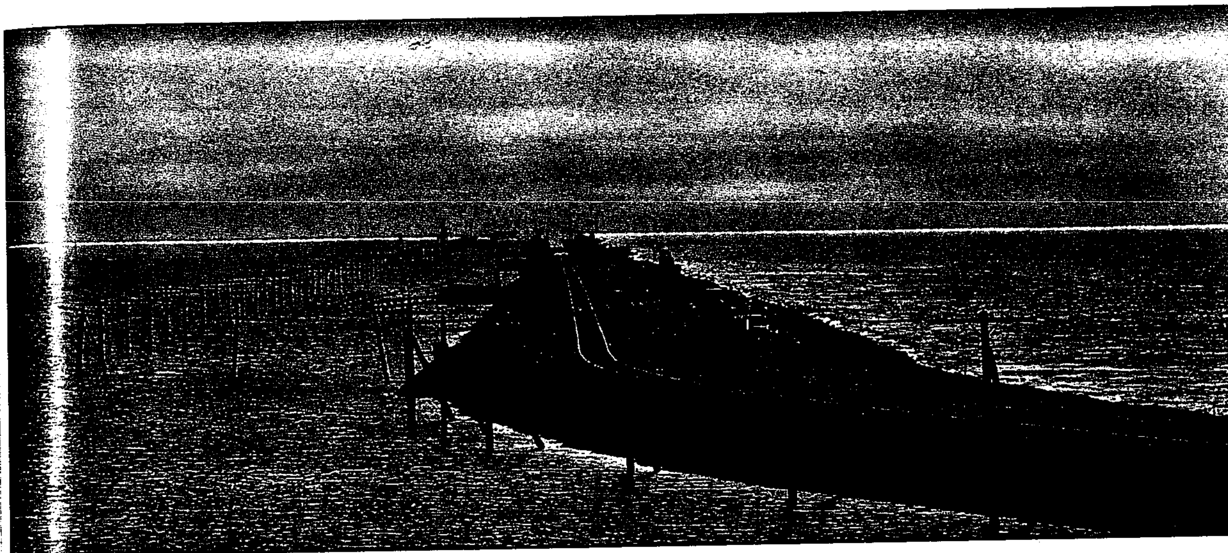
Speculation abounds about whether the global atmosphere is heating up due to the increases in atmospheric carbon dioxide (CO_2) and other trace gases—and, if so, at what rate. There is also much speculation about how a global warming might alter existing regional and local weather patterns. To speak of changes in global average temperatures fails to identify how those changes might affect regional temperature and precipitation variations, local and regional meteorological extremes, and other regional disparities. The average global temperature alone does not provide a true picture of impacts on a worldwide scale. It is like asking someone what his body temperature is while his feet are in a bucket of hot water and his head is in the refrigerator: On "average" it will be normal.

Providing a reliable picture of the regional impacts of a global warming is a major challenge now facing the scientific research community. Equally challenging to social scientists and policymakers is the identification of social responses that might be necessary to mitigate the regional impacts of a global warming.

To date, several attempts have been made to get a glimpse of future climate. One way has been the use of complex computer models to generate scenarios about the future. Scientists identify appropriate parameters (as well as relationships between them, such as carbon dioxide content and atmospheric temperatures) and use these as inputs to construct sophisticated models to be run on the largest and fastest computers in the world.

This sounds impressive. However, the predictions at various research centers do not agree with each other regarding either temperature or rainfall, although temperature projections associated with a CO_2 increase in the atmosphere are in closer agreement than those for precipitation. Despite the fact that the best-trained scientists and the most advanced computers are working on the problem, the reliability of their findings is fairly low. So the search continues for ways to foresee the impacts of and environmental and societal responses to possible changes in the climate.

A different approach to identifying regional climate change is based on some principles associated with global warming projections. Scientists have speculated that whatever the temperature rise in the mid-latitudes of the Northern Hemisphere, it will be considerably higher in the polar regions (and considerably lower in the equatorial regions). Based on this premise, scientists have identified the 10 warmest Arctic summers of the past century in order to make a composite of what the climate was like in the mid-latitude regions during these years and to see whether recurring climatic patterns could be identified. This is an innovative approach, but it has some drawbacks. For example, a wet autumn produces soil



JOHN BARSTOW/THE STOCK SOLUTION

The level of the Great Salt Lake in Utah fell consistently until 1962, enticing planners to allow development on land formerly under water. In 1962 the trend reversed, and in 1982 the lake began to rise rapidly due to dramatically increased precipitation.

moisture, which is important for the next year's crops as well as for the region's climate.

Yet another attempt at a glimpse of future climate impacts has focused on reconstructing global climate using paleoecological data of the period when the earth was considerably warmer than it is today. Such a period occurred between 4,000 and 8,000 years ago and is referred to as the Altithermal period. This approach, while also innovative, likewise has problems. First of all, the factors bringing about the warmer temperatures in that period were not the same as those of today. Thus, a future warming would most likely have different regional impacts. Second, the reconstructed global map puts 4,000 years of climate history (with all of its year-to-year variability) all on one map. We know how misleading this is by trying to apply this method to this century alone, with its intermingling periods of hot, cold, wet, and dry years.

Interestingly, these three approaches agree on one point—that the U.S. Great Plains, America's agricultural heartland, is expected to become drier than it is at present.

Another recent approach attempts to identify how well society is prepared today to deal with climate variability. This method is based on the assessment of responses to impacts of recent climate-related extremes (such as droughts, floods, and freezes) on society. Such scenarios have more credibility for policymakers because they have experienced these problems and have had to respond to the concerns of their constituents.

By assessing the impacts of these events on contemporary societies and societal responses to them, researchers and policymakers perhaps can learn how society might better cope with the effects of a possible climate change in the future. To this end, a recent study examined the impacts of 10 recent regional climatic events and societal responses to them to assist decision makers responsible for evaluating climatic changes with respect to public policy.*

Society prefers to view any change in normal weather patterns as a short-term deviation.

The following examples, taken from that study,

* *Societal Responses to Regional Climatic Change: Forecasting by Analogy* (Boulder, Col.: Westview Press, 1988). The author was the principal investigator of this study, which was completed for the U.S. Environmental Protection Agency by the Environmental and Societal Impacts Group of the National Center for Atmospheric Research in October 1988.

illustrate how well society is prepared to cope with today's climate extremes.

THE GREAT SALT LAKE

Utah's Great Salt Lake has been viewed as a fairly stable system. In 1962 the lake reached its lowest level in recorded history. Although one cannot know exactly what was on the minds of local decision makers (including urban planners) at that time, their actions suggest that they viewed the lake level as either stable or in a state of continual decline. As the lake receded, urban development encroached onto the newly exposed lake bed. After 1962, however, lake levels started to rise, but slowly enough not to cause alarm. All that changed in 1982.

As the result of heavy rains locally and increased snowpack in the neighboring mountains, the lake began to rise sharply in the spring of 1982. Sharp increases continued over the next few years, pushing the lake in 1986 to its highest level in the 130-year historical record. Since 1982 the level has risen about 12 feet!

In 1982 the tendency of decision makers was to see the rapid increase in lake level (about 5 feet) as a fluke of nature. Heavy rains and the timing of the melting of the snowpack were viewed as an unfortunate chance occurrence, and ad-hoc responses were deemed appropriate. After all, the level of the lake would soon recede, or so they thought. For example, railroad beds threatened by rising waters were elevated to keep them operative. As sharp increases in precipitation once again occurred, sending lake levels higher than expected, they were raised again and again.

> Forecasting by analogy does provide insight into decisions that societies must make in the event of a future change in climate.

Four years of continued increases prompted officials to view rising lake levels in a different light. Some observers began to believe that perhaps the rising lake level was the result of a worsening greenhouse effect. If that were the case, the region could be more severely affected as the proposed global warming intensified.

In 1986, the Utah state government decided to build an expensive pumping station to draw water out of the Great Salt Lake and into nearby dry lake beds. Since then rainfall has declined, furthering the controversy surrounding its construction.

After considerable political debate, and several temporary technological fixes, it was decided to build a pumping station to pump excess lake water into nearby dry lake beds. The governor of Utah was a leading proponent of this approach, and at a cost of $60 million the station was constructed.

Since the construction of the station, rainfall in the region has declined and so has the lake level. Debate over the need for the pumping station continues, despite the fact that it was considered a good decision, given the then-existing scientific information.

What this case study suggests is that society prefers to view any change in normal weather patterns as a short-term deviation. As a result, ad-hoc responses are usually favored over decisions that involve long-range planning. Technological solutions are often preferred over solutions that might involve social dislocations (e.g., land-use planning that will recognize the oscillating nature of the Great Salt Lake and the need to discourage lakeshore development during low lake-level periods).

STEVE KAYE/TAURUS

Freezing temperatures caused extensive damage to orange groves in Leesburg, Florida, in 1982. An unusual run of hard freezes continued to plague the Florida citrus industry throughout the early 1980s.

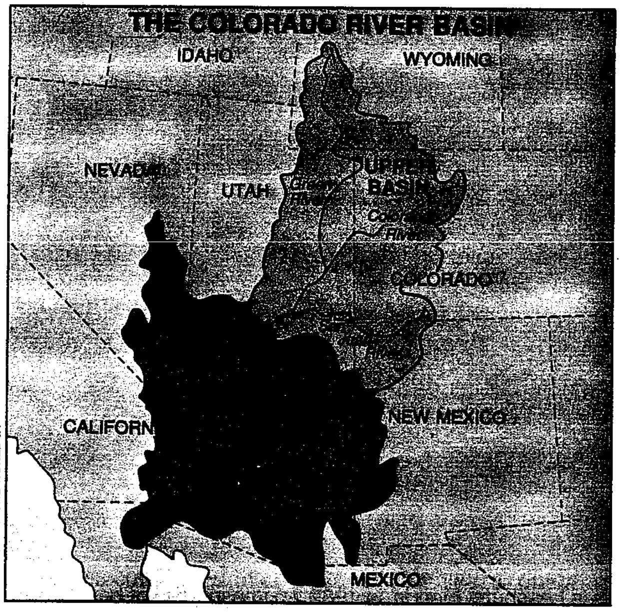
Florida Freezes

For decades Florida has been viewed as the "king of citrus," not just in the United States but in other countries as well. Citrus production, especially for frozen concentrate of orange juice (FCOJ), is an $8 billion industry in Florida, although it makes up only a small percentage of the state's total annual agricultural earnings. Perhaps until 1980 the claim of King Citrus was a valid one. However, in the early 1980s Florida's citrus-growing regions were plagued by recurring hard freezes—freezes that decimated some of the state's major citrus producing groves in four out of five years. Such a run of freeze years had not occurred this century.

Following the first freeze, citrus growers believed they had been hit by a to-be-expected occasional freeze. The second freeze year was considered unusual but not improbable. The third freeze year, however, raised the eyebrows of grove owners and raised questions about whether the climate was changing. Was this increase in the frequency of freezes a possible consequence of the greenhouse effect that was increasingly being described in the media? The fourth freeze year was devastating. It prompted some citrus owners to get out of the business. Some sold their land to developers, an irreversible change in land use in central Florida. Others considered planting groves at the southern edge of the citrus-producing region, where climate is more certain but soil is less favorable. For their part, researchers intensified their efforts to develop hardier citrus species that might withstand mild freezes. They also developed new techniques for protecting trees from cold temperatures.

The winters of 1986 and 1987 were favorable ones for citrus production. The situation in 1987, however, was not the same as it had been in 1980, before the onset of the run of freezes. One new factor was that Brazilian entrepreneurs were in a position to capitalize on the decrease in FCOJ production in Florida. In the past, when freezes occurred in Florida the price for the undamaged citrus crop rose sharply because of reduced supplies. With Brazilian FCOJ stocks available to fill in for losses due to the Florida freezes, prices failed to rise as sharply. Because of favorable climatic conditions in Brazil, the inexpensive labor supply, and large FCOJ stocks, Brazil has managed to capture a large share of the North American FCOJ market.

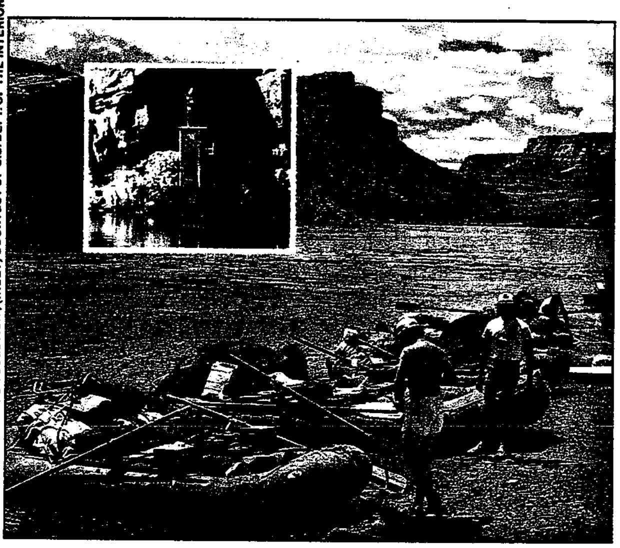
The Florida case study suggests that although we are constantly concerned about a "global" warming, the impacts of that warming will be felt at the regional and local levels, and that decisions to cope with those impacts will most likely be made at those levels. The situation also shows that grove owners



EMIKO OZAKI/THE WORLD & I

Above: The Colorado River Compact divided the area drained by the river and its tributaries into upper and lower basins, then decreed that the upper-basin states would provide the lower basin with an average of 7.5 million acre-feet of water per year. Shortly afterward the climate became considerably drier, placing a burden ultimately on the upper-basin states.

Below: Lee's Ferry, Arizona, is the point of departure for rafting trips through the Grand Canyon, but it is also the site of the gauging station (inset) measuring the streamflow of the Colorado River. This measuring point between the upper and lower river basins shows in recent years a flow of about 13.5 million acre-feet annually.



RICK McCLAIN/THE STOCK SOLUTION; (INSET) COURTESY OF U.S. DEPT. OF THE INTERIOR

are basically risk takers. Despite the adverse impacts of this recent series of freeze events, many of them have remained in the business. In fact, it seems that the grove owners tend to weigh in their minds the most recent climatic events more heavily than earlier ones. The recent mild winters have led many of the growers to believe that there has been a return to what they would like to consider "normal" climate, that is, the climatic conditions that existed before the onset of the recent run of freezes.

Freezes in Florida also underscore the role of climate variability in the ability of countries (states or industries) to compete economically. It was a severe freeze in Florida in 1962 that prompted Brazilian businessmen to consider developing a citrus industry for export markets. Thus, changes in climate in the future can alter in yet-to-be-determined ways the economic competitiveness of countries involved in the export of crops that are sensitive to climatic factors.

Colorado River System

The Colorado River system is very important for the arid and semiarid western United States. The river basin is divided into upper and lower basins. Colorado, Wyoming, and parts of Utah, New Mexico, and Arizona make up the upper basin states, while California, Nevada, most of Arizona, and part of New Mexico make up the lower basin states [see map]. The river's water is used for municipal, agricultural, and industrial purposes, as well as for recreation and for the production of hydropower.

In the early 1920s, representatives of concerned state and federal agencies decided that the water from the Colorado River should be divided between the upper and lower basin states. States in the lower basin were rapidly developing and wanted to secure a large share of the water, while the upper basin states wanted to act to preserve water for local needs against the claims of the rapidly growing lower basin states, especially California. Representatives came together under the chairmanship of Secretary of Commerce Herbert Hoover to draw up a legal compact for the allocation of water in the Colorado River system.

To determine how much water was actually in the system, representatives decided to rely on government estimates of the system's annual streamflow for the previous two decades, 1899-1920. After much

Eastern Colorado, April 1977. Drought episodes reminiscent of the 1930s have caused many in parts of the upper Colorado River basin to be concerned about the prospects of a long-term change in climate.

debate they decided that the yearly volume of the Colorado was about 15 million acre-feet (maf) and that the upper basin states would provide to the lower basin states an average of 7.5 maf per year over ten-year periods.

Shortly after the compact was finalized, it became apparent that the volume estimates were too optimistic. Volume began to decline. The 1930s proved to be extremely dry years—for example, 1934 yielded only 6.6 maf. The decade itself produced an average annual volume of only 12.5 maf, considerably below the expected 15 maf. However, the lower basin states were guaranteed in the compact to receive a fixed amount of water, and any decrease in the basin's total supply would have to be borne by the upper basin states.

Today the volume of the Colorado River system is on the order of 13.5 maf per year. A retrospective analysis of rainfall using tree-ring data suggests that the 1899–1920 period, on which the compact was based, had been the wettest in the last 450 years.

This case study suggests that the region has in fact undergone a climate change, one that thus far has lasted about 60 years. In discussions of the climate change issue, it has been suggested that no action can be taken and no bargaining strategies can be developed until and unless winners and losers can be identified. This Colorado River study suggests, however, that once the winners and losers are known, there would be even less chance for altering existing legal arrangements. This case study also suggests that societies should avoid building rigidity into their decision-making processes, especially in the face of an uncertain climate. No provision was made in the compact for redressing inequities in the distribution of water based on original (erroneous) streamflow estimates.

Concluding Comments

Gaining a glimpse of the future is no easy task. Civilizations have been attempting to do this since the beginning of history. The approaches have involved the use of stars, chicken bones and feathers —and computer models. Some have had a bit more success than others. But no one approach has yet been successful in producing reliable forecasts of the future.

Speculation about future states of the atmosphere and what those states mean for society is an important activity. The approach described here—forecasting by analogy—does provide some insight into our understanding of the kinds of decisions that societies must make in the event of a future change in climate. The fact of the matter is that a warming of the atmosphere by a few degrees does not mean that all temperatures will increase by that amount. Regional and seasonal changes could include a cooling as well. At this time no one can really present decision makers with credible or reliable scenarios of the future. What this approach does is to provide them with examples of how well societies (local, regional, and national) are prepared to deal with today's climate variability. After all, a climate change will most likely be felt through regional changes in the frequency, intensity, duration, and even location of extreme meteorological events. Having information about how well we deal with these factors today can help our society to maintain flexibility to respond to unknown climate extremes of the future. ■

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