its relatively sparse specification of hurricane dynamics, indicates that general environmental conditions, and not just internal features of the storm itself, are determinants of hurricane motion and intensity.

Perhaps the first of the new generation of hurricane models, and the most extensively tested, is that developed by B. Miller of the National Hurricane Center (NHC) in Miami. His model, although similar to that later developed by the Florida State team, differs in some details and currently uses a coarser computational grid (100-km spacing). It is, however, correspondingly faster to compute and has made reasonably accurate forecasts when run against half a dozen documented cases. Like the Florida State model, it requires more input data than is commonly available —reconnaissance flights through hurricanes ordinarily gather data at only one altitude, and they generally do not include a large region outside the storm. Nonetheless, NHC plans to use Miller's model for hurricane forecasting on an experimental basis this year, and plans are under way at the National Meteorological Center to develop a much larger and more ambitious model for operational forecasting in coming years.

The outlook for controlling hurricanes or modifying their strength is less clear and far more controversial than for prediction. For one thing, the rain produced by these storms supplies the water needs of large areas in the southern and eastern United States. Steering hurricanes away from land—if it could be done—would thus also change rainfall patterns, perhaps dramatically. Modification experiments have instead tried to reduce the intensity of the storm by seeding its clouds with Dry Ice or silver iodide.

In what appears to have been an unfortunate coincidence, however, the

Speaking of Science

Weather and Climate Modification: Progress and Problems

Surveying the field of weather modification some 7 years after an earlier study, a National Academy of Sciences panel in a new report (*1*) finds both progress and problems. Progress comes in the form of more statistically valid evidence that cloud seeding can increase precipitation under some circumstances and more detailed knowledge of what those circumstances are. Problems, to judge by the recommendations contained in the report, have to do in the first instance with the lack of research funding and organizational muscle given weather modification by the federal government. To remedy this situation, the panel proposes three national goals with a target date of 1980: (i) to put rainmaking and other precipitation modifications on a sound basis; (ii) to develop means of mitigating the effects of the most severe storms and weather hazards; and (iii) to determine the extent of inadvertent modification of local weather and the global climate by man-made pollutants.

To reach these goals, the panel recommends research funding of no less than $50 million annually—a figure the report compares with federal spending of about $12 million for weather modification in recent years—and the establishment of a national laboratory for weather modification, among other programs. The panel did not, however, tackle the sticky job of recommending what programs should have top priority in the all too likely event that $50 million is not forthcoming.

Among the specific advances cited by the panel was confirmation of the effectiveness of seeding orographic clouds—those produced by topographic features. More than 14 years of randomized experiments near Climax, Colorado, showed that seeding clouds in which the temperature ranged between −11° and −20°C at the cloud tops could increase the snowfall in this mountainous region by 10 to 30 percent. The results of seeding convective clouds such as the ordinary cumulus rain cloud, according to the panel, are more mixed. Seeding experiments in Missouri and Arizona seem to have reduced rainfall in the experimental area, while other experiments in Israel, Australia, and the Soviet Union have yielded positive results. In Florida, numerical models of cumulus clouds were used to select "seedable" clouds, which did produce significantly more rain. The panel notes, however, that questions have been raised about the downwind effects of cloud seeding (outside the intended target area) and recommends more serious study of these effects.

In regard to modifications of weather hazards, the panel reports that means of dissipating warm fogs over airports or of reducing the intensity of tornadoes do not yet exist and that attempts to reduce forest fires caused by lightning have been inconclusive. On preventing hailstorms, the panel notes the spectacular successes claimed by Soviet scientists and, on a lesser scale, by investigators in France and Kenya, but bemoans the lack of statistical controls that would make the results more convincing.

Opinions differ as to the prospects for modifying hurricanes (see accompanying story), but for that reason, the panel believes, randomization of seeding experiments on these storms in some form is all the more important, despite the expense and operational difficulties such procedures might involve. Indeed, concern over statistical methods and the impact of criticism by statisticians of early weather modification experiments is obvious all through the report. Some researchers believe that the panel may in fact have gone overboard in its concern for statistical rigor, neglecting the extent to which knowledge of physical processes can lead to very specific predictions to be tested in weather modification experiments. It is generally agreed, however, that predictions based on numerical models will be increasingly closely coupled with modification experiments.

Inadvertent weather modification now receives little attention, a circumstance the panel regrets. But despite a suggestion that monitoring of pollutants should be undertaken, the panel's report does not spell out specific new programs or funding recommendations. It does step into the arena of international policy, citing with approval a proposed ban on military use of weather modification techniques. That such concerns are now germane may be one of the best indicators that weather modification is no longer an esoteric bag of tricks but is rapidly approaching the status of an operational technology.—A.L.H.

References

1. Review Panel on Weather and Climate Modification, T. E. Malone, chairman, *Weather and Climate Modification, Problems and Progress* (National Academy of Sciences, Washington, D.C., 1973). $6.25, paperbound.